CAPT. A.W.C. ALDERS

Reefer Transport & Technology

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CONTENTS

INTRODUCTION

Following the success of Captain A.W.C Alders' "Marine Refrigeration Manual" which we published in 1987, the technology within the reefer industry has shown *a* rapid development.

We sincerely believe that his "Marine Refrigeration Manual" contributed in many ways to this development. In the intervening years both the author and the publishers have frequently been asked to give their advice in Arbitration, Second Opinions and Surveys.

With the end of the century now rapidly approaching, we perceived a growing need for information about more recent practical developments in the transportation of perishables.

In his present book Captain Alders has researched the transport of various new commodities, with the scientific support of international agricultural universities.

Thanks to a little help from our business associates, we are now proud to offer this new book to the industry.

We are convinced that this book will again provide a wealth of practical information for all those involved on a day-to-day basis in the reefer industry.

The Publishers

R.M.C.A. Rotterdam Marine Chartering Agents B.V.

PREFACE

Because of the fast-moving and interesting developments in the reefer trade in recent decades, the need arose to expand on the information given in our previously published book "Marine Refrigeration Manual",

The underlying aim of the present book is to enable readers to learn about the essentials of their specific area of the reefer trade without having to resort to the reading of extensive literature. We hope that, as such, this compendium will prove to be an invaluable guide to readers in all branches of the "cold chain", i e. shippers, carriers, fruit surveyors, ship's officers and everyone involved in the storage and transport of perishables.

In this book we have devoted specific attention to growth and post-harvest handling, containensation, modern reefer design and the world reefer trade. Detailed information is also given about the cultivation, perishability, storage and transport of various fruits, especially the increasingly popular exotic fruit varieties.
Present and future changes resulting from the Montreal Protocol are discussed in the chapters on CFCs and the alternative refrigerants.
This book does not describe the principles of refrigeration, the technical aspects of reefer plant or subjects such as the transport of frozen cargoes; these were dealt with in "Marine Refrigeration Manual".

The information given in this book has been checked with the greatest of care. However, the author can accept no liability for errors or omissions, for subsequent changes in the details provided, or for the results of the application or use of the information.

Any comments or remarks which might help now or in the future to supplement and update this manual would be appreciated.

August 1995 Capt. A.W.C. Alders

THE DEVELOPMENT OF REFRIGERATED TRANSPORT BY SHIP

In its initial period refrigerated shipping was characterised by the following key developments:

1) The development of mechanical cooling in Great Britain.
2| Hold refrigeration with the aid of a cold-air cooling installation.
3) Hold refrigeration with the aid of cryogenic substances such as ammonia vapour and CO_2.
4) The development of mechanical cooling in France.
5) The transport of chilled and frozen meat.
6) The transport of cooled fruit (see Chapter 2).

Early developments

The roots of present-day refrigerated shipping can basically be traced back to the transport of natural ice by sailing vessels in the nineteenth century.
At the end of the 18th century the port of Boston was the first to exploit the fact that no natural ice was available in the Southern States of the United States. The ice was used in those days to preserve food products which were subject to spoilage. Its second use was in the making of ice cream, which was regarded as a true sensation in a warm climate in those days.
Initially, natural ice was transported occasionally by ships which picked up their cargo in Boston and were destined for New York, Philadelphia or Charleston. This also occurred during ballast trips to destinations located even further south. Very soon a lively trade developed, moving beyond the United States to cover other countries as well.

In 1825 some 3,000 tons of ice were exported from Boston to the colonies in the West Indies. Ultimately, apples, butter and cheese packed in ice were also exported to those islands. By the end of 1840 some 18 shiploads of these goods were being transported each year, each shipment having a value of some 2,500 dollars. The transport of meat packed in ice was not possible on these voyages. The peak in ice exports was reached in 1870. In that year the U.S.A. exported 65,000 tons of natural ice, principally to the West Indies. Boston accounted for 90% of these exports.
Because natural ice was relatively cheap, this obviously delayed the spread and acceptance of machines which could make ice. It even lasted until 1914 before the output of mechanically produced ice overtook the tonnage of harvested natural ice. But, whether machine-made or natural, ice is suitable only for cooling and not for the freezing of cargoes. Meat, for instance, has to be shipped in a quick-frozen state. To meet this transport requirement the first freezer installation was built into a steamship in 1868.

The development of the mechanical cooling of seagoing cargoes only really started in the second half of the 19th century. A combination of factors contributed to the development of refrigerated shipping. The most important factor was, without a doubt, the industrial development in Western Europe after 1800. The initial years of that industrial revolution were characterised by an explosive population growth, especially in the big industrial cities. In highly populated areas there was a threat of food shortages, especially a shortage of meat. Specifically in those years there was an enormous expansion in the livestock herds reared in the still sparsely populated regions of North and South America and Australia. Until the second half of the 19th century those countries had only been able to ship the hides, wool and tallow of slaughtered livestock to Western Europe. It was therefore not surprising that the livestock farmers were prepared to sell their meat for any price they could get. The difficulty, however, was ensuring that the meat was fresh when it arrived in Western Europe. The voyage from Australia to Britain took about two months in those days, which was too long a duration for meat packed in ice. In about 1860, therefore, Australia started canning its meat. In 1880 some 7,000 tons of canned meat were shipped to Britain from Australia. However, its flavour was not greatly to the liking of the workers for whom it was primarilyintended.

One method of getting really fresh meat to Britain was to ship live animals. But this had one major drawback Britain, as an island, is better able to control infectious livestock diseases. Since 1770 Britain had simply kept its borders closed to live animals and hides. However, with the emergence of free trade and the growing demand for fresh meat, Britain's import regulations were relaxed. Argentina in particular profited from this and for a brief period there were even quite substantial imports of live animals. The result, however, was that in 1865 an epidemic of rinderpest broke out in Britain, the vectors being imported live cattle. A lot of cattle had to be slaughtered to prevent the disease from spreading and, as a consequence, the import regulations were tightened up again. A different solution was therefore needed.

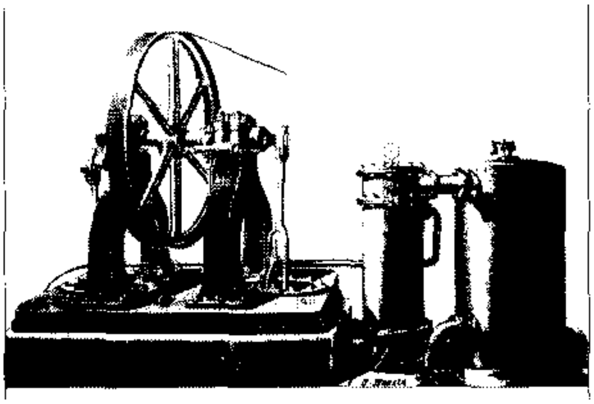
By that period the development of land-based cooling machines had already started in Europe. It was therefore in everyone's interest that a cooling machine should be designed which was suitable for use in the transport of seagoing cargoes, so that the abundance of meat from those sparsely populated countries could be shipped to Western Europe.

Many experiments were carried out in this field, but it was mainly Messrs. Carre and Tellier in France and the Bel! brothers and Mr Coleman in Scotland who succeeded in developing the most suitable cooling installation for use on board ships.

Cooling with cold air

The oldest methods used to give meat and fish longer storage times involved packing them in ice, brine-curing or smoking. In 1873 the first shipment of chilled beef was sent from New York to London. With the aid of (steam-powered) ventilators the air in the hold was blown over blocks of natural ice. Later on, this method was improved by mixing the ice with salt to achieve an even lower temperature. But the ice blocks took up a lot of useful hold capacity and the drainage of the brine water also caused quite a few problems.
In 1873 the Frenchman Paul Giffard developed the first cold-air cooling machine. The cold cooling air was produced by compressing and expanding the air. On the basis of this same compression-expansion principle the Bell brothers and Mr Coleman developed the "Bell-Coleman" cooling machine.

The historic British s.s. 'Strathleven' (2,436 grt), built by Burrell & Son in Glasgow, was fitted out with a "Bell-Coleman" machine. The ship departed from Sydney on 29 November 1879 and left Melbourne one week later. On board were 40 tons of beef and lamb which arrived in London in excellent condition on 2 February 1880. Even Queen Victoria was offered a lamb carcase from this shipment of meat.
Regrettably, the cooling installation was removed from this ship despite the clear proof it had provided of the feasibility of transporting frozen meat from Australia to Britain. The ship was subsequently put into general cargo service. In 1901 she went down during an Atlantic crossing.



Paul Giffard's cold-air machine

The second shipment of Australian meat was of much greater importance for Britain. In the winter of 1881 a very prolonged snowstorm had cut London off completely from the surrounding countryside. But the steamship 'Protos' came to the rescue when it arrived from Australia with a cargo of 4,600 carcases of slaughtered livestock (sheep and lambs) and 100 tons of butter. Not surprisingly in view of the circumstances, the cargo fetched very high prices. One interesting feature is that during this voyage the holds were insulated with sheep's wool which was sold after the vessel's arrival in London.

In that very same year the British Orient Line started its services to Australia and its first steamships, the 'Cuzco', the 'Orient' and the 'Garonne', brought substantial quantities of frozen meat to Britain. In 1882 the Glasgow-based Albion Shipping Company merged with the Shaw Savil Company in London to form the Shaw Savil & Albion Line, and this company was likewise one of the pioneers in the shipping of frozen meat.
Also in 1882 the company shipped its first cargo of frozen meat from Port Chalmers (New Zealand) to London in the sailing ship 'Dunedin' (1,250 grt) which had been chartered by the New Zealand and Australian Land Company Ltd. This sailing ship was fitted with a Bell-Coleman 'cold air freezer' and, since no freezing equipment was available in New Zealand, the meat had to be frozen on board ship. In November 1881 the 'Dunedin' docked at Port Chalmers and the chartering company supplied the meat. The pigs and sheep were slaughtered in that company's abattoirs and sent by rail to the docks where the meat was first cooled and then frozen.

After about 2,000 carcases had been frozen, the crankshaft of the cooling installation broke. That meant that the meat had to be unloaded again and sold locally. An engineering works in Port Chalmers first had to make a new crankshaft before the loading and freezing operations could be resumed. On 15 February 1882 the 'Dunedin' eventually set sail, arriving in London on 24 May 1882 with a cargo which was in excellent shape. The ship was subsequently chartered for a further 9 voyages. In 1890 she started out on her 9th charter trip on this route but unfortunately she sank during the voyage. Some other examples of famous British shipping lines that were engaged in this trade are: the Aberdeen Line, the P & 0 Line, the Port Line and the Federal Line.

The importance of these meat shipments for Britain cannot be overestimated. The British aptly

S.S. "SELEMBRIA"—3041 TONS REGISTER.

Extract from "THE TIMES" of the 16th July, 1886.

FROZEN MEAT.—The importation of frozen meat to this country continues to increase, and the recent arrival in the East India Docks of a cargo of over 30,000 frozen carcasses of mutton in excellent condition is the latest and as yet the most extensive contribution that has been made in the form of a single cargo to the meat supply of this country. This has been brought by the steamer Selembria from the Falkland Islands, and when one considers that East Falkland was only colonized by British subjects in 1853, and West Falkland in 1861, and that there are now nearly 600,000 sheep in the islands, it seems indeed, little short of marvellous. Those brought over are described as being of prime Canterbury type, well fleshed, and with no superfluous wasteful fat, and they average from 60lb. to 70lb. each. Sales have been effected of portions of the cargo at over 5d. per pound. The steamship Selembria, chartered by the Falkland Islands Meat Company, who have entered into agreements with the owners of sheep for the supply of 60,000 per annum, is a steamer of 3,041 tons register, and was fitted out completely by Messrs. J. and E. Hall, of Dartford and London, for this trade. She left England in December last, and would in the ordinary course have returned in April but for the preparations that it was necessary to make in the first instance before the meat could be shipped, as no labour or materials were to be found on the other side. Thus it was necessary to take out a staff of butchers to deal with the meat in the first instance, stevedores to stow away the carcasses in the lower hold as soon as these were frozen, this latter operation being carried out in the 'tween decks, and mechanics to erect the necessary buildings, tramways, and derricks at the three principal ports where the meat is obtained, all this plant being taken out in the ship. The colonists have hitherto contented themselves with what they could realize with the wool, skins, and tallow, to be obtained from their sheep, but now, in consequence of this most recent development in refrigerating machinery by means of cold dry air, they will be able to send their mutton to the English market, not only to their own advantage, but also to that of the consumers over here; and there appears to be every reason to expect that the enterprise which has been entered into in so practical a manner will result in a complete success.

described the cooling and freezer ships as the "Empire Food Ships". Another country which had a surplus of meat was the United States. The advent of the cooling machine also made it possible for that country to export its meat. As early as 1875 the first cargo of chilled meat was transported from the United States to Britain. By the end of 1880 as much as 120,000 tons had already been shipped across to Britain.

The American meat was sewed into sailcloth and suspended from the ceilings in coldstores - cooled by natural ice - on board the ship. In those days the transport of chilled meat from the United States to Britain took two weeks, as against more than two months for the voyage from Australia.

The first refrigerated vessel to be fully fitted out for the transport of slaughtered livestock was the s.s. 'Elderlie' which was launched in Jarrow (U.K.I in 1884.
In those initial years the cold-air cooling machine which operated according to the Paul Giffard principle was continuously improved. Messrs. Hall in Dgrtford, for instance, designed an improved cold-air machine which was installed on board the s.s. 'Selernbria' (3,040 grt). In 1886 this vessel brought 30,000 frozen sheep carcases from the Falkland Islands to London.
After the turn of the century dry-air cooling was completely replaced by the new refrigeration method using a cooling medium (a coolant, or refrigerant! such as ammonia or $C0_2$.

Refrigeration using a coolant

In principle any liquid, i.e. also water, can be used as a cooling medium. For practical applications, however, the only liquids suitable are those whose boiling point (b.p.) is below 0°C at atmospheric pressure.

The liquids which meet this requirement are:
chloride (b.p.-24°C);
ammonia (b.p. -33°C);
carbon dioxide (b.p. -78°C);
R 12 (b.p. -30°C).

Liquids such as sulphur dioxide ($S0_2$), ammonia (NH_3) and carbon dioxide ($C0_2$) can be easily evaporated by lowering the pressure on the liquid. The latent heat required to evaporate the liquid is extracted from the surroundings, in this case the air in the hold. The vapour that is formed is drawn in by the compressor, brought to a higher pressure and temperature and then fed into the condenser. In the condenser the gas is converted back into liquid. We have already explained this circuit in detail in a previous book (see Marine Refrigeration Manual, Chapter 1).
As will be known, various factors play a role in deciding on which is the ideal coolant to use.

The most important factors are:
1) The quantity of heat which is extracted by the coolant from its surroundings during evaporation.
2) The density of the vapour that is formed. (The density in fact governs the size and the manufacturing costs of the cooling installation).

The advantage of cooling with a cold-air machine was that the cold air could be admitted directly into the hold without a complex piping system being required, as for instance is needed in an ammonia refrigeration plant. Besides that, there were no problems caused by a toxic (poisonous) cooling medium like ammonia. The drawback, however, was the small volume of the cold air which meant that, despite the use of fans, it was not possible to achieve a uniform temperature distribution inside the hold.

If the installation works using a coolant, then the gas which has been liquefied in the condenser must be admitted via the expansion valve into the piping circuit fitted below deck in the holds. The liquid evaporates inside the pipes, extracting heat from the hold air as it evaporates (direct expansion grid cooling). One of the biggest problems in this system is ensuring that the pipework remains gas-tight. In the event of leakages the coolant is not only lost but the cargo is also poisoned.
This is why the "brine grid cooling" system was adopted. In this system the brine is used as a secondary coolant.
As described earlier (Marine Refrigeration Manual, Chapter 4), the cooling medium, after passing through the control valve, is admitted into the brine cooler. Inside the brine cooler the coolant evaporates and absorbs heat from the

brine. The cooled brine is then circulated through the piping circuit fitted below deck and/or in the side walls. The heat extracted from the hold air raises the temperature of the brine. The absorbed heat is the transferred back to the evaporating coolant inside the brine cooler.

The development of refrigerated shipping in France

As early as 1860 the Frenchman Ferdinand Carre had developed a cooling machine which operated using ammonia as a cooling medium. But the man who undoubtedly pioneered the development of refrigeration techniques was the German physicist and mechanical engineer Carl von Linde (1842-1934). In 1874 he designed the first compressed ammonia cooling installation. The first truly outstanding success in the transport of frozen meat using an ammonia cooling installation was the voyage of the s.s. 'Paraguay'. This French ship, fitted with a refrigeration machine designed by Carre, sailed in 1877/1878 from Buenos Aires to Marseilles carrying 5,500 frozen sheep carcases. On the homeward journey essential repair work had to be carried out on the island of St. Vincent. Even though this meant that the journey had lasted 7 months, the cargo was still unloaded in good condition.

One decade earlier - in 1868 - the Frenchman Charles Tellier had already installed an ammonia cooling machine in a ship called the 'City of Rio de Janeiro'. That vessel made a trial voyage from London to Montevideo. The refrigerated cargo consisted of 300 kilograms of meat which, after 23 days on board, had to be consumed due to a mishap with the cooling installation. It was not until 1875 that the Frenchman carried out another trial, this time with the s.s. 'Eboe' which was modified to carry frozen meat and had a cooling installation fitted in each of the three holds.

The vessel was renamed the s.s. 'Le Fngonfique'. In 1877 this ship transported a cargo of frozen meat from Buenos Aires to Rouen. Although the cargo was in a reasonable condition when unloaded, this voyage was certainly not as resoundingly successful as that made some months later by the s.s. 'Paraguay'. Despite the auspicious start made by the French, the lead was soon taken over from them, in the first instance by the Australians. For unknown reasons, in fact, the plan to transport even more meat to France was not implemented.

Agents of Australian cattle farmers visited the s s. 'Paraguay' in Le Havre and, on the basis of their findings, the services of a firm in Glasgow were called in. This was the firm of Bell-Coleman which was already experienced in the field of ice-making machines. Bell-Coleman were asked whether they could also manufacture a machine which would provide cooling by means of cold air. The client wanted to make very sure that the machine was reliable and had the installation subjected to a test run lasting 90 days. After this experiment had been completed to everyone's satisfaction, this installation was built into the s.s.'Strathleven'.

None the less, it is strange that French interest in refrigeration techniques declined so quickly after those initial successes. It has to be admitted, however, that those early ammonia cooling machines were not very suitable for shipboard use, specifically because of ammonia leakages (ammonia gas is toxic and inhalation may be lethal). Perhaps this is one of the reasons why the French left the further development of this technique to Great Britain.
As we have seen, however, the transport of frozen and fresh meat to Great Britain continued to expand steadily - possibly because the sales potential was higher there.

And yet the Cold Air Machine developed by Joseph Coleman in cooperation with the Glaswegians Henry and James Bell did not turn out to be a long-term success. This was due to its obvious limitations as regards the minimum temperature it could achieve in the refrigerated hold, the shippers' demands for ever lower carrying temperatures for frozen meats and ongoing improvements in technology. It was around this time that the $C0_2$ cooling installations were developed and the Cold Air Machine was soon replaced in marine refrigeration by installations which used $C0_2$ as the coolant, with brine as the secondary coolant. In about 1915, when banana shipping (United Fruit Company) started to grow in significance, ammonia carne into more general use as a coolant.

However, probably due to widespread fears about the toxicity of ammonia, ammonia's share of the reefer market has never exceeded 20%. Though its share has never been very big, ammonia has over the years outlived the use of former coolants such as air, ether, sulphur dioxide and carbon dioxide. Today it may even be heading for a bright future again!

Of the reefers classified by Lloyd's in 1940, those using $C0_2$ as a coolant accounted for 80% and those using NH_3 as a coolant held a share of 18%. After 1940 the emergence of R 12 as a coolant brought a sharp reduction in the use of $C0_2$ and NH_3.
In 1970 the ratio between the coolants used by Lloyd's classified ships was as follows:
R 12 = 57%, R 22 = 22%, $C0_2$ = 12% and NH_3 =9%.
After 1980 $C0_2$ was virtually no longer in use as a coolant. The number of ships using NH_3 as a coolant then only amounted to a few per cent. Most of them were fishing vessels. By 1990 the percentage breakdown looked as follows.
R 22 = 85%, R 12 = 13% and NH_3 = 2%.

How the classification of reefers developed

The cooling and refrigeration section of Lloyd's Register of Shipping (LRS) handles the classification of:
- conventional cooled and refrigerated vessels;
- cooled and refrigerated fishing vessels;
- cooled and refrigerated container vessels,

In addition Lloyd's also deals with many other aspects relating to the reefer shipping industry. For example:
- coldstores;
- refrigerated gas tankers;
- air conditioning/ventilation on board ships.

Reefers carry a relatively expensive cargo. Sometimes the value of the cargo even exceeds that of the ship. As early as the end of last century the Lloyd's underwriters realised that the entire cargo could be lost as a result of a malfunction in the refrigeration plant. In 1898 they therefore complied the first Refrigeration Rules. These Rules were written into the Register Book under the heading RMC (Refrigerating Machinery Certificate]. The name of this certificate, which relates solely to the refrigerating equipment on board the ship, was changed in 1910 to Lloyd's-RMC.
In 1898 the first RMC certificate was issued to the steel-hulled vessel 'Wakool'. This ship was fitted with a cold-air cooling machine of the compound duplex type. The installation supplied 3,800 cubic metres of cold air per hour to two insulated holds with a cargo capacity of 2,032 cubic metres.
The 'Southern Cross' was the first ship built outside the British Isles to be issued with an RMC certificate. The refrigeration installation on this ship used ammonia as a primary coolant and brine as a secondary coolant

The Rules

By 1905 the number of classified cooling installations on board ships had already increased to more than 100. In 1922 the 1898 version of the Rules was revised and expanded. It was stipulated that the technical drawings and the machinery itself had to be examined and that certain parts of the installation had to be tested. In 1935 full testing of the refrigerating machinery was made mandatory and in 1950 it was ruled that the refrigeration capacity and the minimum attainable temperatures had to be stated on the certificate.

The year 1978 brought publication of a new edition of Lloyd's Rules and Regulations for the Classification of Ships. Besides detailed modifications to the existing Rules, a new chapter was added with regulations for refrigeration installations on board container ships.

Chilled and frozen meat

As consumers prefer chilled meat to frozen meat, meat is nowadays mainly shipped in a cooled condition. In previous days, however, the frozen or chilled quarters, packed in linen, were suspended from hooks under the decks. Today, the boned-out, chilled meat is packed in cardboard boxes or plastic bags in the form of "meat blocks" or even in "ready-to-cook" portions. This method of packaging therefore makes this cargo very suitable for transport in refrigeratedcontainers.

In the early days of meat transport consumers also preferred chilled meat, which therefore fetched substantially higher prices than frozen meat. At that time, however, the transport of chilled meat was subject to limitations, as chilled meat had a keeping time of only 3 weeks at most.

In the year 1873, therefore, though it was certainly possible to ship chilled meat from New York to London, it was still not possible to ship chilled meat from South America or Australia to Western Europe because of the long duration of the trip and the higher temperatures during the voyage. Since mutton and lamb soon tend to discolour, it was absolutely impossible to ship chilled sheepmeat - e.g. from Argentina - to Europe. In former days, therefore, the rejection of incoming meat shipments for public health reasons was a frequent occurrence.

After 1880 Argentina started making large-scale exports of frozen lamb quarters to Western Europe. Since the cost-price of Argentinian meat was considerably lower than that of New Zealand meat, Argentina soon captured the European market.

Thanks to advances in refrigeration techniques and the increase in sailing speeds, exports of chilled meat from Argentina also started to develop after 1900. By the beginning of the 20th century Argentina had therefore grown to become the biggest supplier of beef and lamb to Western Europe. The Argentine Meat Board estimates its 1992 meat exports at some 500,000 metric tonnes.

Brazil's exports of chilled beef, which are mainly shipped to North America and the European Community, currently amount to some 100,000 tonnes a year. In addition, Brazil exports about 300,000 tonnes of frozen chickens to the Middle East every year.

CHAPTER 2

HE BANANA TRADE AND THE WORLD MARKET

Cooled banana transport

In volume terms, banana transport still represents by far the greatest proportion of total fruit transport. In this chapter, which is devoted to cooled fruit shipping, we shall therefore concentrate solely on how banana transport by sea developed from its early beginnings to the present day.

The prior history

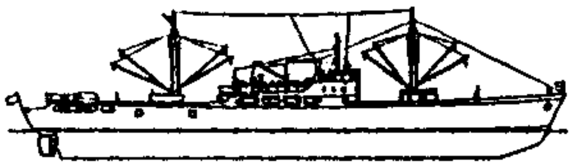
Until 1897 it was only possible to ship bananas, uncooled and in small quantities, from the Canary Islands to Western Europe. The bunches of bananas were carried as deck cargo and were taken below decks if the outdoor temperature became too low. In that same period considerable quantities of bananas were already under cultivation in the West Indies as well, but the lengthy duration of the voyage and the lack of adequate temperature control on the refrigerated ships of those days made it impossible to transport those bananas to Europe. Obviously, attempts were made to ship the bananas from those regions in the "meat ships", but this was not a success, one of the reasons being the insufficient air circulation in the holds. It was therefore necessary to construct ships which were specially fitted to carry fruit.

The first ship specifically constructed for banana transport was the s.s. 'Port Morant'. The vessel was built in 1900 for the British Elder & Dempster shipping company. In 1901 this ship transported 23,000 bunches (approx. 1,500 t) of bananas from Jamaica to Britain. This ship, just like the 'Port Royal' and 'Port Antonio' which were built later, was fitted with a Hall Duplex $C0_2$ cooling machine and equipped with air coolers and fans. A wooden structure of laths ("banana bins") was used to partition the hold into small sections. In these sections the banana bunches were stowed'in such a way that sufficient cold-air circulation was guaranteed between the stems and through the "hands" (bunches) of bananas.
A few years later the 7,000-grt s.s. 'Port Kingston' - a very modern vessel for its time - was launched in Great Britain. This "Atlantic liner" carried not only passengers but also 40,000 stems (approx. 1,800 t) of bananas from the West Indies to Britain. Banana transport from the Caribbean and Central America to North America (United Fruit Company) and to Western Europe rapidly took flight after those initial years.
In the first decades of the present century bananas were transported not only from Central America but also from various former European colonies in Africa. Italy, for instance, imported its bananas from former Italian Somaliland and France from Carneroun.
By 1914 the fruit carrier had developed into a steamship of around 6,000 grt, with piston engines, a speed of 14 knots and accommodation for 12 to 70 passengers. This type of ship also proved highly useful during World War I; both the Germans and the British requisitioned fruit carriers to serve as auxiliary cruisers and wartime losses of these vessels were considerable. After the end of World War I Elders & Fyffe started operating ships of 5,400 grt, with a speed of 13.5 knots and accommodation for twelve passengers, as well as ships of 7,000 grt, 14.5 knots and accommodation for 100 passengers.

The Yeoward Line, which plied the Canary Islands route, had ships of 3,500 grt, 13 knots and accommodation for 150 passengers, whilst the British MacAndrews shipping line, which sailed to the Iberian peninsula and North Africa, operated ships of 1,300-1,800 grt with speeds of 10-12 knots. In 1922 this shipping line brought the first motor vessels (the 'Pinzon' and the 'Pizarro') into operation and in 1929 the Jamaica Direct Fruit Line commenced a service to the West Indies after buying 3 meat refrigeration ships and fitting them out with new cooling systems.

As will be known, bananas produce a lot of heat which needs to be removed by means of a powerful, forced-air circulation system. It was only after 1925 that forced-air cooling found widespread application in shipping. After that year, therefore, fruit transport increased exponentially. By the eve of the Second World War the refrigerated cargo capacity of the world banana fleet stood at as much as 4 million m^3 (140 million cubic feet).

In the early 1930s Scandinavian ship operators also began to take an interest in this transport sector. They started out with fast motor vessels of the 'Express' type: small ships of approx. 3,650 grt, a speed of 16 knots and 180,000 cbft of refrigerating capacity. The Danish Lauritzen shipping line (red ships) introduced reefers of



The fruit reefer 'Priamos' (1958, 3.027 grt, cargo capacity 3, ^ 771) has refrigerated holds with a total max. capacity of 6,626 m^3 and reaches a speed of 17.25 knots).

1,830 grt and other Scandinavian shipping companies soon followed suit. MacAndrews, Elders & Fyffe and the Jamaica Producer Company then modernised their fleets by adding fast fruit carriers. Furness-Withy and the Royal Mail Line likewise had fast fruit ships, the Union Castle Line had the 'R' class, the German company Laeisz had the fast 'P' ships and the Blue Star Line the 'Star' class of ships.

Until 1958/1960 bananas were shipped on the stem. After that a start was made on shipping bananas in "hands", packed in cardboard boxes. To achieve even bigger savings on transport costs, there was a change-over to palletised transport in about 1965. In banana transport the boxes are often also stowed loose in the hold in the port of despatch and are not placed on pallets until they reach the port of unloading. Stacking on pallets takes place either during unloading operations in the hold or otherwise on the quayside.

New trends in banana shipping after 1965

After 1965 the "banana boats" were increasingly replaced by what are known as "polythermal" reefers. On board these reefers it is possible to maintain all required temperatures between -25°C and +12°C. The same period also saw the introduction of automation, with temperature recording equipment being used to monitor the hold temperatures. The speed of certain reefers was raised to more than 20 knots. The average cargo capacity grew in size from 200,000 to 350,000-450,000 cbft.
Thanks to the transport of bananas in boxes instead of in bunches (on the stem) the loading degree was boosted by 50%. Horizontal hold ventilation was superseded by vertical ventilation. The use of improved insulating materials reduced cold losses to approx. 5%.

Especially in the 1970s the size of conventional reefers increased enormously. The biggest non-containerised refrigerated vessel for banana transport in those days was the 15,710 grt 'Snow Crystal'. She was one of the world's biggest and fastest reefers and could carry 305,000 boxes of bananas (5,650 t).

In 1972 shipping of bananas in refrigerated containers started on a small scale. The first experiments with this method of transport were carried out by United Brands. (United Brands later changed its name into "Chiquita Brands"). A start was made in 1972 on the transport of bananas in two ships, each carrying 93 containers, from Honduras and Galveston, Texas. These two ships were replaced in 1983 by one big ship of 15,900 grt which transported 209,000 boxes of bananas (18 kg per box) per voyage in 286 40-ft containers.

Chiquita Brands is the world's biggest producer and distributor of bananas. The Chiquita reefers are operated by the "Great White Fleet", the shipping arm of Chiquita Brands. Danyard

'Ditlev Lauritzen'

shipbuilders in Frederikshaven (Denmark) were commissioned by Chiquita in 1992/93 to build six conventional reefers. These ships have a capacity of 640,000 cbft. On deck they can carry 95 43-ft containers (28 t each) and there is room in the holds for seventy (43 ft) containers. For the sake of completeness we would point out that the four ships of the 'Ditlev Lauritzen' series (765,000 cbft) which were built by Danyarcl in 1990-1992 for Lauritzen Reefers (Denmark) very much resemble the Chiquita ships described above. In addition to the conventional ships which were added to the Great White Fleet, four container vessels, each of 418 FEU (Forty foot Equivalent Unit), were built for this shipping line by the Japanese Tsuneishi Yard in 1991/92. Mention must also be made here of Castle & Cook (brand name), the second biggest banana distributor after Chiquita. This shipping line also took delivery of three 639 FEU container reefers built in Italy in 1991/92

However, it was only in about 1982 that transport of bananas in refrigerated containers became more widespread. In 1983 the French shipping line Compagnie Generale Maritime (CGM) began transporting bananas in refrigerated containers. This company, which ships bananas to France from the former colonies of Martinique and Guadeloupe (now French Overseas Territories) certainly gave containerised transport a substantial boost. These big vessels of 32,000 grt carried 900 porthole containers (20 ft) which were connected up to the air ducting system below deck, with the central shipboard air cooling system providing the air circulation inside the containers (collective system).

The general market expectation is that within five years all banana transport to the USA will be containerised. Despite this, however, modern "pallet-friendly" reefers will also continue to play a major role. It will be clear that because of the very nature of bananas as a product, their transport is only possible by using containers with a high cooling capacity and with a built-in forced ventilation system.

The banana: reasons for its success

The banana plant (Latin: *Musa,* especially the genus Musa *sapientum)* originates from South

East Asia and can grow in any tropical or subtropical region, given sufficient rainfall. Long Pefore the start of our era the plant was taken by earlier seafarers to other regions in Asia and, much later again, to Africa. The Portuguese transferred the banana plant from West Africa (Guinea) to the Canary Islands. The first colonists to settle in South America in turn took the plant with them in about 1520.
The banana plant's great success is based on the fact that it can bear fruit all the year round. Moreover, the fruit is rich in carbohydrates, minerals and vitamins and thus also has a high nutritional value. Another property that makes the banana so popular is its high potassium content (340 mg). Potassium quickly restores the strength of the muscles and the balance of body fluids. That is why athletes are big banana consumers, especially marathon runners, racing cyclists and competitors in similar types of endurancesports.

The table below gives a comparison, per 100 grams of edible matter, between the banana and several other fruits.

	Banana	Apple	Grape	Peach	Orange
Water %	75	84	82	87	87
Calories	as	58	70	46	45
Protein (g)	1,2	0.3	0.5	0.5	0.9
Fat(g)	0.2	0.4	1.4	0.1	0.2
Carbohydrates (g)	23	14.9	14.9	12	11.2
Iron (mgl	0.6	0.3	0.6	0.6	0.4
Potassium (mg)	340	140	250	150	150
Vitamin A (I.U.)*	430	90	80	880	190
Vitamin 81 [mg)	0.08	0,04	0.06	0.02	0.06
Vitamin B2 (mg)	0.05	0.03	0.04	0.05	0.03
Vitamin C (mg)	10	5	4	8	49

" Note: 1 mg vitamin A = 3,300 I U (International Units) o1 vitamin A

Not only is the banana a highly nutritious fruit, it is also a relatively low-priced fruit. Experience has shown that when economic growth in a country increases, more exotic fruits also appear on the market. In those countries where people had sufficient purchasing power, they also started to buy these novel and more exotic varieties of fruit. This is the factor that put a slight brake on the initially fast growth of banana exports to Western Europe. In Third World countries, however, the banana continues to be the most affordable type of fruit - even though it is looked upon in Western Europe more as a "luxury" consumer article.
This explains why banana exports to the former Eastern Bloc countries have increased so tremendously in recent years. The likelihood is that, once the economy picks up in those countries, there will also be a slowdown in the growth of banana consumption.
One highly promising "developing country" for banana imports is undoubtedly South Korea. Banana exports to that country are expected to increase over the next few years from their present level of 25,000 t to some 200,000 t annually.

The world market

The world banana market can be subdivided into "open markets" and "preferential markets". In the open markets there is no restriction on the quantity of bananas imported nor on their country of origin. Bananas destined for the open markets mainly come from Central and South America. The United States sources its bananas from the cheaper, efficient producers in Latin America - the region in which 75% of the tota export quantity is grown.

Bananas destined for the preferential markets are imported from the former colonies of the relevant countries. France, for example, imports its bananas from Martinique and Guadeloupe. Most of these bananas are carried by the French shipping company CGM. France also ships in bananas from Cameroun and Cote d'Ivoire. These bananas are mainly shipped on the lines operated by Sitram (Societe Ivorienne de Transport Maritime) and SNCDV (Societe Navale et Commerciale Delmas Vieijeux).
Italy obtains its bananas from various countries, including Somalia (formerly Italian Somaliland); Portugal's supplier country is Madeira; Spain obtains a large proportion of its bananas from the Canary Islands.

In the UK the Geest Line (Geest industries Limited) is the exclusive carrier for bananas from the Windward Islands to the British market. The Windward Islands consist of Dominica, Grenada, St. Lucia and St. Vincent. Banana production and exports on these islands are controlled by the Windward Islands Banana Growers Association (Winban).

The European Union (EUI is the world's biggest importer of and preferential market for bananas. Approximately 40% of the total world production quantity of bananas is shipped to the EU Member States.
But, specifically because of the historic ties with and preferential treatment accorded to the former European colonies, the internal EU market had grown completely out of balance. Germany, for instance, was in fact the only EU country which did not apply import duties and had an unlimited quota for bananas. One consequence was that German consumers could buy the lowest-priced bananas in Europe. Annual per capita consumption in that country therefore amounted to 8 kilos.

It is likely that in the future, too, the monopolistic privileges enjoyed by importers and wholesalers of bananas from the former overseas colonies will be maintained. Although these arrangements are primarily intended to support the banana growers in the former colonial territories, it seems that the importers and wholesalers in the EU Member States are the ones who profit most from this situation. Ultimately, the outcome is that consumers in the EU countries pay too high a price for their bananas. And that in turn means that the relatively over-priced "Euro-banana" puts a brake on consumption and also encourages production inefficiencies.
In the final analysis it is the USA - the country with the world's cheapest bananas - which benefits most from the distorted global banana market, since the USA obtains its bananas from the cost-efficient producers in Latin America.
As a passing remark in this context: the greater part of banana transport is handled by Chiquita Brands, Castle & Cooke and Del Monte.

Trade blocs and the banana problem

The aim of trade blocs is to improve mutual trade and to protect the internal market against competition from producer countries outside their trading area. With regard to the banana problem we mainly have to deal with the European Union (EU) and the GATT (General Agreement on Tariffs and Trade).

The EU

The EU sets rules to ensure that the imported fruit is uniform and of good quality. It also imposes a policy of restrictive volumes in order to create sufficient sales opportunities for domestic producers. Within the European Union four forms of market regulation are frequently enforced for the fruit sector:

1. a system of what are known as "reference prices";
2. technical rulings (phytosanitary [= plant health] and quality requirements);
3. import certification;
4. intervention buying.

Reference prices are aimed at preventing products from other countries from being imported at prices below a certain level. These reference prices are fixed annually and are applied to apples, pears, peaches, plums, cherries, grapes, oranges, mandarins and lemons.

Another EU regulation is that all its Member States should levy identical import tariffs, except for imports from a few groups of countries which receive preferential treatment. The most important of these countries are covered by the Lome Agreement which was concluded between the EU and the former European colonies, including 66 countries in Africa, the Caribbean and the Pacific (known as the "ACP countries"!.

Banana imports into the European Union have for many years been the centre of a conflict with countries outside the EU.
The EU classes bananas in three categories.
First, its own "Euro-banana" which is cultivated in the Spanish Canary Islands, in the Portuguese Azores and the Algarve, on the islands of Crete and Madeira, and in the French overseas territories of Guadeloupe and Martinique.
Second, there are the "ACP bananas" originating from former European colonies which are covered by the Lome Agreement.
And, third, the "dollar bananas" from Latin

America. These derive their name from the dominant position held in that region by the three Americanbananamultinationals.
Some 3.6 million t of bananas are consumed within the European Union each year. The biggest share, some 2.6 million t, is accounted for by "dollar bananas". "Dollar bananas" are shipped in by exporters from Central and South American countries such as Costa Rica, Honduras, Panama, Venezuela and Colombia.

The CATT

The GATT is an initiative which attempts to reduce or eradicate global import restrictions. In the rounds of talks held since 1947 the participating countries have attempted to create greater freedom of trade. Nowadays, 125 countries which are together responsible for 90% of all world trade participate in these talks. The GATT principles are based on non-discrimination, transparency and reciprocity in tariff reductions. All GATT members must in principle receive the same treatment in trade as those most favoured. The GATT also aims at further reciprocal reduction of customs duties. In effect, this means that any country which lowers its import tariffs can expect other countries to do the same in return.
The GATT has made a substantial contribution to the rolling back of customs tariffs worldwide. These fell from an average of 25% in 1950 to 5% in 1990.
On 14 April 1994 the final document of the latest GATT agreement was signed by 125 countries in Marrakesh (Morocco). The world trade agreement, which runs to 22,000 pages and was concluded in 1994 as part of the "Uruguay Round", was the result of eight years of negotiations.
This GATT Agreement on the reduction of world trade tariffs was ratified at the beginning of 1995 by the governments of Japan, the EU Member States, Canada and America. The expectation is that the governments of those countries which have signed the agreement but not yet ratified it will soon follow suit.

WTO

On 1st January 1995 the WTO (World Trade Organisation) was set up in Geneva as a

"Geest Dominica'

successor to the GATT. The first task of the WTO is to implement all agreements which were laid down in the last GATT Accord in Marrakesh. Compared to the GATT, the WTO has been given more powers to settle trade conflicts and to oblige its member states to comply with the rules. Under the GATT the countries had a right of veto, whilst under the WTO the members officially have an equal vote. In the case of trade disputes the winning party is now entitled to take sanctions against the losing party.

We should add here that the Americans have set the following conditions to prevent an erosion of their national sovereignty in the field of trade. If during a period of five years the WTO takes three decisions which run counter to American interests, then US Congress is authorised to withdraw America's membership.

Another task of the WTO is to cooperate closely with the International Monetary Fund and the World Bank so as to improve the harmonisation of financial, monetary and trading policies.

APEC

Although they are not directly linked to the banana dispute, we would for the sake of completeness like to mention the NAFTA and APEC trading blocs.

The APEC (Asia-Pacific Economic Cooperation) is a loosely knit association of 18 countries in the Pacific region. In Bogor, Indonesia, these countries stated in November 1994 that they were willing to open up their markets in full by the year 2020. The target date for this declaration of intent is still a comfortably long way away and none of the member states are obliged to meet it, as the APEC's decisions are non-binding on the affiliated countries. However, the intention is that the declaration of intent will be given a firmer foundation in future via annual meetings between the member states. The aim is to clear away the obstacles to free trade in goods, services and capital, but definitions of such terms as free trade, trade barriers and restrictive regulations have still not been drawn up.
In summary, the APEC can be described as an extremely heterogeneous grouping whose members have little more in common than their geographical location on the Pacific Rim. The only cement that binds the APEC members together consists of American, Japanese, Korean and Taiwanese investments in East Asia and networks of ethnic Chinese entrepreneurs in the region.

NAFTA

The NAFTA (North American Free Trade Agreement), which was ratified in 1993, is a free trade zone consisting of Canada, the USA and Mexico. Its objective is to achieve a phased lifting of import restrictions between the three countries.
Under the agreement trade barriers will either be lifted immediately or will be subject to a transitional period of five, ten or fifteen years. In all probability NAFTA countries will expand their free trade zone in the near future. Chile is one of the countries referred to in this context. We will discuss this in more detail in Chapter 5.

The banana problem between 1992 and 1994

Under the Lome Agreement the EU gave an undertaking to protect the interests of the producers of the "Euro-banana". Until 1st January 1993 each EU Member State applied its own banana policy. The Mediterranean Member States and the United Kingdom shielded their markets to protect them against the cheaper dollar bananas. The other Member States applied a 20% import tariff. As mentioned earlier, Germany was the only country which applied no restrictions. In 1957, when signing the Treaty of Rome (the treaty establishing the European Economic Communityl, Germany had in fact insisted on having a clause inserted which made bananas exempt from import duties in Germany.With the establishment of the Single European Market on 1 st January 1993 (the "Maastricht Treaty") the situation of calm on the banana market came to an end. The creation of the internal market implied that the import policy for bananas had to be uniform within the European Union. If that does not happen, no free movement of bananas will be possible.

In 1992 five Latin American states (Colombia, Costa Pica, Guatemala, Nicaragua and Venezuela) announced that the EU's existing and proposed import regimes constituted discrimination against their banana exports. They pointed to the fact that, following the introduction of the new regulations accompanying the establishment of the Single European Market in 1993, Latin American banana exports to the EU would probably be cut by half. These countries wanted the trade conflict to be submitted to an independent GATT panel.

In principle, the EU had proposed in 1992 that the import tariff (20%) on dollar bananas should also be applicable to Germany and that the quantity imported annually into the EU should be subject to a strict quota. This caused the banana problem to grow into a full-blown agricultural conflict with the United States within GATT. In fact, as part of the GATT Uruguay Round aimed at the liberalisation of trade, efforts were being made to abolish the quotas for agricultural produce and to have them replaced by import tariffs (a process known in Euro-jargon as "tariffication"). The idea behind replacing quotas by import tariffs is to bring about fairer competition.

Early in 1993 the European Commission ruled that one single import regime would be applicable to the entire EU. It decided to allow 2 million t of dollar bananas to be imported each year. Each tonne will be subjected to a levy of 100 ECU, which is equivalent to a duty of 20%. If more than 2 million t imported, then each tonne in excess of the threshold will attract a super-levy of 850 ECU per tonne. In this way the southern Member States of the EU ensured that their producers were not forced out of the market by the competition, whilst the EU did not endanger the agreements it had made previously with the developing countries on banana imports. However, the outcome was an increase in banana prices for consumers in the EU Member States.

The effect of the 1994 GATT Agreement

As we said earlier, the final document of the last "Uruguay Round" was signed by 125 countries in Marrakesh (Morocco) on 14 April 1994. The expectation now is that a definitive end has come to the endless rounds of negotiations on a greater liberalisation of world trade.

Thanks to the agreement reached at the final GATT meeting the banana conflict, which had broken out on 1st July 1993, ended in a truce The agreement concluded on 14 April 1994 on banana imports is important for both parties:

In 1994 Latin America was allowed to ship 2.1 million t of ("dollar") bananas to Europe instead of 2 million t, and in 1995 2.2 million t This still works out at some 0.5 million t less than Europe's consumption of Latin American bananas prior to 1993. The import levies were reduced by 25% with effect from April 1994 (from 100 to 75 ECU per tonne).
The compromise reached in 1994 will remain in force until 1st January 2003.

The important factor for the EU is that this liberalisation of imports goes some way towards meeting the objections made by the Benelux countries and Denmark and specifically by Germany against the protection afforded to the "Euro-bananas" and ACP bananas, which had ultimately led to higher banana prices because of the higher levies.

To summarise, we can say that the submission of the banana problem to the GATT panel by Costa Rica, Colombia, Nicaragua and Venezuela tipped the balance in the favour of Latin America. Except for Guatemala, the Latin American countries agreed to the above-mentioned concessions. However, Guatemala - which no longer wished to be bound by the weakened European restrictions - is a trading partner of little significance, accounting for a mere 1.5% of Europe's banana imports. Although the GATT's successor, the WTO, will now ensure a stricter supervision of fair trade, Guatemala may perhaps in future still cause problems for the EU by submitting a new complaint to the WTO.

The situation after theuneasy truce

As we can see from the above brief outline of the banana conflict, the trade in bananas - unlike the fruit itself - is a very tough business. The economic reason why the EU gave preferential treatment to ACP bananas rather than dollar bananas will meanwhile have become clear.

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There is, however, also a practical distinction between ACP and dollar bananas.
Euro-bananas and ACP bananas largely consist of the Gros Michel variety, whilst dollar bananas are generally of the Cavendish variety (see also Chapter 13).
Gros Michel bananas vary in quality, are smaller and thinner and are less perfect in appearance than the guaranteed yellow Cavendish with its constant length and thickness. This is another reason why France and the UK put up protective barriers around the ACP banana long before the abolition of the internal borders in Europe (1993). Without this protection the ACP bananas would have been completely ousted by the superior-quality Cavendish dollar bananas.

A further argument for protecting imports of ACP bananas was that ACP bananas are generally cultivated on small-scale plots by family-owned businesses or by cooperatives. By contrast, dollar bananas epitomise the large-scale plantation approach adopted by the US multinationals. This implies that Euro-bananas and ACP bananas can be as much as 30-40% or even more expensive than dollar bananas. Greece, Spain, Portugal, France and the UK argued that this was a legitimate reason for giving preferential treatment to imports of Euro-bananas and ACP bananas. As we have seen earlier, the protection of these bananas was upgraded into European policy via enormous political pressure.

Not only during the banana trade conflict, but very probably in the future as well, a key role is played by the intense rivalry between the American multinationals as advocates of the dollar banana and their three big European competitors, whose interests are principally focused on the ACP banana.
The European Big Three are the British trading house Geest, the French Pomona/GIEB group and the Irish firm Fyffes (formerly part of Chiquita).
The three big American multinationals are United Fruit Company/Chiquita; Standard Fruit/Dole; and West Indies/Del Monte.

In recent years bigger and more economical banana carriers have been built for the major banana companies. As an example we would mention the 6 reefers in the "Chiquita Deutschland" class. These vessels of 640,000 cbft can carry a total load of 285.000 boxes (each holding 18 kilos of bananas). Other companies have been quick to follow suit. In 1993, for instance, the Geest Line started operating the 'Geest St. Lucia' and the 'Geest Dominica', each of 640,000 cbft (see also Chapter 22).

The current fear of banana growers in the smaller countries is that they will not be able to supply the vast quantities of fruit needed to keep up with the sailing rhythm of these big vessels. The consequences are clear: Chiquita or the competitors will send these vessels only to the production areas which are able to supply the required quantities. But even Ecuador, the world's biggest banana exporter, may perhaps also fall victim to this trend.

The three American multinationals operate efficiently, on a large scale and, most importantly, on the basis of vertical integration. Some 60% of their bananas originate from their own plantations, and they buy in 40% under contracts concluded with independent growers. Despite the agreement that was reached in the banana conflict, imports of dollar bananas in the EU are still limited.

It seems likely that the multinationals will prefer to source from their own "captive" plantations, which means that the supply contracts with independent banana growers will come under pressure. A further factor is that none of the three multinationals has production operations in Ecuador. The country is unfavourably located for the markets in the USA and Europe. Though Ecuador's biggest banana exporter Noboa is a vertically integrated group, it produces only 20% of its bananas itself and buys in the remainder. Here again, the independent growers will be the first to feel the repercussions of the European restrictions.

Only the future will tell whether the banana agreement reached in 1994 will restore peace to the banana trade until the year 2003, or whether the parties concerned see the agreement more as an uneasy truce.

The historic development of banana exports

From the very outset banana exports have shown constant growth, though the percentage growth rate was not the same for each separate period.

The pattern of export growth over the past four decades was as follows:

in 1950: approx. 2.3 million t per year
in 1960: approx. 4 million t
in 1970: approx. 6 million t
in 1980: approx. 6.9 million t
in 1990: approx. 9 million t

At the present time exports are in excess of 10 million t per annum.
As can be seen from the above figures, the increase between 1970 and 1980 was not as spectacular as in the preceding years.
Similarly, the freight and charter prices have not increased proportionally over the past decades.

As an example: the average time-charter rate on an annual basis for a reefer of 350,000-450,000 cbft revealed the following pattern for a 30-day period:

1960: $0.19 cbft/30 days
1965: $0.23 cbft/30 days
1970: $0.23 cbft/30 days
1975: $0.45 cbft/30 days
1980: $0.61 cbft/30 days
1985: $0.36 cbft/30 days
1990: $0.73 cbft/30 days

During 1982 *a* sharp decrease occurred in charter rates, which fell to their lowest point in 1985, i.e. dropping from $ 0.61 to $ 0.36. Between 1985 and 1988 the rates picked up quickly and by 1988 they stood at $ 0.62 per cbft/ 30 days.

On the basis of this price about $ 0.10 extra was paid fora "fuel economy/pallet friendly" reefer built from 1985 onwards.

As we can read from the table below, the difference between the rates for pallet and non-pallet reefers became more significant after 1990:

	non-pallet reefer	pallet reefer
1991	$0.65cbft/30days	$0.81 cbft/30 days
1992	$0.60cbft/30days	$0.74 cbft/30 days
1993	$ 0.47 cbft/30 days	$0.62 cbft/30 days
1994	$0.38cbft/30days	$0.58 cbft/30 days

Strangely enough, the price which banana growers receive for their crop has also dropped sharply compared to the price in 1950. Although the economies in the importing countries have grown over the years, the FOB price for bananas fell by 50% between 1950 and 1980, though it has picked up again since 1980.

The following table shows that the export prices for bananas from the major exporting countries were not the same for each country in the 1980-1992 period. The price difference is not always attributable to a fall in demand for bananas. In certain banana-growing areas other factors played a role, e.g. plant diseases, or natural disasters like flooding. Moreover, new banana-growing regions have also been developed in recent years, bringing even keener competition.

BANANA EXPORT PRICES (US s / tonne)					
Year	Panama	Philippines	Ecuador	Costa Rica	Colombia
1980	120	125	150	210	135
1985	110	135	180	230	205
1990	120	170	205	210	250
1991	120	195	275	285	290

Both in the past and today the difference in prices may be a consequence of export taxes. For instance, the introduction of export taxes in Panama in 1975 led to what was termed the "banana war": a conflict between United Brands (now Chiquita Brands) and the Panamanian government. The outcome was that the Panamanian government set up its own banana export corporation "Cobana" (Corporation Bananera Atlantica) with the aim of keeping control over its own exports of bananas Despite this conflict, however, Chiquita still remained the biggest exporter of bananas from Panama.

The table below shows the development of banana exports (in thousands of tonnes) over the 1980-1992 period.

EXPORT OF BANANAS (x 1,000 1)						
	Panama	•tondoras	Philipp,	Colombia	Costa Rica	Ecuador
1980	505	987	923	692	999	1290
1981	573	820	870	803	1026	1230
1982	524	913	927	733	1010	1261
1983	652	714	644	910	1033	910
1984	655	830	800	906	1030	906
1985	686	920	789	1074	882	1074
1986	587	810	856	987	885	1365
1987	676	908	775	994	991	1406
1988	583	910	867	978	1025	1551
1989	677	850	851	985	1276	1770
1990	745	811	840	1148	1444	2210
1991	706	705	950	1473	1541	2662
1992	718	786	821	1500	1755	2500

Source; *FAO. USDA*

Exports and exporting countries

Only 7% of the world's fruit production is traded internationally in the form of fresh produce, Over the past two decades international trade has increased considerably as a result of a growth in demand for fresh fruit the whole year round. World imports of fresh fruit have a total value of $ 23 billion. The EU imports $ 12.3 billion worth of fresh fruit, half of which consists of intra-EU trade.
For the major fruit products North America has an export share of 32%, Europe 31 %, South America 23% and Asia 13%. Exports of the principal fruit products are valued at $ 13 billion. Citrus is the main product group, accounting for $ 3.8 billion, followed by bananas with $ 3.1 billion and apples with $ 2j5 billion.
Banana exports are of great importance by comparison with those of other fruits. The export volume of 10.3 million t alone accounts for 22% of world production. It is worth noting that the

largest exporters are not the largest producers. India and Brazil, the largest producers, grow bananas for the domestic market only. The big exporters in Central and South America export between 80 and 90% of their banana production.

Marketing Boards

Marketing boards are public bodies established by governments in order to export fruit. The marketing boards receive sorted fruit direct from the grower, transport the products to the importing countries and also conduct negotiations with the importing countries.
The use of a Marketing Board is a good option specifically for countries which are located far away from the consumption centres The boards enjoy a monopoly position because they are the sole representatives of their government. This creates stability and optimises the prices obtained for the fruit grower. On the basis of market research the boards also provide advice to producers on a range of issues, including which variety to grow.
Countries which make use of Marketing Boards include New Zealand (the New Zealand Apple and Pear Marketing Board and the New Zealand KIWI Marketing Board), South Africa (Unifruco), Israel (Agrexco), Morocco and Algeria

Major fruit exporting regions and countries

AFRICA

Within Africa only South Africa and Morocco play a role of significance in international fruit trading. South Africa is one of the Southern Hemisphere's biggest exporters of hard fruit to the EU.
In 1992 South Africa exported 0.45 million t of citrus fruit. Exports of fresh fruit represent 80% of South Africa's cultivation production value. High quality and a large off-season supply stimulate the export of fresh fruit All marketing activities are coordinated worldwide by a single marketing organisation, Unifruco. Europe is the main sales market, followed by North America.

Morocco concentrates its efforts on citrus. In 1992 its exports of citrus fruit amounted to 0.5 million t.

ARGENTINA

Argentinian exports have stagnated and are well below their 1980 levels. A lack of cooperation between growers means that Argentina has insufficient market strength in the most competitive markets.
In 1980, for example, the country's apple exports amounted to 0.27 million t, after which they declined, reaching their lowest point (0.13 million t) in 1986. In 1992 Argentina exported some 0.2 million t of apples, mainly to Brazil, Scandinavia and the EU. A substantial proportion of Argentinian apples are of the Red Delicious variety.

ASIA

Asia's premier export countries are Turkey, Israel and the Philippines.

Turkey exports only 7% of its production. Its main export products are citrus fruits. Exports account for 18% of Turkey's orange and mandarin production and 37% of its lemon production.

Israel exports some 40% of its fruit production. Citrus is the most important product category. In 1992 Israel exported around 0.3 million t of citrus fruit.

The principal export products of the Philippines used to be coconuts, sugar, rice and tobacco. These have meanwhile been joined by exports of bananas and pineapples. The Philippines produces 3.5 million t of bananas annually, with 25% (0.9 million t) being exported.
The main importers of bananas from the Philippines are the USA and Japan. The bananas are grown on Mindanao, the most southerly island of the Philippines.
Japan used to import its bananas from Ecuador, but today they are largely shipped in from Mindanao. In 1975 banana exports from the Philippines to Japan amounted to some three-quarters of a million tonnes a year, In subsequent years Japan's imports declined slightly, but they currently seem to have stabilised at around some 0.5 million t per annum. Against this, however, banana exports to S.W. Asia and South Korea have increased enormously. The three big multinational groups Castle & Cook, Del Monte

and Chiquita Brands obtain their bananas chiefly from Ecuador, Costa Rica, Honduras and Panama, but they are also the leading exporters for bananas grown in the Philippines. The Philippines also produces 1.2 million t of pineapples yearly, of which 0.2 million t is exported in the form of canned pineapple.

BRAZIL

Fruit is Brazil's main export product. A large proportion of its exports are accounted for by citrus fruit in particular. Annual exports of oranges, mandarins and lemons alone amount to more than 200,000 t. The 25 other types of fruit exported by Brazil include bananas, mangoes, pineapples, pears, apples and avocados. Because of its fertile soil, sunny climate, sufficient rainfall and cheap labour and thanks to the improvement in the quality of its products, Brazil may be able to establish a leading position in the world market for fruit. Since 1980 fruit exports from Brazil have revealed a tremendous upsurge. Particularly exports of frozen concentrated orange juice in bulk tankers have contributed to this fast growth (see also Chapter 51.

CHILE

Chile exports a lot of fruit to the USA and the EU during the northern hemisphere's off-season. Chile's export growth during the 'eighties can best be described as explosive and comprises a wide variety of fruits. In 1992 Chile exported some 0.4 million t of apples and about 0.4 million t of grapes.

COLOMBIA

Colombia comes a close second in the export rankings for bananas. This country produces 1.7 million t annually, of which 90% (1.5 million t) is exported. In Colombia the independent banana growers from the Uraba district have joined forces within the trading company "UNIBAN" (Union de Bananeros de Uraba). This trading company exports bananas under the "Turbana" brand name. Another Colombian banana company is "Proban" (Promotora de Banano). The bananas from Santa Marta are mainly shipped by Standard Fruit's sales organisation which is called "Tecbaco" (Technicas Baltime de Colombia).

CUBA

Traditionally, Cuba always used to ship its bananas to the former Soviet Union and the former Eastern Bloc countries. Now that the protected Communist market has disappeared Cuba, too, will have to make attempts to penetrate other markets.

ECUADOR

Ecuador is still the world's biggest banana exporter. In 1992 this country produced 2.9 million t of bananas (excluding plantains) and in that same year it exported 2.5 million t (86% of its production), thus providing 25% of the world supply of bananas.

EUROPEAN UNION (EU)

Within the EU Spain, France and Italy are the principal exporters of fruit.
Belgium and the Netherlands are the main re-exporters.
Spain and Italy are by far the biggest citrus producers in Europe.
Spain is the largest exporter of fresh oranges and exports around 3 million t of fresh fruit annually (mainly oranges, mandarins and lemons).
Italy's annual exports of fresh fruit run to some 1.5 million t.
Italy, France and Germany are Europe's major apple producers, each having a crop of around 2 million t per season.
France is the world's largest exporter of apples (0.55 million t in 1992), accounting for 18% of the world trade in apples. In 1992 Italy exported 0.4 million t of apples.
Europe's share of the international fruit trade largely consists of intra-EU trade.

MEXICO

Mexico produces 1.9 million t of bananas, 3.2 million t of citrus (of which 2.8 million t of oranges) and 0.8 million t of mangoes. Initially, this country exported its bananas to its neighbouring markets (mainly the United States). However, Mexico is now also exporting its

bananas on a modest scale to Western Europe, one importing country being Poland. These bananas are shipped from the port of Coatzacoalcos.
The local banana growers in Tabasco state have combined together within the "Union Agricola Regional de la Sierra del Estado de Tabasco Productores de Platano".

USA

After Brazil, the USA is the world's largest producer of fruit.
In 1992 the USA produced 10.4 million t of citrus (13.4% of total world citrus production); 5.5 million t of grapes; 4.9 million t of apples; 0.8 million t of pears; 0.5 million t of pineapples; and 1.3 million t of peaches.
Despite the fact that the vast majority of US-grown fruit is destined for the domestic market and though exports account for only 7% of total production, the USA is still the world's biggest overall exporter of fruit.
Its main markets for export are Canada and South East Asia, but the importance of the EU as an export market is increasing.
In 1992 the USA exported 0.5 million t of apples, 0.23 million t of grapes, and 1.1 million t of citrus fruit.
US apple exports to the Far East, especially to Taiwan and Hong Kong, are showing a rising trend.

Loading bananas from barges in Colombia

MATURATION AND POST-HARVEST TECHNOLOGY

The maturation process

After fruit and vegetables have germinated from seed, they undergo three physiological phases during their lifetime: growth, ripening (maturation) and ageing (senescence).
In fruit transport "ripening" is understood to mean the period between the end of maturation and the start of senescence. The senescence period - the final phase in the development of the living plant - starts as soon as the organism loses its capacity to keep building up its cell structure through the intake and processing of nutrients. The anabolic (= constructive) biological process then changes into a catabolic (= degenerative) process involving the breakdown of cells, leading to the ageing of the product and ultimately to degeneration of the cell tissue.
During maturation the fruit shows distinct changes in the following respects:

(a) respiration pattern;
(b) ethylene production;
(c) colour of the peel or skin and/or the fruit tissue;
(d) permeability of the peel/skin.

The extent to which the quality and keepability of perishable products can deteriorate is highly dependent on their respiration rate. A graph of the respiration rate of different types of fruit shows that this rate is at its highest before ripening, after which it gradually declines. The unusual feature of some types of fruit (including apples, pears, bananas, kiwis and avocados) is that their respiration rate does not decrease further during ripening - in fact, they breathe faster!
This increase in the breathing rate during ripening is known as the respiratory climacteric ^ or climacteric rise. On the basis of the respiration characteristics, it is possible to divide fruit into two categories: "climacteric" and "non-climacteric" fruit. All vegetables fall in the "non-climacteric" category. During the ripening process climacteric fruit reveals a substantial increase in its production of carbon dioxide ($C0_2$) and ethylene (C_2H_4). Non-climacteric fruit shows no change in what is already a low production of $C0_2$ and ethylene.

Growth and respiration pattern of fruit during development

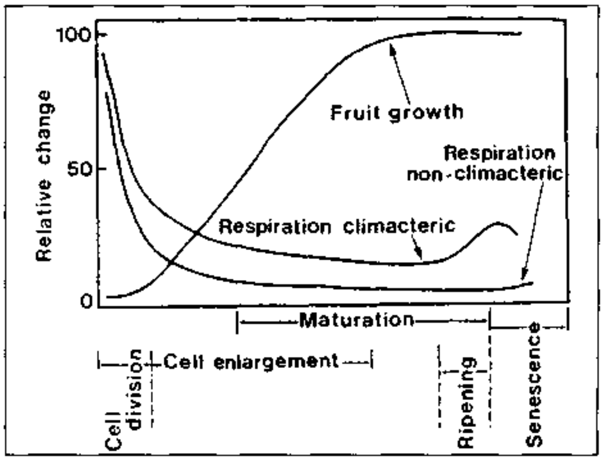


Fig. J.B. Baile

The respiratory climacteric phase starts just before the fruit reaches its full size and before ripening begins and this phase also continues, as does the ripening process, after the fruit has been harvested. Generally speaking, climacteric fruit reaches full ripeness after the respiratory climacteric phase. Climacteric fruit will ripen normally after harvesting. During ripening the taste and aroma develop and the sugar content increases. The fruit flesh also becomes softer during maturation. If the fruit has been picked too

Respiratory climacteric: this is the period when an important change occurs in the breathing process in which a living organism or cell absorbs oxygen, distributes it and consumes it by forming compounds with oxygen and releasing the resultant products, specifically carbon dioxide.

early the fruit will turn softer but its taste and aroma will not develop further.

The Avocado is one exception to this: this fruit does not change colour or ripen on the tree but only after being picked. Non-climacteric fruits (Citrus fruit. Pineapples, etc.} display the most distinctive signs of ripening, e.g. colour changes, but their maturation process is normally slower than that of climacteric fruit.
Grapes are not harvested until they are completely ripe. Unlike climacteric fruit they do not ripen any further during transport. Grapes therefore give off little heat and $C0_2$ during transport and have a very low ethylene production.

Climacterium

The transitional phase between unripe and ripe is also referred to as the "clirnacterium". This is the period when the fruit has a higher ethylene production, accompanied by an increase of as much as 60-200% in respiratory intensity. After this period the respiration rate slows down again as the fruit reaches its ripe stage. Depending on the time of harvest, the climacteriurn may take place either on the tree or during storage. Climacteric fruit destined for prolonged intermediate storage is usually picked before the climacterium begins.

The table below subdivides fruit into two categories based on the respiration pattern.

CLIMACTERIC FRUIT	NON-CLIMACTERIC FRUIT
Apples	Blackberries
Apricots	Cherries
Avocados	Cucumbers
Bananas	Grapefruits
Kiwis	Grapes
Mangoes	Lemons
Nectarines	Pineapples
Papayas	Pomegranates
Passionfruit	Raspberries
Peaches	Satsumas
Pears	Strawberries
Persimmons	Tangerines
Plums	
Tomatoes	

CO_2 production

As will be known, the air that we breathe consists of 21 % oxygen (0_2) and 78% nitrogen (N_2) and an average of 0.032% carbon dioxide ($C0_2$). "Living" products breathe, which means that their cells absorb oxygen and produce carbon dioxide. Respiration can be described as all the oxidative metabolic processes which convert the high-molecular substances which are stored in the cell, such as carbohydrates (mainly glucose), fats and proteins, into simpler molecules such as $C0_2$ and water (H_20). This releases energy in the form of respiratory heat. The loss of the stored reserves of nutrients through respiration has the following results:

1. faster ageing (senescence) of the product;
2. reduction in nutritional value;
3. dehydration of the product;
4. deterioration in (sweet) taste and aroma.

To summarise, we can say that the respiration rate is a crucial factor as regards the extent of the deterioration in the quality and keepability of perishable products.

A product's respiration rate can be determined by measuring either its oxygen consumption or the quantity of $C0_2$ it produces. The respiration rate is a reliable indicator of the product's metabolism and can therefore be used to calculate the possible storage time.

Influence of CO_2 percentage on storage time

The influence of the $C0_2$ that is produced is not the same for every product. An increased $C0_2$ percentage may prolong the lifetime of various types of fruit but it may also give rise to disease, e.g. brown heart in apples. If the $C0_2$ percentage is too high (more than about 7%) the product may "suffocate". The fruit shipper will generally require that the CO_2 percentage in the hold does not exceed 0.5 to 1.0%.

CA storage

In recent times many new storage methods have been developed. All of them are aimed at reducing the respiration rate and thus prolonging the storage time. One of these methods is known as Controlled Atmosphere (or CA) storage. Depending on the product, CA storage involves increasing the carbon dioxide content and/or reducing the oxygen content. The aggregate of the carbon dioxide and oxygen contents in normal CA storage amounts to approx. 21 %. Because of the changed gas composition the respiration rate of the product is inhibited, as is the ethylene production and the ethylene effect.

CA storage ensures a substantially longer keeping time and improved preservation of product quality. Other benefits are: delayed onset of rot, delayed discoloration, preservation of taste and consistency, delayed ripening and a reduced risk of physiological storage diseases.

In the case of scrubbed CA storage the 0_2 percentage is roughly 2-4% and the CO_2 percentage 5-7%.

Though transport of fruit in CA containers is still limited, it is increasing all the time. The New Zealand Line and the Australian National Line have several hundred CA containers in use, but such containers are also used by Refrigerated Freight Lines, Blueport A.C.T. and Mitsui O.S.K.

Attempts have recently also been made to find a packaging method which will allow the air composition to be changed in such a way that a climate similar to that used for CA storage can be created inside the packaging. For example, bananas for shipment to Italy and the Middle East are packed in Banavac bags.

Inside the banana crate the 'hands' of bananas are packed inside a Banavac bag: this is a sealed polyethylene bag of a special thickness (0.4 mm). As a result of the respiration process the CO_2 percentage in the bag is increased to 5% whilst the 0_2 percentage is reduced to about 2%. As will be known, $C0_2$ and ethylene are each other's adversaries. After some lapse of time, therefore, the ethylene percentage inside the bag is dramatically reduced. This enables transport times of as long as 40 days. However, if the journey lasts even longer, the $C0_2$ percentage will increase to above 6-7% and the banana will suffocate. Its green skin will turn dullish and the pulp will become soft and tasteless, making the fruit unmarketable.

Ethyleneproduction

Almost all ripening fruits give off volatile gases, one of which is ethylene. Ethyiene is the simplest of the organic compounds which affect the physiological processes of crops. Ethylene gas contains a hormone which causes accelerated senescence, which is why high ethylene concentrations can cause considerable damage. Besides reducing the product's keeping time, an excessive level of ethylene gas in the storage hold also brings a higher risk of fruit pulp softening and the occurrence of rot. In the case of **Leaf products** it also leads to yellowing and eventually to leaf drop. Against this, however, ethylene is specifically used to stimulate the ripening of fruits which are picked in an unripe state, such as **Avocados, Kiwis and Bananas.** Another point to note is that climacteric and non-climacteric fruits also differ as regards the amount of ethylene they produce. During ripening, climacteric fruit produces considerably bigger quantities of ethylene than non-climacteric fruit. Products subject to spoilage are adversely affected by ethylene in the following ways:

(a) accelerated senescence (ageing) of the product;
(b) accelerated ripening of fruit;
(c) loss of green colour (yellowing);
(d) leaf drop and rot in vegetable products;
(e) formation of reddish-brown patches (e.g. on lettuce};
(f) sprouting of potato tubers;
(g) softening of the fruit flesh.

Fruits such as **Bananas, Avocados and Mangoes** produce a great deal of ethylene. Conversely, little ethylene is produced by smaller types of fruit, such as **Strawberries, Redcurrants, Blackcurrants, Cherries and Grapes.** Most vegetable crops have a relatively low ethylene production, less than 1 microl/kg/h. Only ripening **Tomatoes** produce more, up to 1-10 microl/kg/h. However, some low ethylene producers like **Cauliflower, Lettuce and Kiwi** will ripen faster if exposed to ethylene gas!

The general rule is that unripe fruit produces little ethylene and ripe fruit a lot. In particular, products which are starting to rot produce big quantities of ethylene, which means that over-ripe fruit must be removed from the hold without delay. Ethylene production alone provides no indication of the expected keeping time, since other factors may sometimes play a more significant role. These factors include: growing conditions, variety of plant, extent of damage suffered and whether rot has started to develop.

In addition to the gas given off by the product itself, an increased ethylene percentage in the air may also be caused by other sources. These include exhaust gases from internal combustion engines. This is why it is essential to use solely electric forklift trucks for loading and unloading work. Obviously, an excessive ethylene concentration in the hold can be prevented by ensuring sufficient ventilation.

The following table gives a rough indication of the ethylene production and respiration rate for various products.

	Ethylene production	Respiration rate
LOW	Beans Berries (e.g. Redcurrant) Cabbage Cauliflower Cherries Citrus fruit Cucumbers Grapes Kiwis Leaf vegetables Persimmon Pineapple Potatoes Root crops Strawberries	Apples Citrus fruit Dried fruit Grapes Onions Potatoes (ripe) Vegetables (greens)
MODERATE	Bananas Kiwis (ripe) Mangoes Melons Plantain (banana) Tomatoes	Apricots Bananas Cabbage Cherries Lettuce Nectarines Peaches Pears Plums Potatoes Tomatoes
HIGH	Apples Apricots Avocados Nectarines Papayas Passion fruit Peaches Pears Plums	Asparagus Avocados Beans (Lima beans) Berries ie.g.ftedcurrantl Broccoli Cauliflower Chicory Cut flowers Spinach Strawberries

Properties of ethylene

Ethylene (chemical formula C_2H_4) is a hydrocarbon gas whose insipid, weak, sweet odour is identifiable even in smaller concentrations. The gas has both a suffocating and a pain-killing effect. High concentrations will cause loss of consciousness in humans and may even result in death through suffocation. If ethylene gas is mixed with air at between 3 and 32 vol.%, the resultant mixture is combustible and may even be explosive.

Ethylene as a ripening hormone

The actual concentration of ethylene needed to speed up the ripening of climacteric fruit is not the same for each product, in most cases a concentration of between 0.1 and 1.0 ppm {= parts per million) will be sufficient. However, the product must then be exposed to this concentration for at least 12 hours, if not longer. Even then it still takes a few days before the product is fully ripe. By contrast, non-clirnacteric fruit hardly reacts at all to an increased ethylene concentration.

In ripening chambers ethylene is used to bring about a faster and more uniform ripening of the products. Depending on the required ripeness and the type of product, this process takes place at a cell temperature of between 18 and 25°C (and a relative humidity of 90-95%}. At a lower temperature the ripening process lasts longer, whereas a higher temperature will promote bacterial growth and rot. Ethylene concentrations of between 10 and 100 ppm are usually applied for a period of 24 to 72 hours. The air circulation in the cell must be powerful enough to circulate the ethylene effectively. On the other hand the number of air-changes must be such that no excessive $C0_2$ percentage can arise. On average the ethylene concentration will amount to 100 ppm; this is equivalent to approx. 0.03 m^3 in a cell capacity of 300 rn^3 (a ratio of 1 cbftto 10,000 cbft hold capacity). Higher concentrations will not speed up the ripening process any further.

Combined cargo

Practical considerations often make it necessary to combine the shipment of various perishable products. The important point to watch here is that each product will have different requirements as regards temperature, relative humidity, exposure to ripening gases (ethylene} and odour transmission. If various cargoes are loaded together in one compartment it is sometimes necessary to deviate from the recommended optimum transport temperature. In such cases the prevailing temperature in the hold will be that of the "warmest" product. The longer the journey lasts the lower the tolerance in the temperature variation.
The packaging also plays a major role here. **Hermetically sealed products** can usually be shipped in combination with other products. **Quick-frozen products,** for instance, are usually sealed in hermetically closed packs and can therefore easily be shipped in combination with other products.

Ethylene sensitivity

The drawbacks of combined transport tend to become bigger as the journey time increases, especially as regards the harmful effects of ethylene. And yet, even during a short voyage, damage can still be caused by ethylene-laden air and the products will only show the adverse effects later.
The following table gives a breakdown of a number of vegetables and fruits according to their sensitivity to ethylene. As an aid to decide on whether a cargo should be shipped either combined in one and the same compartment or in separate holds, the following table should prove useful:

Sensitivity to ethylene

high	moderate	low
aubergines	asparagus	artichokes
avocados	beans	berries
bananas	celery	blackberries
cabbages	endives	cherries
cauliflowers	oranges	grapes
cucumbers	paprikas	kohlrabi
kiwis	pineapple	mushrooms
lettuce	potatoes	onions
mangoes		raspberries
papayas		rhubarb
spinach		root crops
tomatoes		strawberries
		water melons

The ethylene producers which cause most problems are ripening fruits and vegetables such as **Apples, Pears, Peaches, Nectarines, Plums, Apricots, Melons and Tomatoes.** A lot of ethylene is also produced by tropical fruits such as **Bananas, Avocados, Mangoes, Papayas and Passion fruit.** Small fruit varieties such as **Strawberries, Redcurrants and Blackcurrants, Cherries and Grapes are** low ethylene producers.

Vegetables which are sensitive to ethylene exposure must definitely not be transported in combination with ripening fruits which give off a lot of ethylene gas. This means that there is a great risk when **Apples and Tomatoes** are shipped together with other vegetables and fruits.
Bananas and Kiwis cannot, in principle, be shipped together with any other fruit. Two other incompatible products are **Apples and Kiwis.** These must never be shipped in the same vessel. Even if the holds are far apart (e.g. hold 1 and hold 3) there is still a great risk that the ethylene given off by the apples may enter the air supply system and discharge ducts and affect the ripening process of the kiwis so that they are over-ripe and/or too soft upon outturn!

Aroma and taste transmission

Apart from the product's sensitivity to temperature and ethylene, allowance must also

be made for the possibility of aroma and taste transmission.
Since products like **Citrus fruits** develop pungent aromas that can taint other products, they need to be stowed separately. **Citrus fruits** must never be transported in combination with **Apples, Tomatoes or Bananas.** But there are some fruits and vegetables which can be shipped in combination. Examples include the combination of **Potatoes or Onions** with **Hard Fruit. If Potatoes** are stowed together with **Apples, the apples** may be tainted with an earthy taste, whilst the **Potatoes** will lose their mealiness under the influence of the ethylene given off by the apples.

PREVENTION OF DAMAGE BEFORE AND AFTER HARVEST

The causes of damage

During or shortly after the unloading of the cargo a damage claim may be submitted by the consignee. In view of the carrier's liability it is important for him to know in such cases whether the quality deterioration occurred during the voyage or whether the damage was attributable wholly or in part to circumstances which occurred before the products were loaded into the vessel. One possibility, for instance, is that the products may have been damaged during growth due to an imbalance in the composition of the plant feed. Calcium deficiency, for example, can cause bitter pit in Apples or top rot in Tomatoes.

Freshly picked fruits and recently harvested vegetables have a high moisture content. In such cases a loss of moisture will lead not only to weight loss but also to shrivelling and discoloration and, ultimately, to a loss of aroma and keepability. The actual amount of moisture loss is determined by the difference in vapour pressure between the product and the ambient air. To minimise moisture loss, some fruits are coated with a layer of wax, sometimes in powder form. Such a wax coating may also be applied to replace the natural surface layer of wax ('bloom'} which disappeared after the fruit was washed. In some cases the wax coating is applied solely for 'cosmetic reasons', i.e. to make the fruit look more attractive and appealing.
To prevent mould growth many fungicides (= mould-inhibitors) are incorporated in the wax. However, the coating of wax must never be applied so thickly that it impedes respiration. Certain products, including Cucumbers, Broccoli and Cauliflower, are also wrapped in plastic film to reduce moisture losses.

As a general rule, products which have to be transported by sea are supplied in a pre-cooled state. With a view to preventing moisture loss an important factor is the speed of the circulating air during storage and transport. Excessive ventilation may cause the product to dry out, especially if its surface is big in relation to its mass, as is the case with Lettuce. In Citrus fruit, dehydration causes the peef to weaken at the base of the stem (stem end breakdown). On the other hand, insufficient ventilation raises the $C0_2$ content and the result may be a discoloration of the fruit flesh, e.g. in Apples (brown heart).

To summarise briefly, damage to "living" cargo can be caused by one factor or by a combination of various factors, as described below.

1. Surface damage and bruising

If the fruit suffers bruises and open wounds during growth, these will form a good point of entry and a breeding ground for the ever-present micro-organisms and will increase the risk of damage caused by insect attack. But fruit can also be damaged as a result of rough human or mechanical handling during and after plucking. The resultant bruises stimulate respiration. This in turn increases ethylene production and reduces the product's keepability. Even if the damage marks are limited, such blemishes still make the fruit less attractive, which means that it is given a lower quality rating, thus diminishing the market value of the entire batch or consignment.

2. Temperature-induced damage

Too-high or too-low a temperature during growth or during cold storage can damage the fruit. Temperature damage may also occur during the growth phase because of too much heat (temperature in excess of 25°C) or because of over-exposure to "direct" sunlight. The consequences may be: discoloration, uneven ripening, dehydration and burning (sunburn). The result of too much direct sunlight, especially in Citrus fruit and Avocados, is surface burning. In the case of Apples in particular, the problem is

that the damage caused by sunscald is not visible at the time of harvest. Only after a few weeks in storage do the effects become apparent in the form of yellowish or brownish discolorations on the side that was exposed to the sun's rays.
The storage temperature for tropical and subtropical products is roughly between 0°C and 15°C, depending on the crop. If the storage temperature drops below the minimum level (i.e. the highest freezing point}, then the product may become chilled. The results of this are: pockmarks on the skin (pitting), especially in **Grapefruit;** moisture build-up in the fruit flesh (watery breakdown); brown patches on the skin in **Apples and Pears** (darkening); and a deterioration in flavour. **Citrus fruit, Avocados, Bananas, Mangoes and Tomatoes** in particular will no longer ripen normally if they have been chilled. But another cause of fruit damage is below-zero temperatures during the growth period (frostbite).

3. Chemical spoilage

One of the factors that promotes chemical spoilage is exposure to light. Light encourages the start of sprouting in tubers and bulbs. If too many chemical products (e.g. fungicides) are used to prevent mould, bacterial or insect attack or "scald", the crop may be damaged. One example is the use of sulphur dioxide to prevent the growth of Botrytis cinerea in **Grapes.** If fungicides are used to excess, then the remedy will often prove worse than the cure.

Respiration pattern and harvest time

As we saw in the previous chapter, the respiration patterns of vegetable and fruit crops are not the same for every product. Non-climacteric crops (which include most varieties of vegetables, citrus fruit and 'bush fruits') do not ripen further after harvesting and their respiration rate remains more or less constant. These products can therefore only be picked after they have ripened. Climacteric crops have a different type of respiration pattern and they continue to ripen after harvesting. The quality of these 'living and breathing' products is determined by such factors as taste, size, colour, shape, texture, keepability and appearance.

If fruit is picked or harvested too early or too late, this will affect its maturation and, consequently, will reduce the product's quality and keepability when it arrives at its point of sale.

An important point to bear in mind here is that in many cases the greater proportion of the time that elapses between harvesting and delivery to the end-consumer is accounted for by the time taken to transport the product by ship to its country of destination. The question that we must therefore ask ourselves is: At which point in time must the fruit be harvested so that it can safely survive the voyage in a perfectly intact condition and without any adverse effects on its quality and keepability?
Because of economic considerations this may sometimes even mean that it is necessary to delay the ripening process. In such cases the fruit is treated with plant-growth regulators (gibberellins) or with other growth-retardants and transport then takes place in CA containers.

Assessing the ripeness

As a rule, fruit should be picked when it is mature, i.e. at the moment when it is sufficiently developed in size, so that after harvesting, and possibly after further ripening, its quality and appearance are still acceptable to the end-consumer. **Bananas,** for instance, are not picked when mature but while still green. At that moment they are basically inedible. Only after further ripening do they become suitable for consumption. In addition, the harvesting time of bananas depends on how long the transport by sea will last. If bananas have to be shipped from Latin America to Europe, they can be picked in a less ripe state than bananas destined for shipment to North America.
In the case of climacteric fruit the peak of the climacteric rise more or less coincides with the time when the fruit is physiologically ripe. To ensure maximum keepability, the fruit is harvested just before the climacteric rise begins. After being harvested, the products are stored as quickly as possible at a low temperature to slow down their respiration rate and delay the onset of the climacteric rise.

The ripening process is the result of complex, sometimes interrelated changes. The fol owing

internal and external changes are typical of this process:
(a) The fruit grows to its full size,
fb) The fruit flesh becomes softer,
(c) Starch is converted into sugars,
{d} Sucrose is converted into fructose and glucose.
(e) The degree of acidity decreases.
(f) Aroma and flavour develop further.
(g) The basic green colour changes to another colour (i.e. yellow, orange or red).
fh) In the case of climacteric fruit the respiration rateincreases.
{i) The rate of ethylene production changes,
(j) A change occurs in the soluble substances and proteins.

The above-mentioned characteristics of the ripening process can be used to work out an approximate harvesting time for most vegetable and fruit crops. Depending on the product involved, use is often made of one or a combination of the following instruments or methods:

1. Measuring the size with the aid of *callipers.*
2. Determining the shape with the aid of *standard indicator charts.*
3. Determining the firmness with a *penetrometer.*
4. Measuring the starch content via *chemical tests.*
5. Measuring the sugar content via chemical tests or with the aid of a *refractometer.*
6. Measuring the degree of acidity via chemical tests.
7. Determining variations in external colouring with the aid of *standard indicator charts.*
8. Measuring the ethylene production with the aid of a *gas chromatograph.*
9. Measuring the juice content via chemical tests.
10. Determining internal variations in colouring with the aid of light rays (dubious criterion).

For some fruit types like **Apples, Pears and Bananas** the right harvesting time can also be approximately determined on the basis of the average time that elapses between flowering and maturation. Obviously, the measuring of changes in the starch composition provides a much more reliable indication as regards the ripening of apples and pears.
For some types of fruit (e.g. **Citrus fruit, Melons** and **Kiwis)** the stage of maturation can also be determined by measuring the quantity of soluble solids. To give one illustration: the earliest time when kiwis can be picked is when they have a soluble solids concentration (SSC) of 6.3%. **Kiwis** are ripe enough to eat when their SSC percentage is between 13 and 15%. In the case of **Avocados** the appropriate time to harvest is determined by measuring the ratio between the oil content and the percentage of dry matter. By the start of the harvest time for avocados their oil content should amount to approx. 8%.

For **Citrus fruit** the picking time is also determined by the colour change in the peel. This surface colour change is established by measuring the reflected light or by using standard colour charts. Cold nights followed by warm days are needed to cause citrus fruit to change colour from green to yellow or orange. If grown in the tropics, therefore, citrus fruit remains green, even though the fruits are ripe and edible. By removing the *chlorophyll* (the green colouring matter formed under the influence of sunshine) the fruit can be *"de-greened"* without it deteriorating in quality. To do this, the fruit has to be stored in a room with an air temperature of between 20 and 29°C and an ethylene concentration of 5-10 ppm. However, **Mandarin oranges** which have been plucked early in the season and "fumigated" and which have been coloured by means of "gas exposure" may sometimes reveal dark stripes on the peel *(zebra skin).* This makes them unsuitable for sale.

The fruit tester

As mentioned earlier, the structure of the fruit, e.g. its penetrability, firmness (consistency) and ripeness, can be tested with the aid of an instrument called a *penetrometer.*
Usually, an "Effigi" penetrometer Is used for this purpose. As a rule this meter is supplied complete with two plungers. The plunger with a diameter of 7/16" (11 mm) is used for testing **Apples** and the plunger with a diameter of 5/16" (8 mm) for testing **Pears and Kiwis.**

To test Avocados a plunger with a diameter of 1/4" (6.4 mm) has to be used. The gauge on the plunger shows the pressure both in kgf[1]) and in British pounds - lbs[2]).

Here are a few examples of how to test various fruits to find out whether they are ready to be shipped.

Apples

These have to be tested with the big plunger (11 mm). The pressures for *Red Delicious are:* Hard stage: 16.5 lbs; firm stage: 14 lbs; firm-ripe: 11 lbs; ripe: 8 lbs.

Pears

If the pears are destined for refrigerated storage, they are picked when the pulp pressure reading is between 18 and 20 lbs. If they are for immediate sale, they are not harvested until the pressure is approx. 15 lbs.

Bear in mind that a pressure difference of 2 pounds, e.g. from 20 to 18 lbs, is not the same as a pressure difference from 12 to 10 lbs!

Avocados

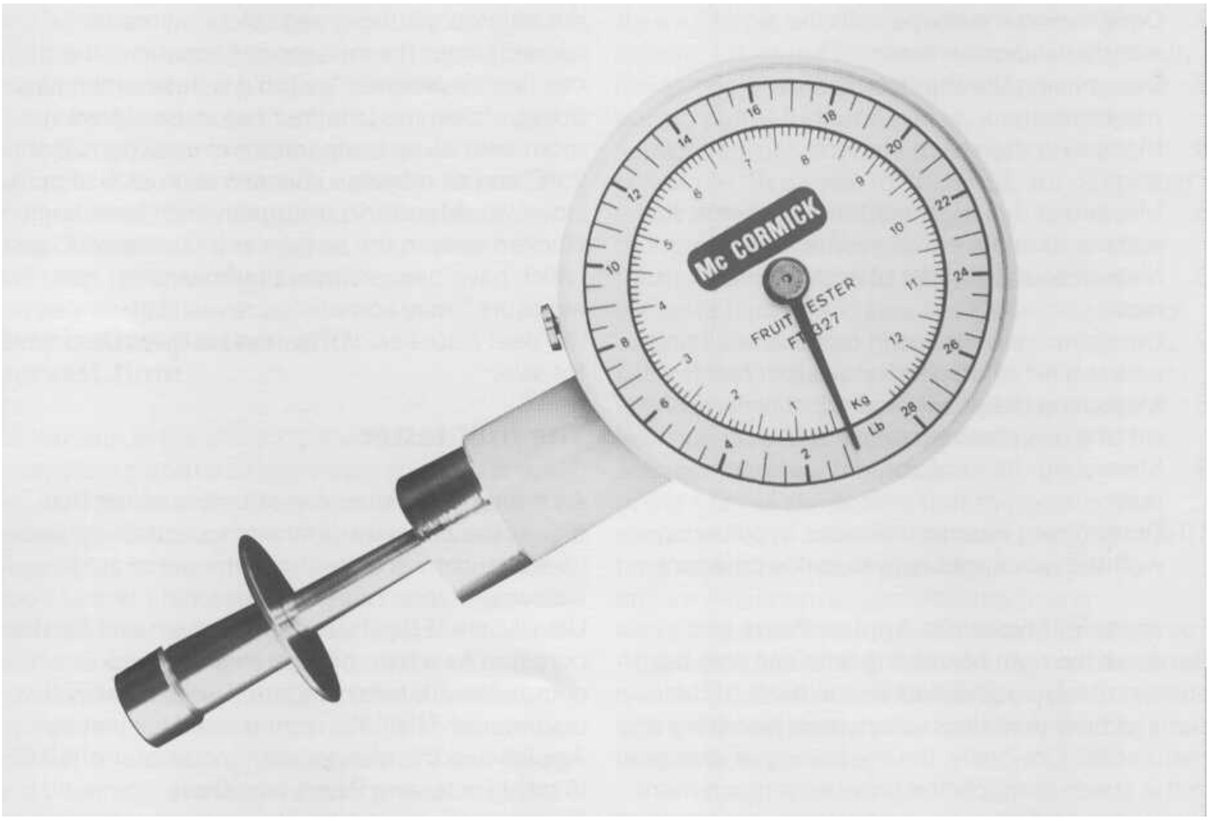
These are harvested when the pulp pressure is approx. 30 lbs. Since 1983 avocados from California have been exposed to ethylene gas treatment prior to shipment. In the case of these preconditioned avocados the pulp pressure decreases to 24-18 lbs during ethylene treatment. When they are subsequently delivered for shipping, the pressure amounts to 19 to 16 lbs. For 'Hass' avocados (use the 6.4 mm plunger) the following pressures will serve as a basic indication:

after post gassing:	18-22 lbs;
at start of ripening (breaking point):	10-18 lbs;
ripe:	6-9 lbs;
edible:	approx. 3 lbs;
over-ripe:	1-3 lbs.

Kiwis

The ripeness of kiwis is likewise determined by the pulp pressure, plus their SSC (soluble solids

1) 1 kgf . 9.80665 N
2) 1 lbf = 4.44803 N



Penetrometer

concentration) percentage. When kiwis are picked the pulp pressure is between 8 and 10 kgf (approx. 18 lbs). During transport (temperature: 0°C) the pulp pressure will decrease to 6 kgf after about 5 weeks if there is no exposure to ethylene. The fruit is only edible once the pressure is between 0.4 and 0.8 kgf.

Penetrometer

The penetrorneter is a relatively cheap instrument and it is advisable to have this instrument on board, especially when carrying fruit. In the event of a possible damage claim, it may prove useful to have data available about the pulp pressure at the time of loading and during the voyage.

To measure the pressure, the procedure is as follows:

1. Select fruits for testing which are about the same size and at about the same temperature.
2. Have the entire test carried out by one and the same person.
3. Test only the green side or only the side of the fruit which is already coloured.
4. Peel the fruit (very thinly) over a surface area of about 3-4 cm*.
5. Place the fruit on a hard surface and press the plunger in for 2 seconds until it penetrates the fruit flesh to the marked line.
6. Read off the pressure displayed on the gauge and note it down.

The penetrometer reading is very much influenced by the speed at which the plunger is pressed into the fruit pulp. Someone in a hurry will tend to press the plunger quickly and firmly into the pulp. The resultant readings will differ completely from those obtained by pressing the plunger calmly and slowly (for approx. 2 seconds) into the body of the fruit.
Where highly accurate measuhngs are required, a mechanically-controlled penetrometer should be used. This ensures that the plunger is always pressed in at precisely the same speed.

Optical testing methods

If it is necessary to conduct an extensive quality test, then the use of some of the methods described above will cause too much damage to the fruit. This is why the following (non-destructive) methods have recently been increasingly used to test ripeness and quality:

(a) Sonic vibration technique

The fruit's firmness can be tested by measuring the way it responds to vibrations. To do this, a vibration of a specific amplitude and frequency is transmitted through the fruit from one side. The vibration exiting at the other side of the fruit is recorded and analysed. A comparison of the vibration figures makes it possible to determine the hardness, and hence the stage of ripeness. Since the ripeness decreases in proportion to the vibration factor, this method will also allow ripeness of, say, bananas to be measured. Since the juice content is closely related to the hardness of the product, this method also provides an indication of the quantity of soluble solids.

At the present time the sonic vibration technique is still in its infancy. Sometimes the technique produces a widely scattered range of readings which do not offer much to go on, thus making the end-results dubious.

(b) Light-absorption technique

Plant cells contain various pigments such as chlorophyll, carotenoids and phytobinins. The pigment content provides a rule of thumb as regards for the ripeness of the fruit because, as the fruit becomes more mature, the chlorophyll pigment - which creates the green colour - disappears and there is an increase in the anthocyanin pigments which are responsible for the colours blue, red or violet. Under the influence of light the cells which contain chlorophyll convert $C0_2$ and water into glucose. In turn, the glucose is transformed into starch (assimilation).

This is the reason why leaf vegetables with a high chlorophyll content (e.g. Lettuce) are of a good quality when fresh and why Tomatoes with a high anthocyanin content are completely ripe.

As this explanation shows, the ripeness of the harvested produce can also be determined on the basis of the pigment content. Each pigment absorbs light at a specific wavelength. For chlorophyll this is 660 nanometre (nm} and for anthocyanin it is 540 nm. A special instrument can therefore be used to measure the light absorbed by each individual pigment. This makes it possible to determine the phase of the product's ripeness and structure at an early stage. This same method can also be used to detect *core breakdown* in Pears or *water core* in Apples. Water core causes light diffraction, and so light absorption is a very simple method to measure how far the ailment has progressed.

In the case of Tomatoes monochromatic light is passed through the fruit. This reveals whether the tomato is coloured red all the way through to its core. The fruits which were the first to set on a tomato plant may still have a very green core; the same also applies if the plant has been cultivated under very warm conditions. Such a green-core tomato is absolutely no use at all if the tomato has to be processed into tomato juice, tomato ketchup, etc.

(c) ***Infrared radiation technique***

The dissolved substances in the fruit chiefly consist of sugars, such as glucose, fructose and sucrose. These substances also have their own specific light-absorption capacity. As regards the sugars, proteins and water, however, the absorption capacity is close to the wavelengths of the infrared rays.
(Most infrared rays are not within the visible spectrum; they are electromagnetic waves with a wavelength of between approx. 780 mm and 1 mm),
By measuring the absorptive capacity of the solubles, therefore, it is possible to determine the quality and the ripeness. This method is still being developed and further refined and is (at the moment) still used mainly in laboratories. It is not yet sufficiently reliable for practical applications. However, in view of the constant advances that are being achieved in modern-day technology, it is certainly possible that the methods described under (a) and (c) above will find wider practical application in the near future.

CHAPTER 5

PALLETISED CARGO AND BULK JUICE TANKERS

Packaging after harvesting

The packing station

As the maintenance of quality is an important, if not the most important factor, most fruit is harvested or picked by hand despite the high costs of manual labour. Rough and/or mechanical handling can lead to internal and external damage (bruises). This not only makes the fruit unattractive, but also raises its respiration rate and stimulates the growth of bacteria and fungi. For this reason steps must be taken during and after harvesting to identify possible hidden defects so that the products are in excellent condition when delivered for shipping and so that the fruit still complies with the relevant quality standards when it is unloaded at its destination.

Bigger-sized fruits, such as Apples and Pears, are collected in plastic buckets or bags during plucking and are then transported in big crates ("field boxes") to the packing station. Small fruits, like Strawberries, are usually sorted and selected on the spot and are then packed immediately into shipping trays or cartons.
After arrival at the packing station the bigger types of fruit are carefully unloaded (in a dry state) and transported via electronically controlled conveyor lines to the sorting machine. In a modern packing station the open crate with the fruit is first submerged in a water tank. The water in the tank contains dissolved fungicides (e.g. chlorine) and is circulated by a pumping system. The fruit a't the top of the tank is propelled by this circulation system to an elevator. There the fruit is rinsed off with clean water. Then the fruit is dried in a brushing machine through which a lot of (warm) air is blown.

It should be noted rrere that within Western Europe only Italy and France allow the addition of fungicides to the water.

Once dry, the fruits are *"coated",* i.e. covered in a layer of synthetic wax. This coating method is used for **Citrus fruit,** since the oil-containing cells in the rind are in fact damaged by the added chlorine. This attacks the natural layer of wax which protects the fruit against dehydration and fungal growth. After this the fruit is passed via a conveyor belt to the sorting machine where it is electronically sorted by size and weight. As it passes along the conveyor belt, the fruit is also visually checked as to its shape, colour and any visible external defects before being mechanically or manually packed into boxes. Where necessary, salt is added to the water so that fruit with a higher specific mass than water does not sink to the bottom of the tank.

Packaging for shipment

If the boxes or crates are filled mechanically, the fruit may be damaged because of the height of the drop. A cushion pad to soften the impact must therefore be placed in the bottom of the box or crate. Bruising can result not only from the height of the drop but also from the boxes being placed too roughly on the pallets or, later on, because the pallets are handled too roughly during loading or unloading operations.

Where the individual fruits inside the pack are approximately the same size, they may press too tightly against each other, resulting in contact bruising. Particularly in citrus fruit this causes a watery bump on the skin. In the initial stage this leads to *blister rot.* Subsequently, the growth of fungi causes blue spores to appear on the skin which eventually lead to *blue mould rot.*
Another well-known form of contact damage is *brown rot.* This can be identified by a brownish discoloration and rotting of the skin and a penetrating, rancid smell.

Damage is frequently also caused by overfilling the boxes. In that case, when the boxes are

stacked, pressure is exerted on the fruit itself instead of on the packaging.
Packaging materials can differ very significantly in strength. To prevent distortion of the boxes, therefore, they must never be stacked higher than their structural stability allows.
In the case of fruit damage caused by distortion of the boxes a distinction is made between:

(a) distortion caused by (over-)filling;
(b) distortion caused by settling;
(c) distortion caused by weight of loading;
(d) distortion caused by moisture absorption by the pack.

During the voyage the pack's ability to retain its shape may deteriorate because the relative humidity of the air in the hold amounts to approx. 85%, whilst the relative humidity inside the pack amounts to 100% owing to the moisture given off by the fruit. The box may also have become damp during loading and unloading because moisture from the outside air may have condensed on the cold surface of the pack.

Simple boxes, i.e. those which are closed with flaps, are difficult to use for mechanical filling. The "telescopic" type of box is preferred, i.e. the box which consists of an inner box which slides inside an outer box. Nowadays, the operation of packing into boxes is usually computer-controlled. A label stating the packing date, size, weight or number, quality, grading, despatcher, etc. is then printed out and affixed to each box.

To ensure fast cooling-down of the product it is better if the box is fitted with a few big ventilation openings rather than with many small holes. Big ventilation holes do cause greater weakening of the box. However, as long as they do not represent more than about 6% of the total surface area of the box and provided the openings are located in the right places, they will not cause excessive structural weakening of the box and they will also guarantee an adequate throughflow of air.
Another factor that should be borne in mind is that the cooling-down speed of the products is governed not only by the size of the ventilation openings but also by the packaging material used inside the box and by the number of air-changes in the hold.

To prevent moisture loss, perforated plastic liners are sometimes used or plastic curtains which are wrapped around the product and are left open only near the ventilation holes. Another effective method of preventing moisture loss is to apply a coating to the box (e.g. polywax).

Damage caused by pressure, also known as *impact bruising,* is prevented in modern packaging methods by using cushion pads and layered packing. In the case of layered packing the fruit is placed on trays made of premoulded plastic, cardboard trays or moulded paper pulp. Generally speaking, the products are pre-cooled for shipping. But it must be remembered that cooled products are even more vulnerable to damage than uncooled products.

Palletised Cargo

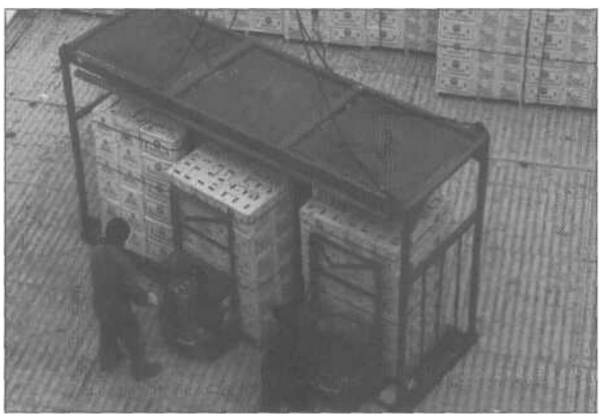
Palletised cargo can be classified more or less as an intermediate stage between "break-bulk" transport in a conventional reefer and transport in refrigerated containers using a cellular container ship. There has been a lot of discussion recently about how to define the concept of break-bulk cargo. That is why we would remark here that palletised transport is nowadays also considered to be break-bulk cargo.
Especially those ports which (as yet) have no facilities available for the receipt and/or handling of refrigerated containers have to rely on palletised cargo transport.

The material from which pallets are made may be cardboard, wood, metal or plastic or a combination of these materials. Cardboard pallets are normally suitable for one-trip use only.
In addition to flat pallets there are also "box pallets". These are pallets which are fitted with collapsible or rigid walls.

In recent years an annual average of 24 million tonnes of refrigerated goods were shipped by sea, of which 7 million tonnes in refrigerated containers. The expectation is that the trend towards containerisation will increase further and that the ratio in the near future will become 1:2. In Chapter 9 we discuss containerised transport in more detail. Formerly, there were some people who felt that the palletised transport of **Bananas** was taking palletisation a little bit too far; nowadays, however, more and more bananas are being shipped in palletised form. But the transport of bananas in refrigerated containers has also shown a sharp increase. The Geest Line, for example, ships bananas from the Windward Islands to the United Kingdom on specially designed pallets (dimensions 43" x 58"). The former Salen Group (Sweden) in particular was *a* great stimulator of palletised refrigerated banana transport.

However, other shippers initially had certain objections to the introduction of palletised cargo. One of their arguments was that the loss of cubic capacity, especially in the narrower forepart of the ship, did not outweigh the benefits offered by the shorter loading and unloading times. Another problem was that on the existing reefers the deck height did not correspond to the modular stacking height of the pallets. In addition, the costs of returning and repairing multi-trip pallets played a role, plus the extra costs of stowing the pallets securely in the hold. The need to purchase new mechanical equipment, such as forklift trucks, etc., was also used as an argument against pallets.

In recent years, probably due in part to pressure from customers, palletised transport has grown enormously. Today's modern ships are fully fitted out for this type of transport. Not only have the loading and unloading costs decreased because this mode of transport requires less manpower, but modern quayside unloading techniques now also make it possible to handle up to 12 pallets in one hoist, which likewise has a cost-saving effect. The photo below shows 3 pallets ready to be unloaded in one hoist.



Dimensions of pallets and packaging

To guarantee the efficiency of palletised transport the pallets need to be interchangeable between the various businesses which have to handle them. This has led to the introduction of standardised dimensions. Basically, there are three standard sizes:

a) 80 x 120 cm,
b) 100 x 120 cm
c) 120 x 120 cm.

European railways use the type a) pallet (80 x 120 cm) and Europe's road hauliers use type b) (100 x 120 cm). It should also be noted here that the 100 x 100 cm pallet is increasingly being used.
The 100 x 120 cm pallet (b) is the size preferred by the ISO (International Standards Organisation). In addition, the further development of size c) (120 x 120 cm) is foreseen, chiefly on account of its greater stability.
In addition to the preferred ISO sizes, pallets with differing dimensions are sometimes also used in practice. Examples include the 120 cm x 106 cm pallet or, in the USA, the 48" x 40" type.
The recommended height for a loaded pallet is 210 cm. The modified deck height (for stacking of unitised pallets) will then have to be approx. 220cm.

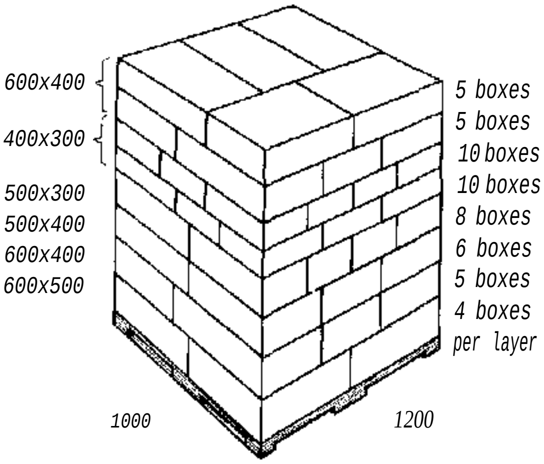
The dimensions of the pack must also be harmonised with the above-mentioned standard pallet sizes. To prevent "overhang" as a result of distortion, the actual dimensions of the boxes must be narrower than the nominal pallet size.

To ensure stackability and automatic handling, it was necessary to standardise the differences in dimensions of the various boxes that were in use. For this purpose the MUM project (Modulation - Unitisation - Metrication) has defined five basic dimensions.

These are the following nominal sizes:

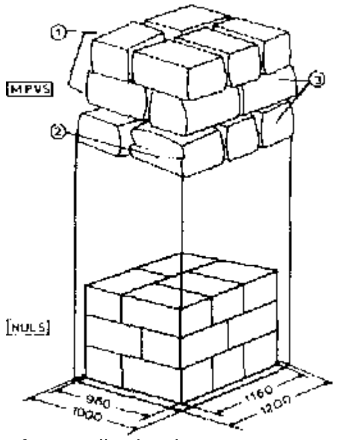
600 x 500 mm;
600 x 400 mm;
500 x 400 mm;
500 x 300 mm;
400 x 300 mm.

These nominal standard sizes can only be complied with provided that non-distorting packs



Mixed pallet load (MPVS!

Source: MUM project, U.S.A. and Canada
MUM = Modulation - Unitisation - Metrication



Tolerances for a pallet load
NULS: Net Unit Load Size
Minimum permissible dimensions
MPVS: Maximum Plan View Size (ISO andAUF) = Maximum permissible dimensions (ISO = International Standards Organisation; AUF -- Australian Fruit & Vegetable Association)
1 = distortion through filling
2 = distortion through settling
3 = distortion through loading.

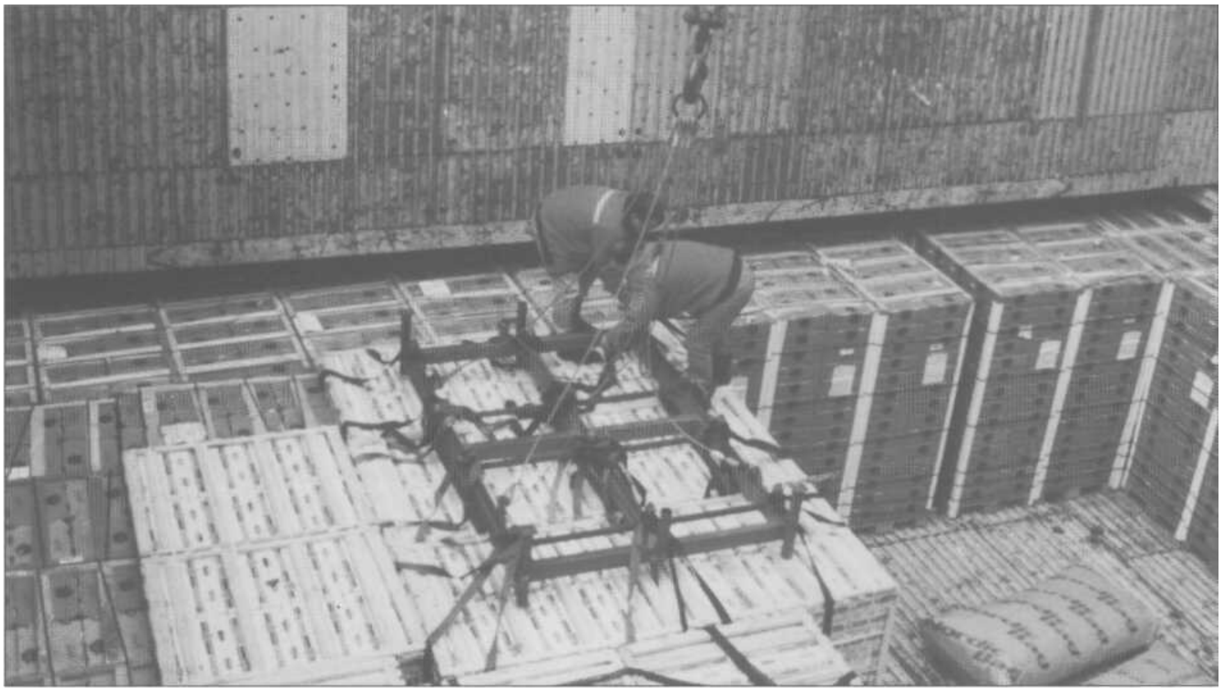
are used which have no ventilation channels and can be packed tightly on top of each other. In those cases where distortion may occur or where ventilation channels are required between the boxes, the actual dimensions must be smaller.
A working group (the Inland Transport Committee) of the Geneva-based Economic Commission for Europe is responsible for the standardisation of packs and pallets.

The deviations from the recommended standard sizes, the tolerances, are being reduced all the time. A pack with a standard "footprint" of, say, 40 x 30 cm is then allowed to measure 39 x 29 cm (the difference always being 1 cm). If the stacking pattern and the dimensions of the box make this possible, then improved stability can be obtained by alternating the stacking pattern for each layer. Even where the ventilation openings are sufficiently sized, this stacking method may still impede a good throughflow. This is particularly the case if liners have been used for internal packaging. Especially during the cooling-down period powerful ventilation is absolutely essential in these cases.

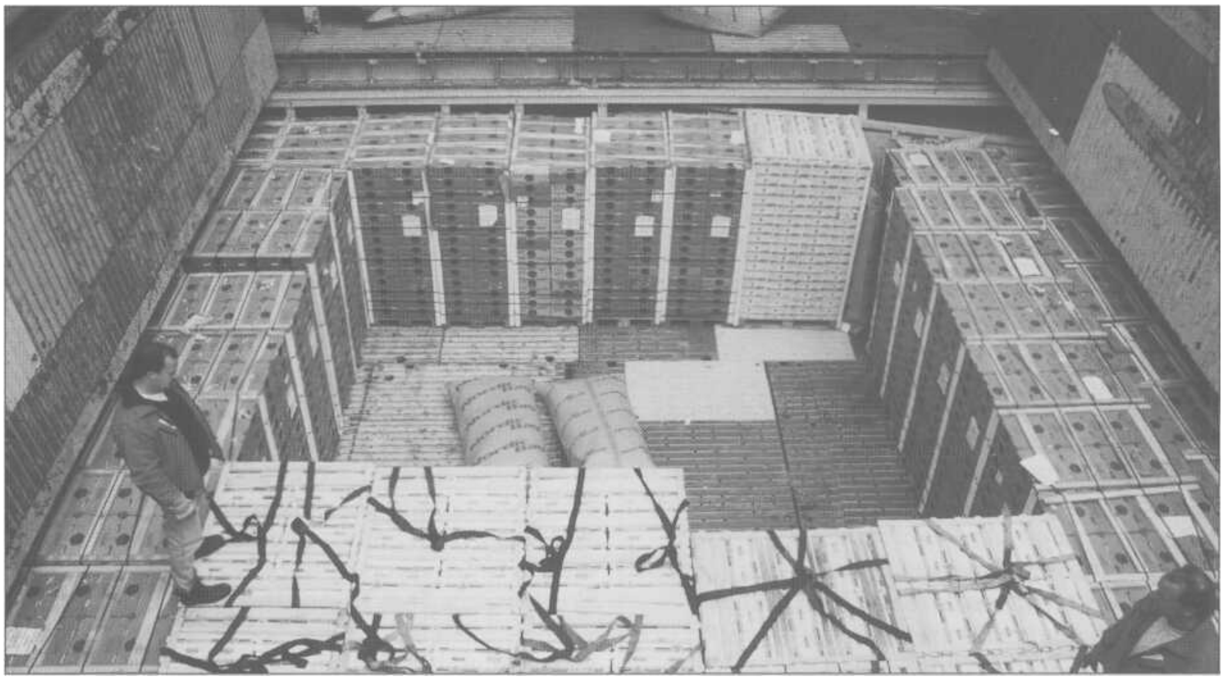
To ensure good stability, boxes have also been designed with pre-shaped end sections so that the boxes can be fitted exactly against one another using a sort of tenon and mortise joint. To hold the boxes securely together and lash them to the pallet, special nylon or steel binding materials are used, or the boxes are covered in shrink-wrap film. For a voyage lasting up to about 6 weeks, sturdily designed boxes can generally be safely stacked 8 to 9 high.

A loaded pallet weighs between 800 and 1,150 kilos, depending on what is stacked on it. One palletload of tomatoes, for instance, is lighter than a pallet of oranges.
Not every port uses the same unloading and loading equipment and the way in which palletised cargo is stowed is not the same in every port. In all cases, however, it is obvious that the hatch square will always be the last to be loaded. Towards the end of the loading operation and at the start of unloading it is no longer possible to work with forklift trucks. This is why the hatch square is loaded with pre-slung pallets. The number of pre-slungs to be used is usually

determined in consultation with the parties involved and will also depend on the size of the hatch opening and the type of loading and unloading equipment that is available.
To secure the palletised cargo the spaces between the pallets and the spaces between the ship's skin and the pallets (especially in the narrower forepart of the ship) are filled up with air bags ('Cargo Pak').
The photos below give an impression of how work is done using pre-slungs and how air bags are placed between the pallets.

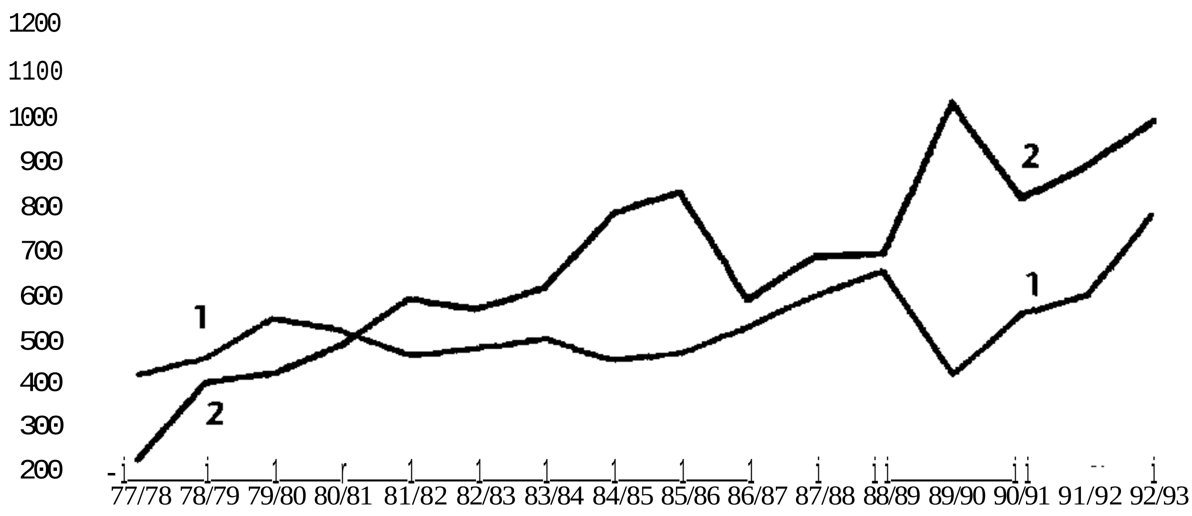


Unloading using pre-slungs



Air bags are placed between the pallets

FCOJ production in the USA and Brazil (1.000 tons)



7 = US
2 - Brazil

Source: FAO, USDA

Frozen concentrated fruit juice

International market

We have to distinguish between 100% juice and fruit drinks. When we refer to "juice", we mean juices prepared from concentrated fresh fruit. As explained later on in this chapter, a large percentage of the fruit is partially processed in the crop-growing areas and is then further processed and bottled or canned in the centres of consumption.

Fruit juices are generally traded as concentrate. In recent years the trade in straight juices has decreased because of the relatively high transport costs involved.

Orange juice is the most traded concentrate and is imported in high volumes by the OECD countries. The most important trade flows consist of exports from Brazil and the USA and imports by the USA and the EU.

Longer term, the expectation is that there will be a substantial increase of imports into the non-traditional markets, such as Japan, Korea, South East Asia, and the countries in Latin America and Eastern Europe.

World trade in other juices (e.g. grapefruit, lemon, grape and pineapple) accounts for about 25% of the total trade in juices. In the remainder of this chapter we shall be using the following abbreviations: FCOJ for Frozen Concentrated Orange Juice and CAJ for Concentrated apple juice.

Juice production from fresh oranges amounts to around 20 million t annually. Roughly 90 per cent of the world's FCOJ is produced in two very small areas of the globe: South/Central Florida and North West Sao Paulo (Brazil). Brazil is the world's largest producer of FCOJ, followed by Florida with a 35% share. The third and fourth largest producers are Italy and Israel, accounting for four and two per cent of all FCOJ processed respectively.

USA

Until the beginning of the 'eighties Florida was the world's biggest producer of orange juice. Subsequently, however, a series of severe frosts caused failure of the Floridan crop, three of which caused severe losses in excess of 40 per cent of the total planted acreage. As it takes 3 to 5 years before an orange tree can bear fruit, Brazil seized the opportunity to capture this market. A vast amount of replanting has meanwhile taken place in Florida, whilst growers have also started to relocate to the more southerly Gulf region so as to minimise the potential risk of frost damage. In the next few years the orange juice sector in Florida will certainly recover.

Brazil

Brazil is the largest exporter of citrus juice. Its volume of exports amounts to some 1 million t with a value of $1.6 billion, which represents approximately three-quarters of the total world trade.
Originally, Brazil's main customers were the USA and Canada. In the 'seventies Brazil sold 60% of its FCOJ trade to the USA and about 39% to Europe.
The major breakthrough for Brazil came in 1983 when its products were able to penetrate the American market following the frost damage in Florida. In the mid-1980s there were some years when North America purchased 70% of Brazil's total export volume.

In 1993 Western Europe accounted for 58%, North America for 30%, and Japan, Korea and South East Asia for 11 % of Brazilian FCOJ imports.

Brazil's main centre of production is in the state of Sao Paulo. Brazil has an advantage in that frosts are exceedingly rare, although the crop may sometimes be affected by drought. Brazil currently has 170 million orange trees of fruit-bearing age.

The Brazilian processing industry is highly concentrated, with the top four processing companies handling 90% of the harvest. The largest processors have access to container ships and can transport the FCOJ to Europe, Japan and the USA.
Brazil's major trading partners for FCOJ are shown in the table below.

In view of the recent plantings in Florida and Brazil, the production of FCOJ has now reached its peak. This introduces an element of risk in that production may increase more quickly than the current demand in existing markets. However, since production costs in the USA are much higher than in Brazil, Florida's exports will no longer constitute a threat to Brazil's world-wide orange juice trade. As regards its exports of FCOJ to the USA, Brazil will continue to be dependent on what the harvest is like in Florida.

Brazil: exports of orange concentrate (FCOJ) (min. tonnes)

	1983	1986	1989	1991	1992
USA	280.3	414.5	266.5	306.3	319.5
Netherlands	79.5	166.1	199.6	315.9	343.6
Belgium	70.6	111.8	104.9	107.3	127.9
Japan	4.4	18.0	25.1	36.7	50.7
South Korea	1.3	0.9	14.7	39.8	36.6
Canada	31.1	41.5	48.4	48.9	19.7
Germany	16.3	25.0	17.4	28.6	9.0
UK	6.0	1.0	3.4	5.8	15.8
Other	62.8	29.5	30.7	30.0	24.8
Total	552.4	808.3	710.7	919.3	947.6

Source: *PGF, USDA*

NAFTA

There is a possibility in future, however, that the NAFTA agreement may form a threat to Brazil's FCOJ exports to the USA. NAFTA (the North American Free Trade Agreement} is a free trade zone formed by Canada, the USA and Mexico. Its aim is a phased lifting of import restrictions between the three countries. Under the agreement trade barriers will either be abolished

immediately or phased out during a transitional period of five, ten or fifteen years.
The NAFTA rules governing origin are also very explicit: only fruit and vegetables produced in the NAFTA countries qualify for the liberalisation regime.
Under the NAFTA, Florida and Mexico have been granted special tariff conditions, which makes it likely that more raw materials and fresh produce will be imported from Mexico. As a result it is quite possible that Brazil's share of the US market will decline by 5 to 10 per cent in the coming years.

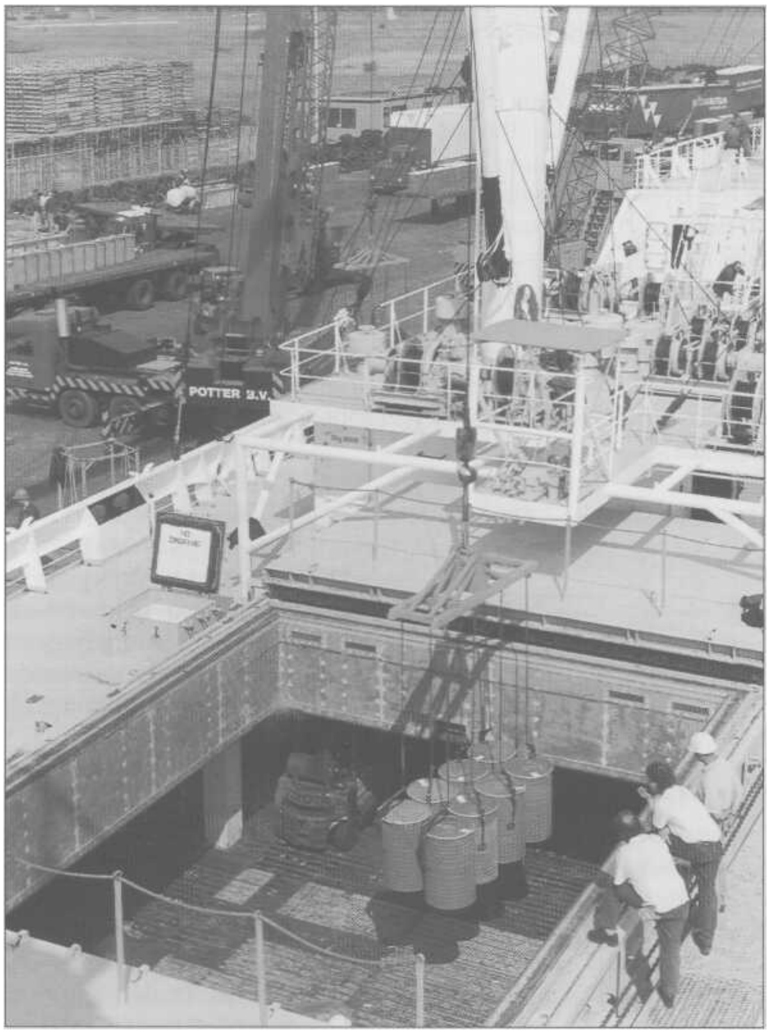
Other juices

The world production of concentrated apple juice (CAJ) is estimated at 700,000 t. The largest producer is the USA with a 22% share of world production. None the less, the USA is at the same time by far the biggest importer of CAJ on the world market, despite the high level of its domestic production. By contrast with the situation for citrus juice, the OECD countries are major exporters of CAJ.
Poland is the largest producer and exporter of CAJ in Eastern Europe, followed by Hungary. Hungary also exports CAJ, for example to Japan.

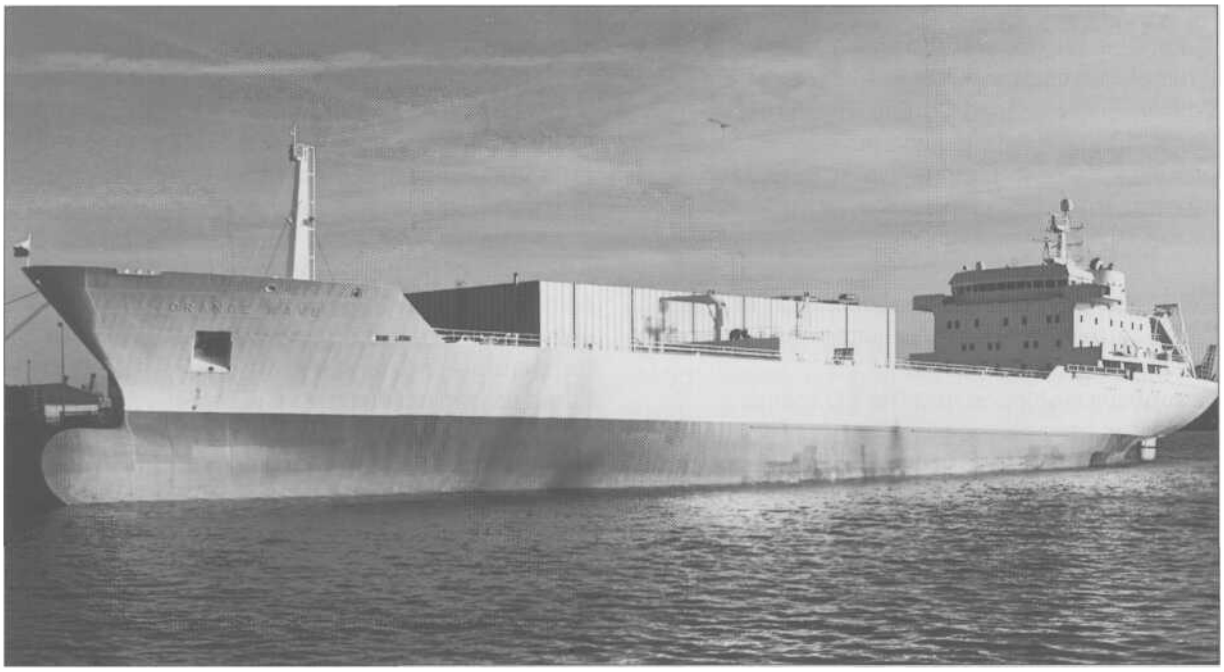
The trade in **pineapple juice** has doubled since 1985. World annual production of concentrated pineapple juice now stands at 160,000 t. Thailand and the Philippines are the two biggest exporting countries. Thailand supplies 30% of European demand, the other main suppliers being Brazil, South Africa and Kenya.
Other producer countries for pineapple juice are Australia and Mexico.

World imports of **grapefruit concentrate** amount to about 115,000 t. The principal processors of grapefruit are the USA and Israel. The main import market for grapefruit juice is the EU, which is mainly covered by Israeli suppliers. Canada and Japan are major sales markets for American producers. Japan's imports of grapefruit juice have doubled since 1985.

The export market for **concentrated lemon juice** is dominated by Argentina, the USA and Italy. In the US states of California and Arizona, half the lemon crop is used for the production of juice.
The main sales market for lemon juice is the EU. Italy is the major supplier, followed by Argentina and, to a lesser extent, by Brazil. The USA is also a major importer. Japan is developing into a leading importer of lemon juice and of straight juice in particular. Israel and Italy are Japan's major suppliers.



FCJO Discharging in Flushing



'Orange Wave'

In addition to the juices mentioned above, more exotic juices have made consistent advances in recent years. Such products include mango, passion fruit and papaya juice. The production of exotic juices will be furthered by favourable export prices.

Bulk juice tankers

Exports of orange concentrate

Today, large quantities of frozen orange juice are still transported in drums in the form of general cargo or in refrigerated tank containers. But the transport of drums is fairly expensive and the empty drums have to be disposed of somewhere. For economy reasons, therefore, bulk tanker transport is preferable, certainly for large quantities.
This applies in particular to exports from Brazil, a country which ships about 1 million t of fruit juice each year. The EU is the most important purchaser of Brazilian FCOJ, with the Netherlands being the largest single importer within the EU.
Since 1981 Rotterdam, Hamburg, Zeebrugge and Ghent have grown in importance as distribution centres for Europe, thanks to the practice of bulk shipping from Brazil.
From the port of Santos Brazil ships about 1 million t of semi-frozen concentrate each year in special container tanks (bulk juice tankers) with a capacity of 9,000 to 12,000 t.

South East Asia is an increasingly significant importer of FCOJ. It is expected that Japanese import requirements will rise from their current level of 70,000 t to 160,000 t by the year 2000. A number of large American multinationals have therefore concluded joint ventures to exploit the potential for sales of fruit juices and fruit drinks. Cuba always used to export its fruit juice to the former USSR and the Eastern Bloc countries. It is quite possible that the latter countries will also start to obtain their orange juice from Brazil in future. At the moment 50% of Brazil's orange juice is shipped to the EU.

The world's first bulk juice tanker was the m.v. 'Orange Blossom' (15,108 dwt) which was built for Brazil in 1985 by Trosvik Verstad in Norway. This ship and her sister ships are 145 m long and are fitted with 12 tanks for transporting a total cargo of 12,000 t of FCOJ at a temperature of

-10°C (this is equivalent to around 72,000,000 litres of finished product). The owner of these vessels is Sucocitrico Cutrale. Brazil meanwhile has a fleet of 7 orange juice tankers. Pictured below is the m.v. 'Orange Wave' (built 1992), moored at the European Juice Terminal in Rotterdam.

Bulk juice tankers are unloaded in port at special "juice terminals" where the intermediate product can be temporarily stored.
Orange juice shipped into the EU mainly originates from Sucocitrico Cutrale. This company, established in 1967, is Brazil's biggest exporter of FCOJ. The oranges originate both from its own plantations and from private growers.

Despite all today's advanced technology, oranges are still picked by hand. After being picked, the fruit is washed and is transported to the factory where each orange is pressed individually. In a completely automated process, which takes only one second, the fruits are peeled and the juice is separated from the pips. The juice is sieved to remove pips and fibres. In the first part of the subsequent processing the oil is then pressed from the peel and that oil is in turn processed into essence. A second pressing of the peel yields limonene, a natural solvent (a sort of turpentine). What is then left of the peel is processed into animal feed.

After extraction the juice undergoes two pasteurisation treatments. In the first phase the enzymes are activated and in the second (low-temperature) phase the juice is condensed to 6 times its original volume. The end-result of this process is a viscous, sticky juice mass at -10°C which is then ready for loading into the ship's tanks.

In the port of unloading the orange juice mass is pumped across into tanks on the quayside. By adding water and several other components, including the pips that had been sieved out, the mass is again made suitable for consumption. To prevent oxidation of the juice and the need to clean the tanks on the return voyage, the tanks are filled during the unloading operation with nitrogen at -10°C. Harmful bacteria cannot survive at this temperature.

CHAPTER 6

CONTROL OF FUNGAL DISEASES

FUNGAL SPOILAGE OF FRUIT

Pathogenic fungi

During refrigerated storage major damage may occur as a result of attack by parasitic fungi, especially in Apples, Pears and Soft fruit. Usually the infection has already occurred during growth, but it remains latent until a later stage of maturation or only becomes apparent during refrigerated storage. Measures to control fungal diseases are sometimes taken during cultivation in the orchard or plantation, but often they are also taken immediately after harvesting. At a later stage the use of fungicides (products which destroy fungi) generally makes little sense. Grapes are one exception to this. To ward off mould attack by Botrytis cinerea. Grapes are treated with sulphur dioxide ($S0_2$) both after harvesting and during refrigerated storage. This helps to prevent grey mould.
Because of the fast growth of moulds, the keepability of small fruit, such as Strawberries, Raspberries, Redcurrants, Blackcurrants and Plums, is on y very limited. Crops subjected to fungal attack suffer from spots, blemishes discolorations, misshapenness and flavour deterioration.

The characteristic feature of fungi is that they do not possess any leaf green (chlorophyll). Almost all fungi are parasites. The plant body (thallus) usually consists of threads of mould (hypha) which together form a tissue-like mass called the mycelium. The reproduction of fungi can be divided into sexual (the haploid mycelium) and non-sexual reproduction (the diploid mycelium).

Pathogenic (disease-causing) fungi can penetrate the fruit flesh in two ways. One group can only penetrate the fruit via existing open wounds, whilst the other group can also enter through a healthy skin. However, if the mould spores are to develop further, they need a favourable (i.e. high) temperature in combination with a high relative humidity. Moreover, their development is time-linked: lengthy refrigerated storage or a longer voyage duration will bring considerably increased risks of fungal growth. Luckily for us, healthy fruit has a good natural defence system against the development of fungal moulds. In addition, the atmosphere immediately surrounding the fruit surface is much too dry for the spores to develop further. In an open wound, of course, sufficient fruit moisture is available to encourage the development of spores. It is therefore not surprising that bruises, windfall dents, handling damage or wounds caused by insect attack represent the greatest risk of fungal growth.
Unripe fruit has a high resistance to fungi. But, as the fruit gets riper, this resistance quickly decreases. Once the spores of the fungus have penetrated into the fruit flesh, the mycelium quickly spreads further. When fully-grown, the mycelium produces poisonous substances (toxins) which cause the death of the cells in the fruit flesh.
When the fruit is almost ripe, it is exposed to fungal attack, e.g. by the fungus strain Monilia fructico a, which causes brown mould, and by Botrytis cinerea, the cause of grey mould on fruit during refrigerated storage. The main strain that develops in ripe fruit is Penicillium expansurn, which causes blue mould.

Penicillium (named after the Latin 'penicillus' - 'tuft of hairs' because of its tufted appearance) is a fungus family consisting of about 100 different strains. This fungus is familiar to everyone as the blue-green patches of rot which can also be seen on spoilt food products like bread and cheese. This parasitic fungus can also penetrate the fruit via an undamaged skin (via lenticels = the pores through which the plant breathes).

Another well-known mould is stem-end rot. This mould is caused by infection of the wounds which may occur on the end of the fruit's stem as

a result of plucking or cutting. Since the stem-end is the part of the fruit that dies off first, it is therefore a vulnerable point for an initial attack by certain fungi.
The fungus strain Diplodia natalensis causes stem-end rot in Citrus fruit and Mangoes.
Thielaviopsis paradoxa is the strain which causes stem-end rot in bananas.

Prevention of fungal growth

Pathogenic fungi grow best given a high relative humidity and an ambient temperature of 20 to 30°C. The most important step that can be taken to prevent fungal growth, therefore, is to store fruit at a low temperature as quickly as possible! A low temperature not only prolongs the keepability but in fact also inhibits fungal growth to a significant extent.
On the basis of the minimum temperature - i.e. the temperature above which fungi can grow - we can subdivide fungi into two groups, i.e. the group whose minimum temperature is below 0°C and the other group with a minimum temperature in excess of 0°C. Fortunately, there are not many strains of fungi whose minimum temperature is lower than 0°C.

But even if the minimum temperature is well above 0°C, immediate cold storage still has a tremendous retarding effect on fungal growth. As mentioned above, not only the minimum temperature is a crucial factor as regards the growth of fungi, but also the duration of the refrigerated storage.

CA storage

Just like other living organisms, fungi also breathe. To retard fungal growth, therefore, their respiration rate can be changed by reducing the oxygen content and/or increasing the CO_2 content. During CA storage the 0_2 content is normally reduced to 2-3% and the CO_2 content is increased to 5%. However, as we have already learnt, not all products are suitable for CAstorage.

Food irradiation

Ionising radiation (beta and gamma rays} can bring about an improvement in the keepability of foodstuffs.
Beta rays pasteurise the surface of fruit and vegetables, thus inhibiting the growth of moulds {e.g. Botrytis).
A radioactive source material, mostly cobalt-GO or caesium-137 derived from purified nuclear waste, is used to destroy the bacterial and fungal spores in food products, so that those products are disinfected and have a longer shelf-life. The treatment also damages the cells of the foodstuffs and this sometimes brings advantages: irradiated Potatoes and Onions no longer form sprouts and will keep for longer. One of the drawbacks of ionising radiation is that the cells of damaged fruit or vegetables are no longer resistant to infections and are thus more susceptible to mould attack and rot. This is one of the reasons why food irradiation has to be performed with the right dosage and at the right moment in time. Unfortunately, a controversy now exists between the experts and the consumers. International bodies such as the WHO (World Health Organisation), the FAO (Food and Agriculture Organisation) and the IAEA (International Atomic Energy Authority) recommend food irradiation as a safe method for food conservation, provided that it is professionally applied.

The discussion about the use of food irradiation is focused on the formation and harmfulness of radiolytes. Food molecules are damaged during irradiation by the gamma rays and this creates unstable chemical compounds (radiolytes). After a while these compounds revert to stable compounds. Both the radiolytes and the stable compounds are produced in extremely small quantities and in many different types, which makes it impossible to analyse them individually. And that is exactly where the problem lies: there may be some compounds amongst them which are toxic or carcinogenic. However, the conclusion of the international bodies mentioned above is that this theory has not been proved.

The second drawback is that, after application of the irradiating technique, there is a decrease in the vitamin content, especially in the vitamin E content. The experts take the view that the vitamins reduction is insignificant because it is of the same magnitude as the reduction which normally occurs during food spoilage.
Because of this debate commercial applications

of ionising radiation are likely to remain limited in the near future.

Other critical comments relate to the fact that in the case of vegetables, fruit and citrus fruit the irradiation has no effect on keepability. In other words: there is definitely no extension of the keeping time. There are three exceptions to this: Potatoes, Onions and Mushrooms.

Irradiation of Potatoes can retard sprouting during storage in a cool place. The irradiation treatment must be carried out as soon as possible after harvesting. The longer the time-lapse between harvesting and irradiation, the less effective the treatment will be. Irradiated potatoes always have a dull, somewhat greyish appearance after being boiled, fried or subjected to some other form of heat treatment. The French fries and potato crisps industry considers this dull colour unacceptable. The manufacturers of potato puree take the same view.

In the case of Onions sprouting is also reasonably suppressed, but here the effect is significantly reduced if more time elapses between harvesting and irradiation treatment. Internally, the onion is damaged by irradiation. The growth point is killed off, and this is revealed by the black colouring of the cells. These black marks cause many objections, especially amongst industrial users. The finished product, i.e. onion powder and onion rings (dried and quick-frozen) has to be white and contain absolutely no discolorations at all.
If the aim is to achieve effective suppression of sprouting in onions, then they must be stored at -2°C immediately after harvesting. They can then be kept from September-October through until June without any noticeable sprouting occurring. If the storage temperature of the onions is increased from -2°C to higher temperatures, they tend to start sprouting profusely and must therefore be processed quickly.

In the case of Mushrooms irradiation delays the opening of the caps by 1 to 1,5 days. This is a benefit but the drawback is that when the mushrooms are boiled or fried, they turn a dull violet colour and look unappetising. Taste abnormalities have also been noted on various occasions.

It is clear, however, that irradiation is an excellent alternative to all sorts of chemical disinfection methods currently in use. The present disinfection methods are undoubtedly more dangerous than irradiation!

Heat treatment

In some fruit types fungal development can be prevented by immersing the fruit in or spraying it with warm water. At the present time this method is only applied on a very limited scale and even then, only in cases where the fruit is being sent to its destination by airfreight.
This method is used, for instance, in Papaya cultivation on Hawaii. The papaya fruit is very susceptible to anthracnose. Although the fruit is already infected on the tree, the disease only manifests itself when the fruit ripens. During transport along the packing line the papayas are passed through a warm water bath with a water temperature of 60°C for about half a minute.
A longer duration causes heat damage, with the result that the fruit will subsequently not ripen normally. However, a shorter duration is not sufficient to kill the fungal spores.
At a lower water temperature the fruit can be left in the bath for longer. The problem of this method is that temperature and time have to correspond very accurately with each other, and the exact balance can only be determined by experimenting.
in Mangoes, too, anthracnose is the most common disease and it is therefore quite possible that this treatment will also be used for mangoes in future.

Fungicides

The development of fungal rot is mainly governed by:

(a) the fruit's natural resistance to infection;
(b) the stage of maturation;
(c) the region, the season and the type of soil;
(d) weather conditions during growth, such as air humidity, rainfall and temperature;
(e) the duration of refrigerated storage.

To prevent mould development, the fruit is treated during cultivation or immediately after harvesting with fungicides such as thiabenzadole

(TBZ), sodium ortho-phenylphanate (SOPP), chlorothalonil and rnancozeb.
Besides these, there are many further fungicides in use and new products are being developed all the time, e.g. imazalil (1980) and flusilazol (1986).
If the crop is treated during cultivation, the fungicides - mostly mixed with oil and/or water - are sprayed over the orchards from an aeroplane or helicopter. The mixing ratio and the method of applying fungicides are dependent not only on the crop but also on the regulations that each country has issued regarding the use of such products.

If the fruit is washed after harvesting, the washing water usually contains chlorine or another fungicide. The liners inside cases of citrus fruit in particular are often impregnated with diphenyl. This is specifically aimed at preventing the development of Penicillium moulds.
It goes without saying that the strictest hygiene must be observed in the packing stations and that rotting fruits must be discarded without delay.

Growth regulators

The use of fungicides and insecticides is under strong pressure as a result of negative publicity, principally by nature and environmental groupings. But also the frequently used growth regulators may end up on the list of banned products - sometimes with complete justification. One example of such a product is the growth inhibitor Alar which is widely used by fruit growers. Treatment with Alar ensures that crops such as Apples and Pears have a healthy colour and an intact, unblemished appearance and also extends their keeping time. Production of Alar world-wide is exclusively in the hands of one American company.
Some years ago, however, an investigation in America revealed that the use of this growth inhibitor has harmful consequences for human health. Although this was not demonstrated again in follow-up investigations, the use of Alar in America is now banned. In Europe, however, fruit is still sprayed with Alar (300 grams per hectare). Obviously, Alar-sprayed fruit is not allowed to be exported to the United States.

Parasitic diseases during cold storage

Thanks to the precautionary measures against damage and fungal growth which have already been taken at harvest-time and during packing, the fruit will generally be supplied to the shipper in a healthy and sound condition.
If mould attack still occurs despite these precautions, it will chiefly occur in **Bananas** (e.g. crown rot) or in **Citrus fruit** (penicillium rot).
This chapter discusses only the mould diseases which affect the fruit types which are most frequently shipped to other countries.

MOST FREQUENTLY OCCURRING FUNGAL DISEASES

Blue mould rot	Grey mould rot	Anthracnose rot	Stem-end rot
Apples Apricots Cherries Citrus Grapes Nectarines Peaches Pears Plums	Apples Apricots Cherries Grapes Kiwis Nectarines Peaches Peare Plums Strawberries Tomatoes	Apples Avocados Bananas Mangoes Papayas Pears Strawberries	Avocados Bananas Papayas
Alternaria rot	**Brown rot**	**Cladosporum rot**	**Rhizopus rot**
Apricots Cherries Citrus Grapes Nectarines Papayas Peaches Pears Plums Tomatoes	Apricots Cherries Citrus Nectarines Peaches Pineapples Plums	Apples Apricots Cherries Grapes Nectarines Peaches Pears Plums	Apricots Cherries Nectarines Papayas Peaches Plums Strawberries Tomatoes

Fungal diseases in some well-known types of fruit

Apples

Apples are frequently not given any fungicidal treatment. However, if they are treated, the apples are dipped in a fungicide such as SOPP or benomyl before being packed. If a wax coating is applied, benomyl may be added to the coating material.
Varieties which are susceptible to "chilling" or apples which have had too much exposure to sun during their growth tend to suffer quite a lot from alternaria rot.

Avocados

If anthracnose or diplodia rot is expected to occur, the orchards are treated as a precautionary measure with a benzimidazole spray such as TBZ or benomyl. To prevent diplodia stem-end rot the avocados are sometimes dipped in TBZ after harvesting.

Bananas

The most common fungus diseases in bananas are crown rot and anthracnose rot. After a bunch of bananas has been cut from the stem, it is washed in a water tank in the packing station. Usually, there are a lot of dead parts of plants floating in the tank, which means that fungus spores can accumulate and spread. The "crown wound" created when the bunch is chopped off the stem forms a good entry for the fungi present in the washing tank.
The most important fungi which cause crown rot are: Colletotrichum musae, Thielaviopsis paradoxa and Fusarium roseum. To reduce the risk of crown rot, sodium hypochlorite, TBZ or benomyl is added to the water. The fungi can grow to deep down in the crown and sometimes penetrate as far as the "end of the finger". After the bananas have been washed, they are sometimes also dipped in a benzimidazole fungicide.

Crown rot first manifests itself as a dry, black rot on the crown, sometimes running down into the "fingertip" of the banana. In a later stage the green-coloured mould spores will develop on this surface.It is impossible to predict to what extent crown rot will infect the fruit. Nor is it possible to explain why some bunches in the same case are affected and others not. However, crown rot is seasonally linked and there is a big risk of crown rot occurring in particular during the humid and wet months (April to September). A long voyage duration, for example from Central America to Europe, increases the risk of crown rot. A high degree of humidity inside the pack, which means that the crown dries out less and remains fresh, reduces the risk of crown rot occurring. This is also the reason why the "Banavac" pack substantially reduces the risk of crown rot (see 'CA storage' in Chapter 3}.

Anthracnose causes skin blemishes on both green and ripe bananas. Green bananas first reveal black/brown marks which subsequently spread and have a tapering pattern. Although the minimum temperature for fungal growth in bananas (3° to 8°C) is below the transport temperature, a fast "cooling-down time" still has a beneficial effect as regards slowing down the growth of fungi.

Citrus fruit

The fungus diseases which occur most frequently in citrus fruit are: blue mould rot, green mould rot, blister rot, brown rot, diplodia stem-end rot and sour rot. Less frequent diseases are alternaria rot and white mould rot.
Blue mould rot and blister rot are caused by the Penicillium mould (minimum temperature 0° to 3°C).
These fungal diseases, which infect the fruit via wounds, do not occur until after the harvest. They are "contact" diseases, i.e. the infection is easily transmitted from infected to healthy fruit.

In the case of blister rot a watery blob appears on the peel. This disease often results from mechanical damage. Blue mould rot starts out as blister rot which changes at a later stage into blue mould rot from which the familiar blue spores develop. Blue mould rot in particular is rapidly transmitted from contaminated to healthy fruit, usually via a wound.

Green mould rot is often transmitted via a fungus to the packaging, especially via fungi on wooden crates. Though the fungus only spreads slowly, a high humidity and inadequate ventilation will stimulate the growth of this green mould.

White mould rot chiefly occurs in lemons and oranges. This fruit spoilage process does not produce any green or blue spores, only a white mycelium.

Brown rot (Phytophora citrophthora, minimum temperature 3°C) already occurs during the growth period. Particularly during prolonged rainfall the raindrops splash fungus spores on to the fruit on the lowest branches. The infected fruit contaminates the washing water, so that the spores are also transmitted to the healthy fruit. The infection can also be transmitted by "contact" with healthy fruit. The infection is not usually visible immediately after harvesting. It only manifests itself during cold storage. After a while a brown discoloration occurs on the peel which emits a penetrating, rancid smell.

Diplodia stem-end rot (Diplodia natalensis, minimum temperature 2°C) chiefly occurs in wet regions. The organism infects the fruit close to the stem-end and then rapidly penetrates through to the core. In the initial stage there is a light brown discoloration on the peel. Later on, this changes to dark brown, with stripes running through to the blossom end. Both high humidity and high temperature as well as ethylene treatment stimulate the growth of the fungus.

Sour rot (Geotrichum candidum, min. temperature 2°C) can be identified during cold storage by the soft, wet, green mould marks on the peel. It gives off a penetrating sour smell, which serves as a major attractant for fruit-flies. Sour rot mostly occurs after a wet growing season. Here again, the infection is transmitted by contact, especially where the skin has been damaged.

Alternaria rot (Alternaria citri, min. temperature -2°C) does not occur very frequently, but the problem here is that the damage cannot normally be seen from the outside. Alternaria occurs most in **Lemons,** and to a lesser extent in **Mandarins, Oranges and Grapefruit.**
The first signs are the development of a black discoloration (black rot) around the core. Only at a later stage does this discoloration also start to show at the stem-end and the blossom-end. As the stem-end is the first to die back, this forms the most favourable gateway for many fungi to enter.
The wax coating therefore comprises a plant growth hormone to delay the die-back of the stem-end. When the fruit is washed after harvesting, fungicides such as sodium orthopheny phenate (SOPP) or chlorine are often added to the washing water. If the fruit is given a wax coating, then this coating often includes a solution of benomyl (trade name: Benlate), thiabendazole (trade names: Tecto, Mertect) or imazalil (trade name: Fungaflor). The paper liners inside the cases are usually impregnated with a fungicide to prevent mould growth.
For the sake of completeness it should be noted that healthy citrus fruit produces little ethylene of its own accord, but will produce substantially higher quantities if green mould that has developed on the fruit.

Grey mould (Botryiis cinerea) principally occurs in various crops grown in the temperate zone. In horticulture the main crops affected are **Strawberries,** but the disease also occurs in **Cucumbers and Tomatoes.**
At the end of the flowering period the fungus first grows on the dying end of the blossom, e.g. in apples and pears. Later on it penetrates deep into the fruit as the flesh becomes softer. The infected part will first start to rot and will subsequently go soft and turn black. Generally speaking, a wound or a damage mark forms a good breeding ground, but the fungus is also capable of penetrating healthy tissue.

Botrytis is difficult to control once it has taken a firm hold on the fruit, but it does need a damp and cool atmosphere to develop further.
That is why the autumn is the most dangerous time as regards the growth of this fungus. The products should therefore be harvested in good time, before the weather turns too cold and too wet. After that, the products should be kept in a dry, well-ventilated storage place.
Grey mould, as its name implies, is easily recognisable by the fluffy grey mould which grows on and around the infected spot. The minimum temperature for this disease is -2°C.

Crapes

Grey mould is also the most common funga! disease in grapes. Generally, it is mainly berries which have been swollen by rainfall which are susceptible to a successful attack by fungi. Directly after plucking, grapes are fumigated for 30 minutes with 0.25% sulphur dioxide gas. This fumigation treatment is repeated about one week later with a lower percentage of sulphur dioxide. If too much gas comes into contact with the fruit, especially via wounds, chemical damage may occur resulting in a pale colouring of the skin around the stalk. During ship-borne transport a plastic sachet with chemicals is sometimes placed with the grapes and this releases a certain quantity of $S0_2$.
The chemicals may also have been absorbed in the packaging material.
During cold storage grapes may be attacked by alternaria rot. During cultivation the fungi penetrate the berries via the stalks.

Kiwis

The principal fungus diseases in kiwifruit are grey mould rot and alternaria rot. The rotting process only starts during cold storage.
Alternaria rot in kiwis is often limited only to "surface" rot. In that case the fruit flesh is not affected and mould only forms on the skin. This makes the fruit look less appetising, bringing a considerable reduction in its market value. In some cases the fruit is treated after harvesting with a wax coating which may incorporate SOPP or botran.

Mangoes

Nowadays many mangoes are shipped abroad, mainly in containers. In the tropics mangoes are second only to bananas as the most important fruit type grown.
Anthracnose is the principal type of fruit rot affecting mangoes. Fungus spores on branches and foliage are transmitted by mist or raindrops to the immature fruit. Whilst the fruit is still in its formative stages the infection remains latent but as the fruit ripens the disease becomes clearly visible because of the increasingly bigger black marks on the skin.
Anthracnose is therefore a typical mould rot of ripening fruit. To prevent fungal growth the orchard is sprayed with a copper solution, such as copper oxychioride, or with benomyl. (Copper vitriol is also applied, e.g. as a fungicide}. To retard fungal growth the harvested fruits are also sometimes dipped in.benomyl or TBZ solutions.

Pineapple

The pineapple is a non-climacteric fruit which, depending on its destination, is harvested at about the time when it is half-ripe.
Frequent complaints affecting pineapple are water blister and black rot. These fungal diseases are caused by the fungus strain Thielaviopsis paradoxa (minimum temperature 6°C). Via the wound which is created when the fruit is severed from the plant the fungal organism penetrates the body of the fruit and expands deep into the pineapple's core. Immediately after harvesting the fruit must be dipped in or sprayed with benzimidazole fungicides or with sodium ortho-phenylphanate (SOPP). Nowadays, products such as imzalil and bayleton are also used for this purpose.

To summarise:

Fungal growth can be prevented in the following ways:

1. by treating the fruit with fungicidal products during growth or immediately after harvest;
2. by avoiding damage caused by rough handling during or after harvesting;
3. by observing the strictest hygiene during harvesting and during any washing and packing of the fruit;
4. by applying heat treatment or irradiation;
5. by placing the fruit in CA storage;
6. by cooling down the fruit to the lowest permissible temperature as soon as possible after harvesting.

International regulations

When considering the possible treatments given to fruit to prolong its keeping time or to prevent fungal growth, it should be remembered that the relevant regulations applicable in this area may differ from country to country. The FAO/WHO, for example, is preparing a draft aimed at establishing international regulations on food irradiation. The addition of chlorine to the washing water is recommended in some countries, whilst in others it is specifically banned. The same applies to the colouring of fruit and the use of chemical additives in fruit coatings.

The regulations on fumigation and gas storage (e.g. using carbon dioxide) of fruit and vegetables are not the same in each country either.

CHAPTER 7

INSECT DAMAGE: PREVENTION AND CONTROL

Parasitic insects

To prevent the spread of insects and diseases by imported products, some countries have drawn up quarantine regulations. This is why it is important that the shipper should be familiar with the methods of insect control that have been applied and the quarantine regulations in force in the relevant country.

For fruit and vegetable cultivation the following insects represent major pests:

l. Aphids:

Aphids (greenfly, blackfly, etc.) are parasites which feed on the plant's organic matter and often contaminate the plant with a virus at the same time. Aphids extract a lot of juice, which is rich in sugar, by sucking it from the plant. They excrete the excess of sugar and the result is that a coating of sugar, known as *honeydew,* is formed on the leaf. This provides an excellent feeding ground for fungi and ants.
Harmful species include the apple aphid (apple sucker) and the vine louse (Phylloxera vastatrix). In the (sub)tropics the coccids (scale insects) are major pests, especially in fruit trees.
The rnoth aphid, an insect which looks as if it is covered in white powder, is also highly injurious in these regions. In Western Europe the whitefly is another warmth-loving insect which is able to overwinter in greenhouses.

2. Nematodes:

Nematodes are tiny worms (about 1 mm long) and 10,000 species of them occur throughout the world. In Cavendish bananas they cause a serious disease but they can also be found in other crops. They attack the root system and create root nodules which disrupt the further development of the roots. As a result the plant is weakened and may topple over. Various types of nematocides (pesticides to control nematodes) are used in attempts to ward off attack by these little worms.

3. Thrips:

These little insects (of the order Thysanoptera) are 0.5 to 8 mm long. Throughout the world there are some 3,000 known species, ranging in colour from yellow to black. Most of them feed on plant juices and they can be very serious plant pests. They also transmit virus diseases. Thrips occur both outdoors and in greenhouses. Especially during warm weather and in a dry atmosphere they cause tremendous damage. Only a few thrips are needed to cause relatively widespread damage. Leaves and stems first go misshapen and later reveal silvery or brown stripes. The flower buds turn brown and will not develop further.

4. Parasitic wasps:

The larvae of parasitic wasps feed on living insects and spiders. The female wasp lays an egg inside or on a larva of another insect. The parasitic wasp larva first feeds on the fatty tissue and then on the vital organs of its "host". These insects are the fruit grower's friends rather than his enemies. Certain species of parasitic wasps are used to destroy specific fruit pests, especially in greenhouse cultivation {see section on 'Biological control methods' below).

5. *Mealy bug:*

This insect derives its name from the powdery, waxy secretion which covers its body. This sap-sucking insect (genus *Pseudococcus)* looks very much like a scale insect (coccid) and occurs only in the {sub)tropics.
Just like the aphid, this insect also secretes honeydew.

6. Fruit flies:

There are many species of fruit flies. They include the Caribbean fruit fly, the Mediterranean fruit fly, the Mexican fruit fly and the Oriental fruit fly. Quarantine measures are taken to prevent their spread to other regions.

Other common harmful insects are: centipedes and millipedes (Myriapoda), which also feed on the root system, ants, beetles, caterpillars, mites, fruit moths (codling moth) and butterflies.

Insect damage in specific types of fruit

Pineapple:

The harmful insects for pineapples are mainly mealy bugs, thrips, nematodes, fruit flies and millipedes.
Especially in Smooth Cayenne the mealy bug causes extensive crop damage.

Bananas:

Unlike other tropical fruit, banana generally suffer few insect problems during cultivation. As a rule, therefore, no insecticides are used in banana growing. Though the fruit is attacked by insects, these attacks are limited only to the skin. Traces of insect damage can therefore be seen on the green skin. As the fruit ripens, these insect bites give rise to brown spots and blemishes on the peel. The pulp is not affected by these spots but they obviously make the banana look less appetising.
Nematodes, however, do form a problem during the growth of the plant, particularly in Cavendish bananas. Because of the honeydew secreted by the mealy bug a black mould *(sooty mould)* may develop on the fruit.

Citrus fruit:

Citrus fruit sometimes suffers from "scale". The damage is caused by the scale insect. The scales are discarded on the skin, though the insect itself is no longer present. The fruit may look somewhat unsightly but the fruit flesh is not affected.
A much more frequent occurrence is "thrips scarring", particularly in oranges and grapefruit. As a result of thrips feeding on the peel, grey rings are created, usually around the blossom-end.
Just like in bananas, "sooty mould" also occurs in citrus fruit. Because of the honeydew secreted by the white citrus fly, mould develops on the peel. The dark-coloured to black mould is mainly concentrated around the stem-end of the fruit.

Insect control

In agriculture and horticulture measures have to be taken to contain insect damage as much as possible. Initially, solely chemical insecticides like DDT were used for this purpose. In general, such products are highly poisonous. However, most of these poisons do not work on a selective basis. Often, this means that useful and beneficial insects, e.g. bees, are also killed. But several selective insecticides also exist which only kill one specific type of insect. One such product is Schraden, which is absorbed into the plant juice and kills only the aphids which suck this juice. The parasitic wasp does not suck plant juice and is therefore not affected.

In addition to the insecticides there are also biocides (substances which control harmful organisms). These include larvicides which destroy insect larvae. On numerous occasions it has been found that an insecticide no longer works effectively after a white because the insect has built up a resistance to it. The chemical industry is therefore constantly seeking new poisonous substances. Much of the poison that is used has a prolonged residual effect because it breaks down too slowly and therefore accumulates in the air, soil or water. This applies in particular to chlorinated hydrocarbons such as DDT. Previously DDT was much used, e.g. for control of the Colorado beetle. Ultimately, however, it was found that virtually all human foodstuffs contained DDT. That is why the use of DDT is now banned in most countries.
However, insecticides also exist which are broken down within a few days at a high temperature, e.g. products like rnalathion and parathion. As parathion is three times more poisonous than malathion, malathion is the most frequently used of the two.
Insecticides can also be prepared from plants, such as nicotine, or from mineral oils.

In the battle to control the notorious fruit fly pest, use is made of an "attractant spray". In the liquid, which consists of 25% malathion, a "bait" is incorporated consisting of foods which are attractive to the fruit fly. The liquid is harmless to humans and is usually sprayed over the crop from an aeroplane. The substance which is fatal to the insects attracts twice as many female than male flies.
In addition insecticides (e.g. dieldrin} are also worked into the soil to kill the larvae hidden there. The use of certain soil disinfectants such as aldrin and dieldrin is currently banned in many countries.

Biological control methods

Because many of the poisonous chemicals that are used are dangerous to hurnans and harmful to the environment, scientists have sought other methods of control.
One such method involves breeding and deploying the natural enemies of the harmful insects. In Californian citrus plantations, for example, the scale insect has been controlled by introducing a sort of ladybird whose larvae feed on scale insects.
In other regions the parasitic wasp has been used for the same purpose. {A parasite is an organism which lives inside or on a "host" and feeds on it.) In greenhouse tomato cultivation the parasitic wasp (e.g. Encarsia formosa) is used to control whitefly. Avocado growers in Israel have combated the mealy bug by releasing a wasp imported from Australia. To control scale insects, parasitic wasps from various countries have been imported into Israel.

Another method used is that of odour attraction. Many female butterflies use an attractant odour to lure male butterflies. By using a synthetically manufactured attractant substance masses of the male butterflies can be lured to a certain spot where they can be caught and killed. This method has also been used with great success to control one variety of fruit fly.

New developments

In laboratories new possibilities are continually being sought to destroy harmful insects or prevent their spread. Research is being conducted into the potential results of applying heat or cold treatment to the products or of storing the products at a very low oxygen content (0.5%) or at a very high $C0_2$ content (80%). On a modest scale a start has been on destroying insects via irradiation with microwaves or gamma rays. Another method is fumigation. In this method, before the products are packed, they are exposed to gas in a hermetically sealed chamber, e.g. using methyl bromide. It will be clear that these methods are expensive and can only be used to treat small quantities.

Low-temperature storage

This method is still the most used one and it is the most important method for the shipper because of the requirements he has to meet. To destroy the Caribbean fruit fly, Japan sets the following requirements for the cold treatment of fruit imported from Florida:

14 days at a pulp temperature of	0.6°C
16	0.8°C
17	1.1 °C
19	1.4°C
20	1.7°C
22	1.9°C
24	2.4°C

Similar regulations are also applied by other countries, such as New Zealand. The Australian quarantine regulations in particular are exceptionally strict. The American requirements for fruit imports are laid down in the **Plant Protection and Quarantine Treatment Manual, USDA 1976 section VI, T 107- T 109.**

For fruit transport from Europe to the U.S.A. (including **Apples, Pears, Grapefruit and Oranges)** the following pulp temperatures are prescribed:

10 days at	0°C	(32°F)	or lower
11 days at	0.6°C	(33°F)	or lower
12 days at	1.1 °C	(34°F)	or lower
14 days at	1.7°C	(35°F)	or lower
16 days at	2.2°C	{36°F}	or lower.

At the start of the transport period the pulp temperatures must already be at the prescribed temperature or lower. Similar regulations apply to

refrigerated container transport. Some products will become chilled at these temperatures and so alternative treatments exist to control fruit pests, such as a combination of fumigation and cooling. Besides this, new studies have shown that some **Citrus fruit** varieties can withstand the cold treatment if they have first been stored at a high temperature.
This treatment method has, for example, been successfully used for the transport of **Grapefruit** from Florida to Japan.

Many countries apply their own rules as regards the maximum permissible pesticide residues in the products. For the European Union countries these regulations can be found in **Council Directive 76/895/EEC, Appendix II.**
It is therefore essential to be fully familiar at all times with the regulations in force in the relevant country.

Quality requirements

To improve the organisation of the international trade in vegetables and fruit some countries have drawn up quality standards for a number of products. In certain countries the quality standards and the quality classifications are binding but in other countries they serve only as a recommendation.
The European Union (EU) has laid down quality standards for 28 products which are mandatory for imports and exports within the EU. There are three quality classes, viz. Extra class (superior quality), Class I (good quality) and Class II (standard quality). Amongst export products Class I is the most frequently found.
The OECD has issued standards for 53 products, though these are not mandatory **(Compendium of Applicable Standards 1988).**

In the U.S.A. the USDA has drawn up quality standards for 87 fruit and vegetable crops. These standards are not compulsory but serve as a recommendation. The USDA standards that have been issued relate to ripeness, size, firmness, colour, insect damage, infections, handling damage, dissolved solids (SSC), etc. The **U.S. Standards** also have a classification, i.e.: U.S. Fancy, U.S. No. 1, U.S. No. 2, U.S. No. 3 and U.S. Extra Fancy, U.S, Extra No. 1, etc.
The **California Agricultural Code** also lays down quality standards for vegetables and fruit. These standards are legally mandatory.

Lastly, a brief explanation of some frequently occurring abbreviations in this context.

APHIS: Animal and Plant Health Inspection Service (USDA};
CDFA: California Department of Food and Agriculture;
EU: European Union (formerly known as the European Economic Community);
FAO: Food and Agricultural Organisation (United Nations);
FSQS: Food Safety and Quality Service (U.S.);
OECD: Organisation for Economic Cooperation and Development;
USDA: United States Department of Agriculture.

RELATIVE HUMIDITY AND THE PSYCHROMETRIC CHART

Transport instructions

Before loading commences, the ship receives the "transport instructions" from the despatcher relating to the cargo to be shipped. These transport instructions contain mandatory requirements concerning the refrigeration process during the voyage. The transport instructions have to be signed by the ship's captain before the cargo is loaded on board.
As an example: the instructions for the transport of boxed Bananas packed inside "polybags" may contain the following rules:

1) Before loading operations start, the holds must be clean and odour-free and pre-cooled to 8°C.
2) Immediately after the loading of a refrigerated compartment has been completed, the temperature of the circulated air must be reduced to 13.3°C as quickly as possible, but in any event within 30 hours.
3) During the first 24 hours of the cooling-down period no fresh air may be admitted. After that period the fresh air ventilation must be such that the CO_2 content in the ho!d remains well below 1%.
4) The relative humidity (R.H.) must amount to 90% during the voyage.
5) The air circulation of the cooled air must amount to 80 air changes per hour (a.c.h.).

Note:
Different instructions may be issued for bananas which are vacuum-packed in "Banavac bags". These are discussed in the chapter on banana transport {see Chapter 14).
For Kiwis the instructions may, for example, read as follows:

1) Cooling air temperature must be between -0.5°C and +0.5°C.During transport the pulp temperature must be 0°C.
2) Fresh air ventilation must amount to 1/5 a.c.h. and the R.H. must be as high as possible.
3) The CO_2 content must remain below 0.2%.
4) The ethylene concentration must be lower than 0.03 p.p.m.

Sometimes the transport instructions may not be completely identical for a specific product which, though it comes from the same region and has the same destination, originates from different despatchers. The instructions are generally based on many years of practical experience but, if we look at them more from a theoretical viewpoint, there are certain aspects which require further comment and explanation.
It goes without saying, however, that the carrier must comply strictly with the instructions that have been given.
Regardless of what the transport instructions say, the following factors must always be closely monitored during the voyage:

1} Hygienic conditions in the hold.
2) The transport temperature.
3) The pulp temperature.
4) The R.H. of the ambient atmosphere and the R.H. of the cooling air.
5) The quantity of fresh air that must be allowed to enter.
6) The number of air changes (a.c.h.) in the hold.
7) The CO_2 content and the ethylene concentration in the hold.

Relative humidity

As a general rule, the relative humidity should preferably be kept as high as possible so as to prevent excessive dehydration. Bear in mind, however, that too high an R.H. will promote the growth of micro-organisms, whilst too low an R.H. will result in moisture loss and thus in weight loss. In the case of *"living"* products, therefore, a compromise must always be found

between an R.H. which is too high or too low. The problem here is that an accurate determination of the R.H. is not always all that simple, particularly where it exceeds 95% or where temperatures are lower than 0°C. Compared to the latest advances in automated temperature control and temperature recording systems it is regrettable that determining the exact R.H. is still very much an "underdeveloped area".
Despite the fact that the control of the humidity level is becoming less crucial thanks to constant improvements in packaging materials, there are still many products whose storage life could be extended through effective R.H. regulation.

The air in the hold

To minimise changes in the chemical processes which affect the composition of the product, the temperature of the cooling air must be kept as uniform as possible. The biggest problem in the transport of *"living"* cargo is posed by the $C0_2$ content and the ethylene concentration in the hold. As explained earlier, an excessive $C0_2$ content will, for instance, cause *"brownheart"* in Apples and Pears. Ethylene gas - even if present only in minute concentrations - will speed up the ripening process. This is the reason why ventilation with fresh outside air is needed. Though such ventilation might seem a simple and cheap solution, it does require a great deal of energy. However, the extra energy consumption can be substantially reduced by making use of heat exchangers. Where fresh air is admitted without any real need, the result is a waste of energy. Some people make a habit of leaving the valves, say, 1/4 open to admit fresh air during the entire voyage. But it is clear that, the lower the temperature becomes, the greater the reduction in the respiration rate and hence in $C0_2$ production. In such a case a lower rate of fresh air ventilation will be sufficient. Please note, however, that not every product requires the same quantities of fresh air.
In recent years methods have been developed for CA storage of products transported in refrigerated vehicles. The same development is now also occurring in reefer shipping. The holds in several vessels have meanwhile been adapted to make them suitable for CA storage.

Air circulation

Over the years the number of air changes for the cooled air has been increased from 40 to 100/hour. Specifically in banana transport there are plans to increase this rate to 120 a.c.h.
A vigorous air circulation has its advantages and its disadvantages. The advantages are: rapid cooling-down of the product and the prevention of "dead air pockets" in the refrigerated hold. The disadvantages: dehydration of the product, loss of volatile aromatic components, and a faster dispersion of mould spores through the refrigerated hold.
In the case of some cargoes, one example being Coconuts, an excessive air circulation is in fact totally wrong. If any ventilation is needed at all during transport of coconuts, then the fans must be operated at their very lowest speed. A higher speed would bring a risk of cracking of the coconut shell. The transport temperature for coconuts is between 16°C and 18°C.

The wider the temperature difference between the hold air and the cargo, the faster the temperature of the cargo will drop. And yet this difference must not be too wide. If it is, there is a risk that the product will become *"chilled"* or suffer localised freezing. This occurs when the heat transport inside the product is slower than the rate of heat release by the product's outermost layer.

Dehydration

As the product coo s down, dehydration occurs: the bigger the temperature difference between the cargo and the cooling air, the more the product will dry out. However, this also means that the product to be cooled will reach a lower temperature more quickly, which improves the product's keepability.
As the air circulation is increased, the boundary layer around the product is replaced more often. The result is that the moisture balance between the boundary layer and the product is permanently disrupted, which means that moisture constantly evaporates from the product. The outcome may be that a thin outer layer of the product becomes dehydrated.
During cooling of the product the heat transfer

coefficient (a) plays a major role. Since the value of a for a certain surface area is governed by the air speed, an increase in the circulation rate of the cold air will hardly have any further effect on the cooling-down time. As already mentioned, an excessive number of air changes per hour (a.c.h.) can cause dehydration of the product's surface layer.
This demonstrates yet again that, for each product, there is an optimum air circulation rate at which the cooling process will take place fastest. But the required air circulation rate is not easy to determine. Generally speaking, the air velocity must be between 0.2 and 0.5 m/s, but the crucial determining factor in all cases is the type of product and the type of packaging.
The stacking method used for the products is also very important in this respect. To ensure rapid cooling and limit dehydration, it is important that the cooling air flows *through the stack.*
During *pre-cooling* in coldstores much higher air speeds are used, but in such cases the respiration rate of the products is still very high.

To prevent moisture loss the packaging used for the products is either impermeable or has low moisture permeability. As we pointed out earlier, the use of this type of packaging means that the atmosphere directly surrounding the product is always saturated with moisture. One drawback, however, is that the stationary, moist air between the product and the pack slows down the cooling process and that the high R.H. of that entrapped air increases the risk of-microbiological spoilage. None the less, the advantages of this modern form of packaging more than outweigh its disadvantages, particularly if the packaging material provides a good, tight seal around the product.

The quantity of fresh air

The quantity of fresh air to be admitted is dependent on the product and the product temperature and can only be calculated with the aid of complex formulas. It is generally claimed - although it must be conceded that this is a very approximate rule of thumb - that the fresh air to be admitted should amount to 1-2 m^3 per tonne per hour.
Another rule of thumb which can be used for an approximate calculation of the quantity of air is:

If the respiration of the product produces 3.6 kJ/h (= 1 Watt) of heat, then the CO_2 production amounts to approx. 0.2 litre.

Let us now use this rule of thumb to make a few calculations.
We shall assume that we have loaded a shipment **of Apples.**
The temperature of the apples is 15°C. The CO_2 content in the hold must not exceed 1 %. The tables section at the back of this book includes Table (2) which shows the respiration rate of various products at temperatures of 0°C, 5°C and 15°C.
As we can see from that table, the average respiratory heat of apples is:

$$\frac{4\text{ kJ}}{\text{kg} * 24\text{ h}} \qquad \frac{167\text{ kJ}}{\text{tonne} * \text{h}}$$

According to our rule of thumb, therefore, the quantity of CO_2 produced is:

$$0.2\ \frac{167}{3.6} = 9.3 \text{ litres per tonne per hour}$$

1 m^3 of air = 1,000 litres;
1% CO_2 = 1/100 * 1,000 litres = 10 litres per m^3.

The quantity of fresh air to be admitted is therefore:

$$\frac{9.3}{10} * 1\ m^3 = 0.93\ m^3 \text{ per tonne per hour.}$$

If a table had been available which shows the CO_2 production of the fruit, then we would also have calculated the quantity of fresh air by using the following rule:

To extract 1 kg of CO_2 from the refrigerated hold, approximately 35 kg of fresh air is needed.

If we look in the CO_2 table, we find that 1 tonne of apples (15°C) produces an average of 0.65 kg/(tonne * 24 h) = 0.027 kg/(tonne * h) of CO_2 and we can then make the following calculation:

The specific mass (s.m.) of air is: 1.2 kg/m^3.
The cubic capacity occupied by 35 kg of air is

$$\frac{35}{1.2} = 29\ m^3.$$

The required fresh air amounts to:
0.027 * 29 m^3 = 0.78 m^3 per tonne per hour.

Let us now assume that we have loaded a shipment of Bananas and that a given moment the pulp temperature amounts to 15°C. The acceptable CO_2 concentration is 1 %. From the table we can see that at 15°C the average respiratory heat amounts to:
7 kJ/(kg * 24 hi - 292 kJ/(tonne * h).

The CO_2 production thus amounts to:

$$0.2 * \frac{292}{3.6} 16.2$$ litres per tonne per hour.

The quantity of fresh air to be admitted is:

$$\frac{16.2}{10} * 1\ m^3 = 1.62\ m^3$$ per tonne per hour

N.B.: If the permissible CO_2 concentration had only been 0.5%, then the fresh air to be admitted would have increased to as much as:

—'—* 1 m^3 = 3.2 m^3 per tonne per hour!!

As our last calculation in this series, let us work out the quantity of fresh air to be admitted in the case where we are carrying a cargo of Cauliflowers.
In this case the transport temperature amounts to 4°C. The CO_2 content is allowed to be 1 % at most.
As we can see from the table, the respiratory heat at 4°C amounts to:
6 kj/(kg * 24 h| = 250 kJ/(tonne * h).

Therefore, the CO_2 production amounts to:

$$\frac{0.2 * 250}{3.6} = 14$$ litres per tonne per hour.

The required quantity of fresh air is:

$$\frac{14}{10} * 1\ m^a = 1.4\ m^j$$ per tonne per hour

The CO_2 content

Because of the accumulation of certain gaseous substances (e.g. CO_2) which are released during refrigerated storage, the products may suffocate and ultimately die. If the CO_2 concentration is too high, the food products will undergo abnormal biochemical conversion processes and this will make them more vulnerable to attack by micro-organisms. However, an increased CO_2 content does slow down the respiratory processes This fact is utilised in MA and CA storage. If the CO_2 content is raised, the storage temperature can also be increased, thus preventing certain *storage diseases* which may result from too low a temperature.

Vapour and liquid

It will meanwhile have become clear that if refrigerated transport is to be performed with professionalism and efficiency some knowledge of physics is essential.
Since we need such knowledge to understand the general operation of refrigerated transport and, later on, for our discussion of the Mollier diagram, a few of the essential principles of physics are briefly summarised below.

1. Air (atmospheric air) is a gas mixture whose main components are approx. 21 % oxygen (O_2), 78% nitrogen (N_2), 1 % argon (Ar) and an average of 0.03% carbon dioxide (CO_2|. This air mixture also contains a varying quantity of water vapour.

2. A gas is considered to be an "ideal gas" if the product of pressure times volume is constant at a constant temperature.
   As a formula: $\frac{P * v}{T} = C$

3. Gases with a low density (e.g. helium) behave like an ideal gas. The common gases such as oxygen and nitrogen can only be regarded as an "ideal gas" at low pressure.

4. The characteristic difference between a vapour fgasl and a liquid is the distance between the molecules. If both a liquid and a vapour are present in an enclosed space (e.g. a ship's hold), the molecules will escape from the liquid and will start to move about as free molecules in the vapour. In that case we refer to evaporation. In the reverse case, the liquid will absorb vapour molecules.

   If both a vapour and a liquid are present in an enclosed space, their interaction will eventually reach a state of balance. In that state of balance the number of molecules escaping from the liquid is equal to the number re-entering it. A vapour which is in

the state of balance has a specific tension or pressure.
This pressure is described as the *maximum vapour pressure* or *saturation pressure.* The maximum pressure of a vapour depends solely on the temperature.

Definition:
The maximum vapour pressure at 3 particular temperature is understood to mean the value of the pressure of that vapour which cannot be exceeded at that particular temperature.

6. tf the quantity of liquid in an enclosed space remains constant, then the vapour has reached the maximum pressure. The vapour in this state of balance is called *saturated vapour.*

Definition:
Saturated vapour is vapour whose pressure is equal to the maximum pressure which the vapour has at a particular temperature.

7. If there is no longer any liquid present in an enclosed space, then the maximum possible number of molecules is still not present and we describe the vapour as *unsaturated.*

Definition:
Unsaturated vapour is vapour whose pressure is lower than the maximum pressure of the vapour at that temperature.

8. If we increase the space which contains unsaturated vapour, the pressure will decrease.
If we reduce the volume, the pressure will increase (Boyle's law). However, if the vapour has reached its saturation pressure and if we then reduce the volume whilst the temperature remains the same, the *vapour* pressure will not increase because the maximum vapour pressure has already been reached.
The vapour pressure will remain the same as the saturation pressure and a quantity of vapour will *condense* until the state of balance has been restored.
If we keep the volume constant and increase the temperature, the pressure will also increase. If we reduce the temperature, the pressure will initially decrease until the vapour is saturated. Upon further cooling the pressure of the vapour, which will now be saturated, will remain constant and some of the vapour will condense.
In other words, there are three ways of condensing a vapour into a liquid: by reducing the volume whilst retaining the same temperature, or by reducing the temperature whilst keeping the volume constant. The third and most important way is to extract heat at constant pressure.

9. The pressure p of a gas is defined as the force F which the gas brings to bear per m^2.
The unit of pressure (p) is the Pascal (Pa).
1 Pa = 1 N/m^2.
If the pressure is expressed in N/m^2 and the volume in m^3, then the product of p * V gives the unit of work, the Joule (J).
p * V = N/m' » m^3; (dimensional equation!
= Nm
= J
The *bar as* a unit of pressure is gradually disappearing from use, both in engineering and in meteorology.
1 bar = 10^s Pa
1 mbar = 10^2 Pa = 100 N/m^2.

10. The *temperature* of -273°C is 0 (absolute zero) in the Kelvin scale of temperature. Kelvin retained exactly the same scale of units as that of Celsius, and so the two scales are linked in the following way:
T = 273 + t, in which T is degrees Kelvin (K) and t is degrees Celsius (°C).

11. *Gay-Lussac's law of pressure:*
- = constant, provided V is constant

12. *Gay-Lussac's law of volume:*
$\frac{V}{-}$ = constant, provided p is constant

13. *Boyle's law/Gay-Lussac's law* (universal gas law):
$\frac{t\_i\_}{T}$ = constant = C
(C is known as the gas constant).
If p is expressed in N/rrr, the volume in m^3 and temperature in K, this yields the

Table 1
Maximum vapour pressure of water

Temperature	Max. vapour pressure	Max. absolute humidity	Temperature	Max. vapour pressure	Max. absolute humidity	Temperature	Max. vapour pressure	Max. absolute humidity	Temperature	Max. vapour pressure	Max. absolute humidity
°C	kPa	g/m^3	°C	kPa	g/tn^3	°C	kPa	g/m^3	°C	kPa	g/m^3
-20	0.125	0.99	11	1.31	10.41	42	8.20	65.14	73	35.43	281.5
-19	0.137	1.09	12	1.40	11.12	43	8.64	68.63	74	36.96	293.6
-18	0.149	1.18	13	1.50	11.92	44	9.10	72.29	75	38.55	306.2
-17	0.163	1.29	14	1.60	12.71	45	9.58	76.10	76	40.19	319.3
-16	0.177	1.41	15	1.70	13.50	46	10.08	80.07	77	41.89	332.8
-15	0.191	1.52	16	1.82	14.46	47	10.61	84.28	78	43.65	346.7
-14	0.208	1.65	17	1.94	15.41	48	11.16	88.65	79	45.47	361.2
-13	0.226	1.80	18	2.06	16.36	49	11.74	93.26	80	47.36	376.2
-12	0.245	1.95	19	2.20	17.48	50	12.33	97.95	81	49.31	391.7
-11	0.266	2.11	20	2.34	18.59	51	12.96	102.95	82	51.33	407.8
-10	0.287	2.28	21	2.49	19.78	52	13.61	108.10	83	53.42	424.4
- 9	0.310	2.46	22	2.64	20.97	53	14.29	113.50	84	55.57	441.4
- 8	0.335	2.66	23	2.81	22.32	54	15.00	119.20	85	57.80	459.2
- 7	0.362	2.88	24	2.98	23.62	55	15.74	125.00	86	60.11	477.5
- 6	0.390	3.10	25	3.17	25.18	56	16.51	131.20	87	62.49	496.4
- 5	0.422	3.35	26	3.36	26.69	57	17.31	137.50	88	64.95	516.0
- 4	0.455	3.61	27	3.56	28.28	58	18.15	144.20	89	67.41	536.1
- 3	0.489	3.88	28	3,78	30.03	59	19.01	151.00	90	70.11	556.9
- 2	0.527	4.19	29	4.00	31.78	60	19.92	158.20	91	72.81	578.4
- 1	0.568	4.51	30	4.24	33.68	61	20.86	165.70	92	75.61	600.6
0	0.611	4.85	31	4.49	35.67	62	21.84	173.50	93	78.49	623.5
1	0.656	5.21	32	4.75	37.73	63	22.85	181.50	94	81.46	647.1
2	0.705	5.60	33	5.03	39,96	64	23.91	189.90	95	84.52	671.4
3	0.757	6.01	34	5.32	42.26	65	25.01	198.70	96	87.68	696.5
4	0.813	6.46	35	5.62	44.64	66	26.14	207.70	97	90.94	722.4
5	0.872	6.93	36	5.94	47.19	67	27.33	217.10	98	94.29	749.0
6	0.935	7.43	37	6.27	49.81	68	28.56	226.90	99	97.75	776.5
7	1.00	7.94	38	6.62	52.59	69	29.83	237.00			
8	1.07	8.50	39	6.99	55.53	70	31.16	247.5			
9	1.15	9.14	40	7.38	58.63	71	32.53	258.4			
10	1.23	9.77	41	7.78	61.80	72	33.96	269.8			

$$\frac{N/m^2 * m^3}{K} = \frac{Nm}{K} = J/K$$

In fact it is not absolutely essential to use Pascals and m^3 in all cases. For the temperature, however, we must always work with an absolute scale.

That brings us, finally, to the "mass formula" which we can use to calculate the absolute humidity. The absolute humidity is the kg quantit of water vapour present in 1 kg of dry air. The specific mass (s.m.) of water vapour is lower tha the s.m. of dry air at equal pressures and temperatures. From this it follows that, the higher the mass of water vapour contained in tht air, the lower the air pressure will be, given a tot; pressure, e.g. atmospheric.

The mass of a gas (m) can be calculated if its volume (V| and its specific mass (p) are known. since $\rho = \frac{m}{V}$

Hence: $m = \rho * V$.

The s.m. (p) of a gas is dependent on the pressure and the temperature. If both the pressure and the temperature change, the volume will generally change as well:

$$\frac{P}{T} = \frac{C}{V}$$

The s.m. is usually given for a "normalised" condition (e.g. 1 bar and 0°C) and this is described as p_n.
The s.m. of air at 0^CC and 1 bar = 10* Pa = 10^5M/m^2 = 1.3 kg/m^3.
For our calculations we shall assume thai p_n water vapour = 0.815 *kg/m^3.*

If p_n is given and we want to calculate the mass of a quantity of gas, then it is necessary to work out the volume at this pressure and temperature. Here we will use the *normal volume* (V_n) and the *normal* temperatureT_n (usually 273 K).
In that case m = p * V changes to m = p_n, * V_n.

The mass formula is then derived from:

$$m = \rho_n * V_n = \frac{\rho_n * V_n}{T_n} ==> V_n = \frac{T_n}{\rho_n} * \frac{p * V}{T}$$

The mass formula for a gas reads:

$$m = \rho_n * V_n = \frac{p * V}{T} * \frac{T_n}{\rho_n} * \rho_n$$

$$m_{water\ vapour} = \frac{p * V}{T} * \frac{T_n * \rho_{n\ water\ vapour}}{\rho_n}$$

The density of water vapour compared to air is 0.622;
s.m. (p) of sir = 1.293 kg/rn^3.

P water vapour = density of water vapour/air « p_n of air
= 0.622 . 1.293 kg/m^3
- 0.804 kg/m^3 (at 0°C and 1 bar).

Since we have calculated that p_n = 0.815 kg/m^3, we can write the equation as follows:

$$m_{water\ vapour} = \frac{p * V}{T} * \frac{Tn}{\rho_n} * 0.815\ kg/m^3$$

in which:
p in N/rrf
T in Kelvin
V in m^3
p_n = 10^5N/m^a(= 1 bar)
T_n = 273 K.

The mass formula for water vapour then becomes:

$$m_{water\ vapour} = \frac{p * V}{T} * \frac{273\ K}{10^5\ N/m^2} * 0.815\ kg/m^3$$

N.B.: If you are asked to make calculations, the relative density of the water vapour may sometimes also be given as 0.625 = 5/8.

TABLE 2
Psychometric table

Dry Bulb ℃	Depression of Wet Bulb (℃)													
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.6	7
-9	85	71												
-8	87	73	59	45										
-7	87	74	62	49	36	24								
-6	88	75	64	52	40	23								
-5	88	77	66	54	43	32								
-4	89	78	67	57	46	36								
-3	89	79	69	59	49	39	29	19						
-2	90	80	70	61	52	42	33	23						
-1	91	81	72	63	54	45	36	27						
0	91	82	73	64	56	47	39	31						
1	91	83	75	66	58	50	42	34	26	18				
2	92	84	76	68	60	52	45	37	30	22				
3	92	84	77	69	62	54	47	40	33	25				
4	92	85	78	70	63	56	49	42	36	29				
5	93	86	79	72	65	58	51	45	38	32	26	19		
6	93	86	79	73	63	60	53	47	41	35	29	23		
7	93	87	80	75	67	61	55	49	43	37	31	26	20	14
8	94	87	81	75	69	62	57	51	45	40	34	29	23	18
9	94	88	82	76	70	64	58	53	47	42	36	31	26	21
10	94	88	82	77	71	65	60	55	49	44	39	34	29	24
11	94	88	83	77	72	66	61	56	51	46	41	36	31	26
12	94	89	83	78	73	68	62	57	53	48	43	38	33	29
13	95	89	84	79	74	69	64	59	54	49	45	40	36	31
14	95	90	84	79	74	70	65	60	56	51	46	42	38	33
15	95	90	85	80	75	71	66	61	57	53	48	44	40	35
16	95	90	85	81	76	71	67	62	58	54	50	46	42	37
17	95	90	86	81	77	72	68	63	59	55	51	47	43	39
18	95	91	86	82	77	73	69	65	61	56	53	49	45	41
19	95	91	86	82	78	74	70	65	62	58	54	50	46	43
20	96	91	87	83	78	74	70	66	63	59	55	51	48	44
21	96	91	87	83	79	75	71	67	64	60	56	52	49	45
22	96	92	88	83	80	75	72	68	64	61	57	54	50	47
23	96	92	88	84	80	76	72	69	65	62	58	55	51	48
24	96	92	88	84	80	77	73	70	66	62	59	56	53	49
25	96	92	88	85	81	77	74	70	67	63	60	57	54	51
26	96	92	88	85	81	78	74	71	67	64	61	58	55	51
27	96	93	89	85	81	78	75	71	68	65	62	59	55	53
28	96	93	89	86	82	79	75	72	68	65	62	59	56	53
29	96	93	89	86	82	79	76	72	69	66	63	60	57	54
30	96	93	89	86	83	79	76	73	70	67	64	61	58	55
	Relative humidity (%)													

This table cannot be used for a frozen wet-bulb thermometer.

Absolute and relative humidity

The absolute humidity of air is the mass of the water vapour which this air contains per unit of mass.
The quantity of water vapour in the atmosphere can vary widely; it depends on temperature, wind direction and other atmospheric conditions.
The *biggest* quantity of water vapour that can be contained in a particular volume of air depends **solely on the temperature of that quantity of air.**
The relative humidity of air is the ratio between the number of kgs per m^3 water vapour and the maximum number of kgs of water vapour that can be present in each m^3 of air at the prevailing temperature.

If the mass of the water vapour present in a particular mass of air is m kg and the mass of the maximum quantity of water vapour that can be present in this volume is m_{max} kg, and if the relative humidity (R.H.) of the air is represented by e, then this can be expressed as the following formula:

$$e = \frac{m}{m_{max}} \implies m_{max} = \frac{m}{e}$$

The R.H. is dependent on the temperature since the maximum quantity of vapour that can be present is also temperature-dependent.
As the vapour pressure increases in proportion to the quantity of water vapour, it is possible to give the following definition:

Relative humidity = the ratio between the existing vapour pressure and the maximum vapour pressure at that temperature.
From this it follows:

$$e = \frac{m}{m_{max}} = \frac{p}{p_{max} * T} \implies p = e * p_{max} * T$$

For dry air (i.e. air containing no water vapour) the relative humidity is e = 0; for air saturated with water vapour e = 1 (or 100%).

Definition
The dew point of a vapour is the temperature at which the vapour starts to condense (when water vapour becomes saturated and dew starts to form).

The dew point of a hold containing moist air is the saturation temperature relating to the pressure of the water vapour present in the hold. To put it in simpler terms: the dew point is the temperature at which the water vapour pressure has reached its maximum.

If we want to work out the R.H. prevailing in a hold, we must first calculate the dew point. Instruments which can be used to measure the dew point include a hair hygrometer and a dew-point hygrometer.

In a hair hygrometer strands of degreased hair are held taut by a spring. Asjhe relative humidity increases, the hair lengthens and the needle moves across the dial. This type of hygrometer is not accurate enough for our purposes. To check its accuracy, this instrument can be wrapped in a wet cloth. After an hour the meter should then show a reading of 100%.

A direct measurement of the R.H. can also be obtained using a dew-point hygrometer. This instrument consists of a smoothly polished meta plate behind which there is a reservoir filled with ether. A pressure ball is squeezed to blow air through the liquid ether. As a result, the temperature of the polished, well-insulated plate and that of the liquid ether decreases. At a certain moment the polished plate mists over because the water vapour is deposited on the plate in the form of water or ice. The temperature at which this occurs is the dew point. At that moment a thermometer inserted in the liquid ether indicates the dew point.

Once the dew point is known, then the table which gives p_{ma}, for various temperatures will then show us the pressure for the dew point we have measured and pmax for the prevailing hold temperature.

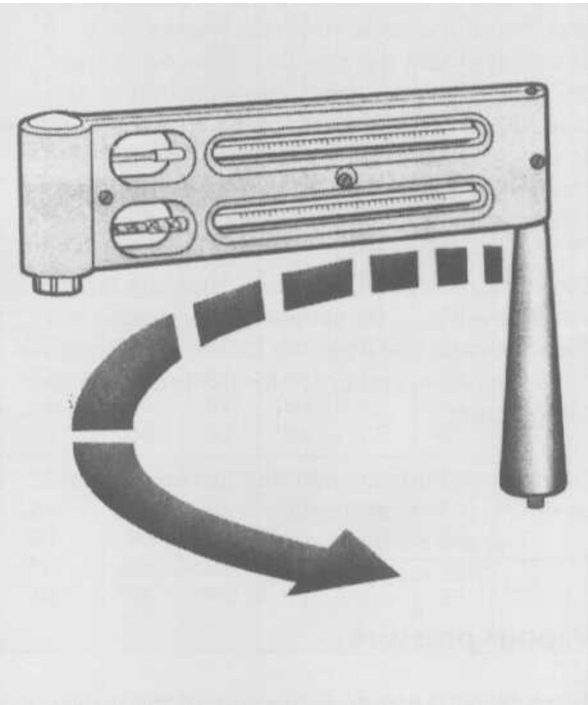
The relative humidity can then be calculated using the following formula:

$$e = \frac{P.\ daw\ point}{p_{max},\ hold\ temperature} * 100\%$$

Vapour pressure

The total air pressure is the sum of the pressure of the water vapour and the pressure of the other components of the air. Water vapour brings pressure to bear in the same way as dry air (air which contains no water vapour). The pressure of the water vapour alone is referred to as the vapour pressure. The pressure of the water vapour can amount to at most 3-4% of the air pressure at temperatures below 30°C. The maximum vapour pressure is dependent on the prevailing temperature. The maximum vapour pressure cannot be exceeded even if water vapour is admitted into or the air is cooled inside an enclosed hold.

If the air is cooled or heated, however, the maximum water vapour pressure (p_{max}) will decrease or increase, but this will have no effect on the prevailing vapour pressure (p, vapour pressure) unless condensation takes place. This is due to the fact that (at temperatures above the freezing point) the water vapour is transformed into water which condenses on the walls or on the cargo in the form of droplets or in a thin layer. As mentioned above, water vapour with a vapour pressure which is less than the maximum pressure is referred to as *unsaturated* water vapour. If the vapour pressure is equal to the maximum vapour pressure, then the water vapour is described as *saturated.*



Sling psychrometer

If a hold contains not only vapour but also water which is still in a liquid state, then the vapour pressure may rise to maximum pressure (p_{max}).

The Sling Psychrometer

Instead of using the dew-point hygrometer described above, we will normally measure the relative humidity on board ship by using a "wet and dry bulb" sling psychrometer. The instrument consists of two thermometers placed next to each other and ventilated by a sling mechanism. The dry bulb is used to measure the air temperature. The bulb on the other thermometer is enclosed in a mantle which is moistened with distilled water. When the mantle is dry, both thermometers will show the same temperature. As can be seen from the illustration, the sling psychrometer looks very much like a "football rattle". As the "rattle" is rotated around its axis, the water evaporates from the mantle. The heat needed for this is extracted from the reservoir of mercury. The drop in the temperature of the "wet bulb" comes to a halt as soon as the evaporation heat extracted from the reservoir is equal to the quantity of heat fed into the reservoir from the ambient air.

Since the extracted and the added heat are equal, the following formula enables the vapour pressure to be calculated:

P vapour pressure =Ptw " 0-67 (tj - t_w)

in which:

p_{tw} = the maximum vapour pressure at the observed wet bulb;

t_w = the temperature of the wet bulb;

t_d = the temperature of the dry bulb;

0.67 = 0.67 mb/K (= the psychrometer constant).

IM.B.: This formula only applies where the air flow speed amounts to approx. 2.5 m/s.

The temperature of the wet bulb is always lower than that of the dry bulb. By using t_d and (t_d - t_w) as arguments, the relative humidity can be read off directly from the psychrometer table.

Example 1:

Given:

t_d = 16°C and t_w = 13°C (1 mb = 0.1 kPa).

In which-
t_d = dry bulb temperature
t_m = wet bulb temperature

Find:
(a) The dew point.
(b) The relative humidity.
(c) By how much must we reduce the temperature of the hold air if we want the hold air to be saturated with water vapour?

Solution:
(a) The dew point is the lowest temperature at which the relevant vapour pressure can occur
$P_{vapour\ pressure} = P_{tw} - 0\ 67\ (t_d - t_w) = 15.0\ mb - (0.67 * 3) = 13.0\ mb = 1.30\ kPa$ (see Table 1).
As we can see from Table 1 (maximum vapour pressure), the related temperature amounts to approx 11°C.
(b) In Table 2 (psychrometer table) we find that for a temperature difference of 3°C and where t_d = 16°C the relative humidity amounts to 71%.
We could also have used Table 1 to find the R.H. in the following way
In (a) above we had already calculated that the actual vapour pressure amounts to 1.30 kPa (or 13.0 millibar, if we use the old system).
At a hold temperature of 16°C we can then see from Table 1 that the maximum vapour pressure is 1.82 kPa.
The relative humidity in the hold thus amounts to:
$$\frac{1.30}{1.82} * 100\% = 71\%$$
(c) Under (a) above we calculated that the dew point is 11°C for a hold temperature of 16°C. The temperature of the air in the hold can still be reduced by five degrees Celsius before the hold air is saturated with water vapour.

N.B.: An approximate indication of the dew point could also have been found by using Table 3. In that table we can see that, if the temperature of the air in the hold is 16°C and the R.H. is 70%, the dew point has to be 10.5°C.

Absolute **humidity**

We are not only interested in the vapour pressure but also in the absolute humidity of the air. The absolute humidity is expressed as the quantity of water vapour present in 1 kg of air.

If the temperature of the product is higher than the temperature of the cooling air, the moisture content of the air-layer immediately surrounding the product will be higher than that of the air in the hold.
The bigger difference in the vapour pressure will then tend to encourage the evaporation process. We can calculate the absolute humidity with the aid of the "mass formula".

Example 2;
Given:
The temperature is 19°C. The air pressure = $10^5\ N/m^2$ (= 1 bar). The pressure of the water vapour amounts to 1.9 kPa (= 1900 N/m^3).
The normalised specific mass (p_n) of water vapour = 0.815 kg/m^3.

Find:
The absolute humidity.

Solution:
$$m_{water\ vapour} = \frac{P * V}{T} * \frac{273\ K}{10^5\ N/m^2} * 0.815\ kg/m^3$$

$$m_{water\ vapour} = \frac{1900\ N/m^2 * 1\ m^3}{292\ K} * \frac{273\ K}{10^5\ N/m^2} * 0.815\ kg/m^3 = 0.014\ kg/m^3$$

The absolute humidity amounts to:
14 grams of water vapour per 1 m^3 of air.

Example 3
Given:
In a closed compartment of 600 m^3 (21,180 cu.ft) the relative humidity amounts to 70% (e = 0.70). After this compartment in the hold has been cleaned, 4 kg of water is left behind on the deck. The temperature inside the hold is 15"C.

The maximum vapour pressure of water at 15°C = 1.70kPa(1700N/m^2).
The "normalised" or standard specific mass of water vapour (p_n) = 0.815 kg/rn^.

Find:
(a) How much water has to evaporate before a state of equilibrium is reached?
(b) How much water and water vapour are still present after equilibrium has been reached?

Solution:
$$m_{water\ vapour} = \frac{P * V}{T} * \frac{T_n}{\rho_n} * \rho_{n'}\ water\ vapour$$

Table **3**

°C	Relative humidity 50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
	Dew point in °C										
0	- 9.2	- 8.2	- 6.5	- 7.5	- 4.9	- 3.7	- 3.0	- 2.2	- 1.5	- 0.6	+ 0
+ 2	- 7.1	- 5.7	- 4.8	- 3.7	- 2.5	- 1.9	- 0.9	+ 0	+ 0.9	+ 1.5	+ 2
+ 4	- 5.3	- 4.1	- 2.9	- 1.9	- 0.9	+ 0	+ 0.9	+ 1.8	+ 2.4	+ 3.2	+ 4
+ 6	- 3.7	- 2.2	- 1.3	+ 0	+ 0.9	+ 1.8	+ 2.9	+ 3.8	+ 4.5	+ 5.1	+ 6
+ 8	- 1.9	+ 0.5	- 0.6	+ 1.8	+ 2.7	+ 3.8	+ 4.5	+ 5.5	+ 6.4	+ 7.2	+ 8
+ 10	+ 0	+ 1.5	+ 2.5	+ 3.7	+ 4.5	+ 5.8	+ 6.8	+ 7.6	+ 8,5	+ 9.2	+ 10
+ 12	+ 2	+ 3.2	+ 4.3	+ 5.5	+ 6.8	+ 7.8	+ 8.5	+ 9.6	+ 10.5	+ 11.3	+ 12
+ 14	+ 3.7	+ 4.8	+ 6.2	+ 7.4	+ 8.5	+ 9.6	+ 10.5	+ 11.4	+ 12.3	+ 13.1	+ 14
+ 16	+ 5.6	+ 7	+ 8.3	+ 9.4	+ 10.5	+ 11.6	+ 12.6	+ 13.5	+ 14.4	+ 15.2	+ 16
+ 18	+ 7.4	+ 8.9	+ 10	+ 11.3	+ 12.4	+ 13.5	+ 14.6	+ 15.5	+ 16.5	+ 17.2	+ 18
+ 20	+ 9.2	+ 10.5	+ 11.9	+ 13.1	+ 14.4	+ 15.5	+ 16.5	+ 17.4	+ 18.3	+ 19.2	+ 20

$= e \cdot p_{max 15°C} = 0.70 * 1.70 \text{ kPa} - 1.19 \text{ kPa } (1190 \text{ N/m}^2)$.

The quantity of water vapour present amounts to:

$$m_{water\ vapour} = \frac{1190 \text{ N/m}^2 * 600 \text{ m}^3}{288 \text{ K}} * \frac{273 \text{ K}}{10^5 \text{ N/m}^2} * 0.815 \text{ kg/m}^3 = 5.578 \text{ kg.}$$

At 15°C the maximum (water) vapour that can be contained in the hold air is:

$$m_{max} = \frac{1700 \text{ N/m}^2 * 600 \text{ m}^3}{288 \text{ K}} * \frac{273 \text{ K}}{10^5 \text{ N/m}^2} * 0.815 \text{ kg/m}^3 = 7.969 \text{ kg.}$$

(N.B.: We could also have calculated this using the formula:

$$m_{max} = \frac{m}{e} \implies m_{max} = \frac{5.578}{0.70} = 7.968 \text{ kg.})$$

Before equilibrium is reached, the quantity of water which evaporates amounts to 7.969 kg -5.578 kg = 2.391 kg,
This then means that 4 kg - 2.391 kg = 1.609 kg of water is still left on the deck.

Example 4
After the state of equilibrium described in example 3 has been reached, the deck and the ship's hull cool down during the night to 10°C.

Find:
How many kg of water condenses against the underside of the deck and on the hold walls?

Solution:
At 15°C the quantity of water in the saturated air amounted to 7.969 kg (see example 3).
The maximum quantity of water vapour that can be present at 10°C is:

$$m_{max} = \frac{1230 \text{ N/m}^2 * 600 \text{ m}^3}{283 \text{ K}} * \frac{273 \text{ K}}{10^5 \text{ N/m}^2} * 0.815 \text{ kg/m}^3 = 5.802 \text{ kg.}$$

The quantity that condenses below deck and on the walls is 7.969 kg - 5.802 kg = 2.167 kg.

As mentioned earlier, the transport instructions sometimes also specify the required moisture percentage during transport. In fact, maintaining the prescribed CO_2 percentage is more important than maintaining the prescribed moisture content. In order to maintain a low CO_2 percentage, we must regularly admit sufficient fresh air. In many cases this will make it impossible for us to comply with the requirements with regard to the moisture content, unless the fresh air is dehydrated. None

the less, we still need to be familiar with aspects relating to the moisture content in the hold.
As a rule, the relative humidity in the holds can be read off directly in the engine room.
It has been found, however, that this reading is not always accurate. It is therefore necessary for this reading to be checked at regular intervals using the method described above.

The Mollier **diagram**

With the aid of the Molher diagram it is possible for us to determine most of the changes in state which may occur in the air/water vapour mixture during the cooling process. The Mollier h/x diagram is applicable at the barometric pressure indicated on it (101.3 kPa = 1 bar) and at 0 m elevation.

For our purposes the diagram can also be applied at a different barometric pressure and elevation above sea level. This diagram enables us not only to make a simple representation of the changes in state but also allows us to calculate them.

We will not consider the underlying theory of the diagram here but will simply give a brief explanation of how to use it in practice.

1) In the diagram the almost horizontal lines show the temperature of the dry bulb (t_d).
2) The diagonal lines which run from the diagonal line outside the diagram to the vertical axis are the lines of constant wet-bulb temperature (U
3) The vertical lines running from the diagonal line to the topmost horizontal axis are lines of equal water content (x).
   The topmost horizontal line gives an indication in kg of the quantity of water (vapour! which is present in 1 kg of dry air (x kg/kg).
   Underneath the diagonal line is a second, parallel line. This line indicates the vapour pressure (p_w).
4) The curved lines show the relative humidity Up). The bottom curved closing line in the diagram is the saturation line.
   (Relative humidity <p = 1.0= 100%).
5) From the saturation line diagonal lines run to the horizontal and vertical axis of the diagram. These are lines of constant heat content. The heat content (h) per kg of dry air can be read on the vertical axis and on the saturation line (h = U/kg).
6) Running from the vertical axis to the saturation line in the diagram are 5 bolder lines which show the specific mass (p) of the humid air in kg/m^3.
7) The horizontal lines and the vertical line drawn outside the diagram give the reading for dh
   dx .

We will explain the use of the Mollier diagram with the aid of a few examples.
The symbols we will be using are as follows:
t_d = dry-bulb temperature in °C
t_w = wet-bulb temperature in °C
h = heat content (enthalpy) of the air mixture per kg of dry air (kJ/kg)
x = kg of water (vapour) per kg of dry air
p_v = maximum vapour pressure.

Given:
Air at 25^{3}C and containing 6 g of water per kg of air is cooled down to the dew point.
We will describe the starting point as point A.
See *diagram 1.*

Find:
a) What is the relative humidity and what is the heat content (h) at *point A?*
b) Which line in the diagram must now be followed further?
c) What do the relative humidity and h amount to when the temperature has decreased to 10°C?
   Refer to this point as *point B.* What temperature does the wet bulb indicate?
d) At what temperature is the dew point reached?
   If we refer to this as *point C,* what then do the relative humidity, h and p_v amount to?
e) What happens if the air is cooled down even further?
f) How much heat was needed per kg of air to cool the air down to the dew point?

Solution:
a) We can find *point Aon* the intersection of the line t = 25° and x = 0.006 kg/kg
   At *point A* we see that the relative humidity amounts to 30%. By following the diagonal line of constant heat content (enthalpy), we can read on the vertical axis that h = 40 kJ/kg.

the less, we still need to be familiar with aspects relating to the moisture content in the hold.
As a rule, the relative humidity in the holds can be read off directly in the engine room.
It has been found, however, that this reading is not always accurate. It is therefore necessary for this reading to be checked at regular intervals using the method described above.

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x = kg of water (vapour) per kg of dry air
p_v = maximum vapour pressure.

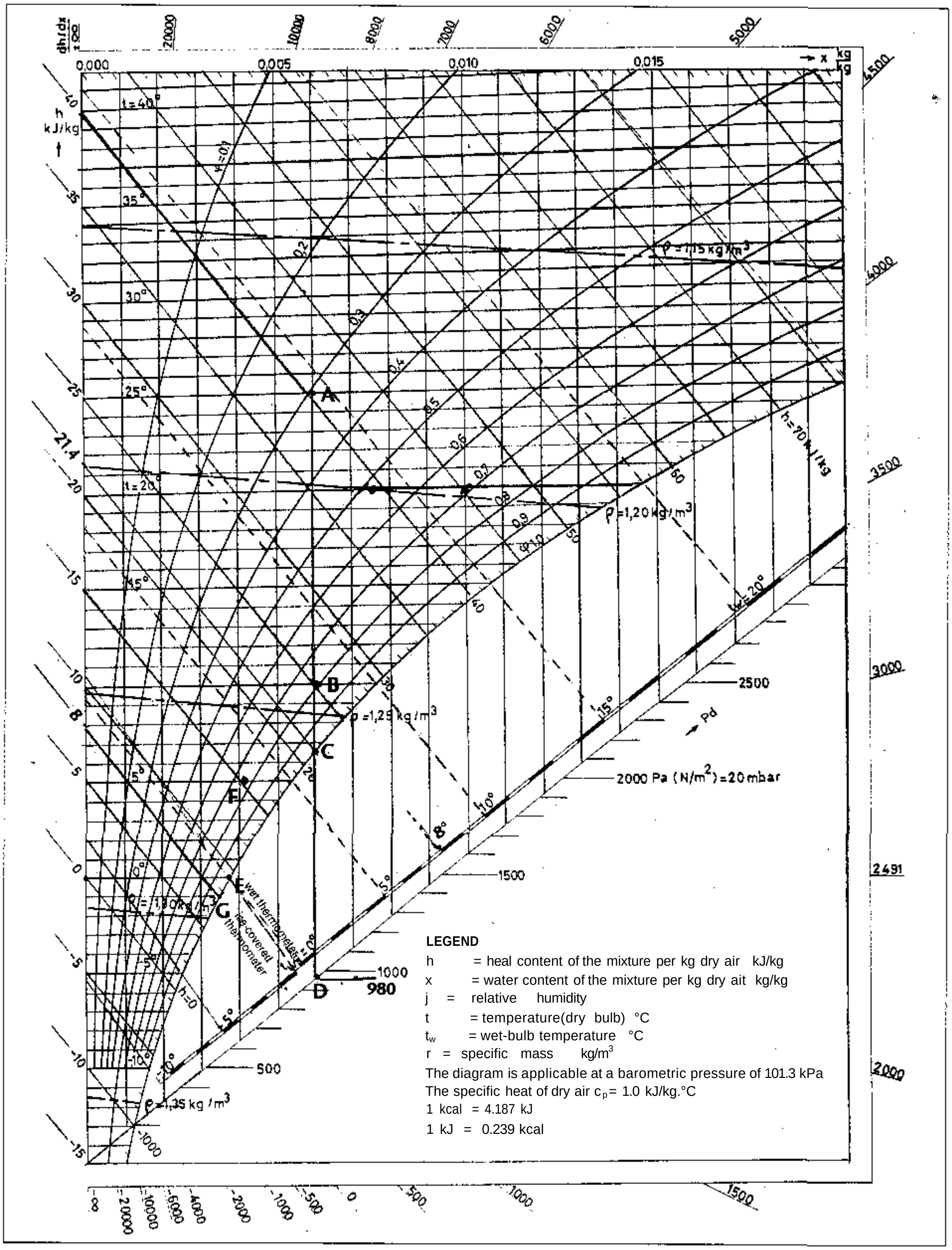
Given:
Air at 25°C and containing 6 g of water per kg of air is cooled down to the dew point.
We will describe the starting point as point A.
See *diagram 1.*

Find:
a) What is the relative humidity and what is the heat content (h) at *point A?*
b) Which line in the diagram must now be followed further?
c} What do the relative humidity and h amount to when the temperature has decreased to 10°C?
   Refer to this point as *point B.* What temperature does the wet bulb indicate?
d) At what temperature is the dew point reached?
   if we refer to this as *point C,* what then do the relative humidity, h and p_v amount to?
e) What happens if the air is cooled down even further?
f) How much heat was needed per kg of air to cool the air down to the dew point?

Solution:
a) We can find *point A* on the intersection of the line t = 25° and x = 0.006 kg/kg.
   At *point A* we see that the relative humidity amounts to 30%. By following the diagonal line of constant heat content (enthalpy), we can read on the vertical axis that h = 40 kJ/kg.

DIAGRAM 1

MOLLIER h/x DIAGRAM FOR MOIST AIR



LEGEND

h = heal content of the mixture per kg dry air kJ/kg

x = water content of the mixture per kg dry ait kg/kg

j = relative humidity

t = temperature(dry bulb) °C

t_w = wet-bulb temperature °C

r = specific mass kg/m³

The diagram is applicable at a barometric pressure of 101.3 kPa

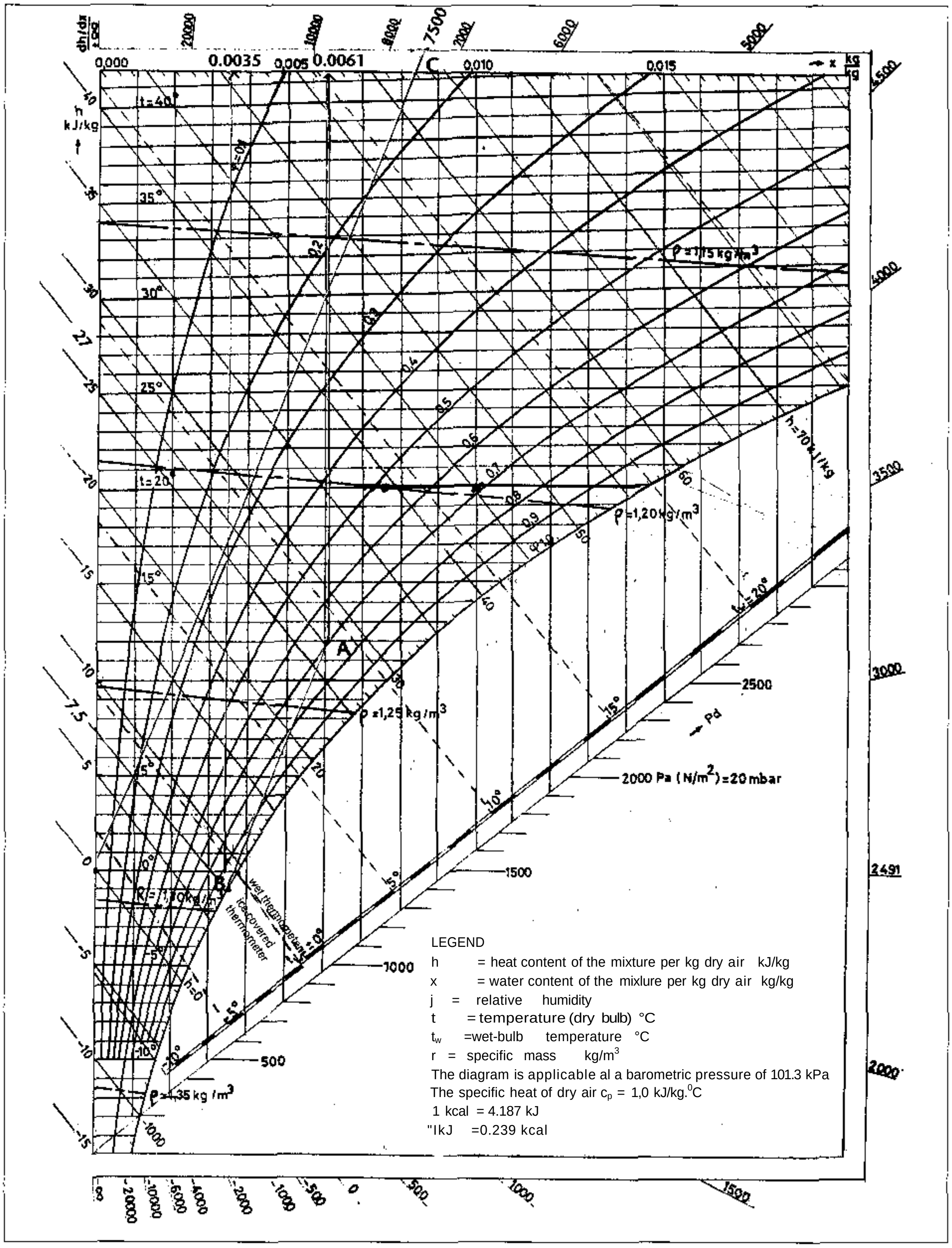
The specific heat of dry air c_p = 1.0 kJ/kg.°C

1 kcal = 4.187 kJ

1 kJ = 0.239 kcal

DIAGRAM 2

MOLLIER h/x DIAGRAM FOR MOIST AIR



b) During the temperature reduction the quantity of moisture initially remains the same. We can therefore follow the line of equal water content (x = 6 g/kg) further downwards.

c) We find *point B* at the intersection of the line t = 10° and the vertical line x = 0.006 kg/kg. The relative humidity at *point B* is 78% and h = 25 kJ/kg. t_w = 8°C.

d) If we follow the x line further downwards, then we find *point Cat* the intersection of the line x = 0.006 kg/kg and the saturation line. In between the t_d lines we can read that at 6.7°C the dew point has been reached. The relative humidity is 100%; h = 21.4 kJ/kg and p_v = 980 Pa *(see point D).*

e| If cooling is continued even further, the water vapour will be converted into water droplets,

f) At the beginning, at *point A,* h amounted to 40 kJ; in the saturation state *(point C)* h amounted to 21.4 kJ.
Cooling down to the dew point therefore required: 40 kJ/kg - 21.4 kJ/kg = 18.6kJ/kgof air.

Find:

a) How does the process continue if the air from the previous example is cooled down further after reaching the dew point?

b) If this air has been cooled to 0°C, what do h and x amount to?

c) How much heat was needed per kg of air to cool the air down from the dew point to 0°C?

d) How much moisture was released in the range between the dew point and 0°C?

Solution:

a) If cooling is continued, the air remains saturated, but moisture is released.
We therefore have to follow the *saturation line* to *point E.* That is the point where the horizontal line (isotherm) of 0°C intersects the *saturation line.*

b) At *point E,* h amounts to 9.5 kJ/kg and x = 3.8 g/kg; p_v = 611 Pa.

c) At *point C* (= the dew point) h amounted to 21.4kJ/kg.
At *point E,* h = 9.5kJ/kg.

Table 4
Air pressure* 707.300 *kPa (1.013 bar)

Temperature in°C	Weight of dry air	Water vapour	
	kg/m³ air	grams/m³	grarns/kg
- 10	1.34	2.3	1.7
- 8	1.33	2.7	2.0
- 6	1.32	3.1	2.4
- 4	1.31	3.6	2.8
- 2	1.30	4.2	3.2
0	1.29	4.9	3.8
+ 2	1.28	5.6	4.4
+ 4	1.275	6.4	5.0
+ 5	1.27	6.8	5.4
+ 6	1.27	7.3	5.7
+ 8	1.26	8.3	6.6
+ 10	1.25	9.4	7.5
+ 12	1.25	10.6	8.6
+ 14	1.23	12.0	9.8
+ 15	1.225	12.8	10.5
+ 16	1.22	13.6	11.2
+ 18	1.21	15.3	12.7
+ 20	1.20	17.2	14.4

The following amount of energy was therefore required to cool the air down from point C to *point E:*
21.4 kJ/kg - 9.5 kJ/kg = 11.9 kg per kg of air.

d) The moisture released in this range amounts to 6 g - 3.8 g = 2,2 g/kg.
(This can also be seen in *Table 4).*
It should be noted here that moisture is only released after the dew point has been reached.
Generally speaking, the hold air is cooled down in the evaporator to below the dew point, which means that theoretically the hold air may have 100% humidity when it leaves the evaporator.

The hourly capacity of the evaporator

The difference in heat content (h) of the air before and after the evaporator, multiplied by the quantity of air per hour, will represent the total hourly capacity of the evaporator.
If we refer to the capacity of the fan as Fc, then the hourly capacity of the evaporator can be derived from the formula:

Hourly capacity of evaporator (Q) = $F_c \cdot (h_1 - h_2)$

In which h_1 = evaporator intake and
h_2 = evaporator outlet.

Given:
The return air from the hold flows into the air cooler at 5°C and with 75% relative humidity. For each 5025 kJ of evaporator capacity 720 kg of air is blown through the cooler.

Find:
a) How much heat per kg of air is extracted by the cooler?
b) What is the heat content (h_2) of the air exiting the cooler?
c) What is the temperature of the air as it leaves the outlet?

Solution:
a) At *point* F the air enters the cooler. In the diagram we can read that x = 4.2 g/kg and that the heat content (h_1) is 15 kJ/kg.
The heat extracted from each kg of air amounts to:

$$\frac{5025 \text{ kJ}}{720 \text{ kg}} = 7 \text{ kJ/kg}$$

b) The heat content of the air at the outlet is 15 kJ/kg - 7 kJ/kg = 8 kJ/kg.
cl From the diagram we can see that, at a heat content of 8 kJ/kg, the temperature of the saturated air is -1°C and that x - 3.5 g/kg *(point G).*

Note:
In the above examples we have overlooked two aspects.
Firstly, we assumed that when the air leaves the evaporator it will be saturated (R.H. = 100%). In theory, this is not correct. It is possible that because of a wider gap between the fins, some particles of air do not come into direct contact with the evaporator surface and are thus not cooled as effectively.
Secondly, it is also possible that the moisture is not fully condensed and that moisture particles are deposited on the evaporator in the form of frost. This imposes extra demands on the capacity and also brings a slight increase in the temperature of the air at the outlet.

Cooling-induced dehydration

Let us now assume that we have loaded products with a high moisture content. During the loading operation the temperature was 20^0C. Our aim is to cool down these products by circulating air at a temperature of -1 °C. The cooling air that flows through the cargo wil! absorb heat and, consequently, the relative humidity will decrease, which means that moisture will evaporate from the product.
Air that flows across the top of the cargo absorbs less heat and will have a higher relative humidity. When these separate layers of air flow back to the cooler, they will mix together. Let us then assume that at a certain moment the air has a temperature of 12^0C and a relative humidity of 70%.

In the second Mollier diagram *(Diagram 2)* we have indicated this as *point A.* In the diagram we can see that, upon entering the cooler, the heat content (enthalpy) h_1 =
27 kJ/kg and x_1 = 0.0061 kg/kg.

When the air leaves the cooler it has been cooled down to -1°C and the relative humidity is 100%. We describe this as *point B.* At this point we can read that h_2 = 7.5 kJ/kg and x_2 = 0.0035 kJ/kg.

From this it follows:

$$\frac{\Delta h}{\Delta x} = \frac{h_1 - h_2}{x_1 - x_2} = \frac{27 - 7.5}{0.0061 - 0.0035} = \frac{19.5}{0.0026} = 7500 \text{ kJ/kg}$$

For each 7500 kJ discharged, 1 kg of water is removed from the air. This is therefore the quantity of moisture extracted from the cargo. The resultant dehydration can be calculated from the formula:

$$\text{Dehydration (\%)} = \frac{h_1 - h_2 * 100\%}{\frac{\Delta h}{\Delta x}}$$

$$\text{Dehydration (\%)} = \frac{27 - 7.5}{7500} * 100\% = 0.26\%$$

The diagram could also have given us an immediate reading for

$$\frac{\Delta h}{\Delta x}$$

To do this we need to join the 1 st *point A* with the 2nd *point B.*
Then we move line A - B in parallel until it passes through the zero point of the diagram
(x = 0; h = 0).
From the zero point we protract the line until it intersects the line Ah/Ax which is situated outside the diagram. In the graph we have marked this point as C
At *point* C we can read 7500 kJ/kg

CHAPTER 9

CONTAINERS IN REEFER SHIPPING

The reefer container

Reefer containers can be subdivided into two types:
- the porthole or isothermic container
- the plug-in or integral container.

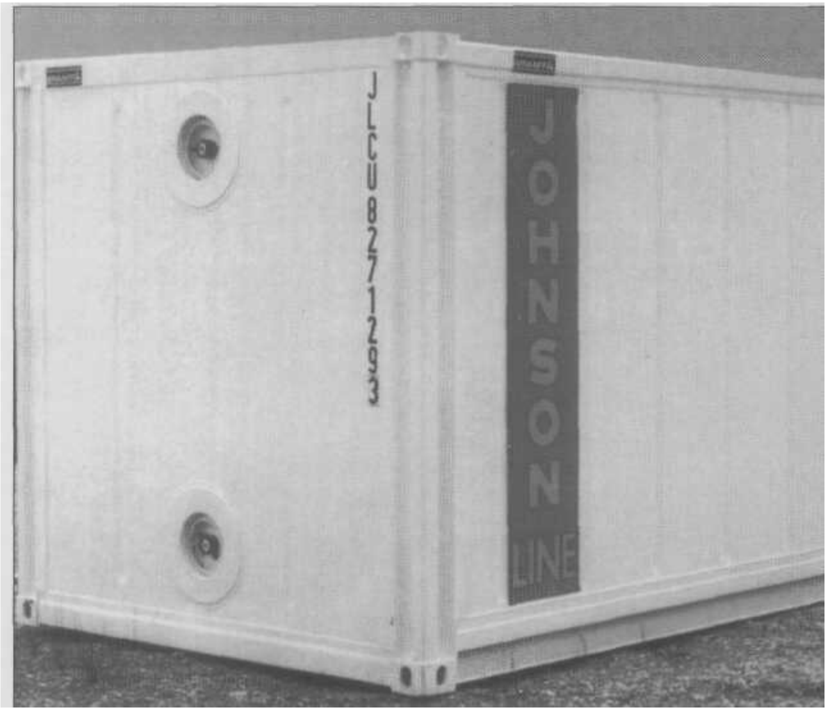
The porthole container is essentially not much more than an insulated box which is linked up to the ship's central cooling installation. Economically speaking, the porthole container can only be used for the transport of large quantities of homogeneous frozen cargoes, such as meat. The ports of loading and unloading must also have special facilities available for handling reefer containers of this type.

The plug-in, integral container has its own cooling aggregate and receives its energy from the shipboard electricity network during seagoing transport. The integral container is much more flexible in its applications, offers wider possibilities for the transport of mixed types of refrigerated cargoes and requires no special facilities in the ports of call.

The collective system

Insulated porthole containers have two round openings in the bulkhead at the opposite end to the loading door. These serve for the intake and discharge of the cooled air *[see illustration].*

The insulated porthole container, also referred to as the "isothermic" container, is transported in cellular container ships. These are known as "open-top" ships and they have 3 rows of hatchways along the entire length of the cargo carrying area.
The containers are coupled up to a system of air ducts below deck and the vessel's central cooling installation provides cooled air circulation inside



20" steel clad insulated/porthole container

"The vertical Ducts system"

the containers. After the containers have been stacked, special couplings are used to link up the air lines to the ducts, after which the cooling installation can be activated.

On "2nd generation" container ships, porthole containers can be stacked 6-high, while on "3rd generation" vessels stacking is possible up to a maximum of 9-high. The photo on page 86 shows the upper deck and the way in which the containers are coupled up and stacked inside the hold.
There are basically two different designs for this air ducting system:
- a system which uses mainly horizontal ducts; and
- a system which uses only vertical ducts.

The usual system applied is that based on vertical ducts.

Vertical ducts

A number of vertical air ducts are fitted across the full breadth of the hold. In this system, each stack of a maximum of 9 containers high is fitted with its own air cooler and fan, i.e. each vertical stack has its own air ducting system and independent cooling air circulation. Fresh air can be admitted to each individual air cooler via completely separate, adjustable intakes. This ensures that no interchange of air can take place between two air coolers, as this would inevitably cause temperature-control problems in cases where different temperatures have to be maintained. To separate the delivery and return air flows, the internally insulated air duct is fitted with a separation wall.
Inside the cellular hold the stacked containers are kept in place by container guides (guide rails). Between the corner supports of the containers and the vertical guide rails there is a clearance of approx. 2.5 cm. If the vessel rolls, the containers can therefore slide back and forth a little between the guide rails on either side. The air-coupling lines which connect the containers to the vertical air ducts in the hold must therefore be of a flexible construction so that a sideways movement of the containers does not damage the airtight connection.

Refrigerated Tank Container

The coupling has to bridge over a gap of some 10 cm between the container and the air duct. By opening an air supply line, the connector element of the coupling is pushed forward, thus ensuring an airtight seal with the container. To decouple the container, this air is simply allowed to escape again. When the coupling is being connected or disconnected, a built-in valve (manually operated) opens or closes the air supply to the container.
Various types of coupling mechanisms are commercially available. One of the best-known types is the "Sterling clip".
The "vertical ducts system" described above was developed in Germany and is known under the name "ConAir". The same system has also been designed in the United Kingdom where it is known as "Sea Rod".

Horizontal ducts

In the vertical system the air coolers are installed inside the hold. In the horizontal system, however, effective use has been made of the space that is available between the ship's hull and the container bulkhead. The fan and the cooler are in fact installed in this space and the air ducts run through this space to the bulkhead. In the horizontal system up to 48 containers can be connected up to one cooling unit, however, this system can only be economically applied in cases where solely refrigerated cargo is being carried.
The advantage of the horizontal system is that less brine pipework is needed and the coolers do not have to be installed inside the hold. By comparison, the air ducts in the vertical system are shorter.
The vertical ducts system, in which each stack has its own separate cooler, offers much greater flexibility, especially if the hold is only part-loaded or if a combination of both refrigerated and cooled cargo is being transported.

Tank container

Tank containers are usually also cooled by means of an integral system. However, the German container manufacturer Tectrans has designed a "porthole" tank container which can be coupled up to the ship's ConAir ducting system.
Compared to other tank containers, this type has a surprisingly simple operation.
Between the tank's aluminium outer wall and the GRP (glass reinforced plastic) inner wall there is an opening which serves as a duct for the supply of cold air which is blown in along the bottom half of the tank. The air is then extracted again from the top half of the tank.
The inside of the outer wall is insulated with a layer of polyethylene foam.

A tank container can be used for the transport of juice concentrates, beer, wine, milk and some chemical products.
An ISO tank container fitted with its own cooling unit can hold about 20,000 litres (4,400 gallons).
The refrigerated ISO container depicted uses standard container refrigeration equipment mounted on and attached to the container vessel. This container uses air as the heat transfer medium, as opposed to those systems that use Freon pumped around inside special coils. CPV containers incorporate their own cooling system and are therefore independent of their surrounding environment, which means that they can also be used as peak storage or seasonal storage facilities.

Hold insulation

When a ship is being built, the choice that has to be made is whether the hold should be fully or partially insulated or not insulated at all. If the hold is insulated, the cold radiated by the containers will make the hold temperature lower than the ambient temperature. On the other hand, however, this will limit the heat transmission from the hold air to the containers. The favourable effect of this is that the air circulation inside the container is lower than in the case of a non-insulated hold.
A lowered air circulation in the hold not only reduces dehydration of the product but also, and most importantly, yields a saving on the cooling capacity of the installation,
One problem with insulated holds carrying frozen goods is that heating is needed to prevent steelwork from getting so cold as to become embrittled. In the case of a hold which is not, or only partially insulated the temperature of the outside air and of the seawater plays a bigger role. Where a high hold temperature prevails, the temperature of the frozen cargo will increase as a result of heat transmission.

Especially in cases where only cooled cargo is shipped, the hold temperature may even become too high under certain conditions. In a non-insulated hold, therefore, the air needs to be circulated through the containers at a substantially faster rate. However, this in turn necessitates a higher fan capacity per container, the result being that the cooling capacity and electrical power rating of the shipboard refrigeration plant will have to be increased.
Nowadays, though, container ships are generally fitted with a brine cooling installation. In such a case the brine room contains a brine regulator unit and a control unit. This unit can be used to adjust the temperature of the brine for a specific group of air ducts.
In most cases the air conditioning system for the hold air also includes heat exchangers which are coupled to the brine piping system. If cold brine is allowed to circulate through the air conditioning system, the hold air can be maintained at a constant temperature, thus preventing heat leakage to the containers. When sailing in cold regions it is also possible to circulate warm brine through the system if required. The available options offered by this system guarantee an even more accurate regulation of the transport temperature.

Even today, controversy still exists about whether or not it is wise to insulate the hold of a container vessel. The arguments used for and against insulation can be summarised as follows:

Arguments for hold insulation:

(1) Even without a higher rate of air circulation in the container, the temperature gradient inside the container remains very limited.
(2) Even if the insulation material used for the container has deteriorated, e.g. because of ageing, this is of lesser importance, since the hold itself is insulated.
(3) Effective control of the air temperature in the hold can help to reduce the "cooling-down" period, without this imposing an additional big load on the central cooling plant.

Arguments against hold insulation:

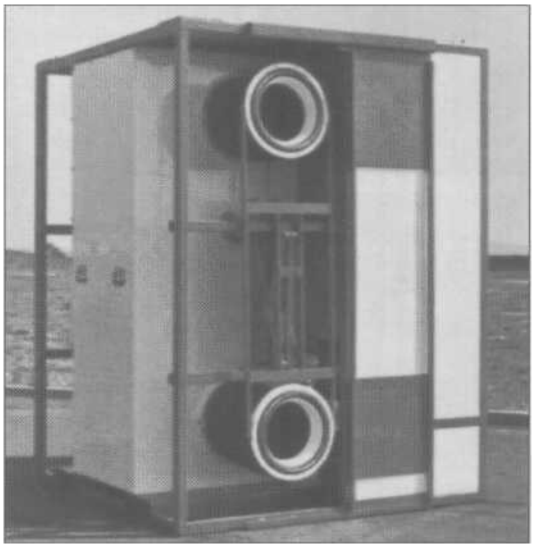
(1) The higher building costs of the ship.
(2) Where frozen cargoes are carried, an insulated hold will have to be heated to prevent brittle fracture damage.
(3) Since the quality of the insulating material and hence its insulating capacity deteriorate as each year passes, the insulation value will show a constant decline.

Storage of porthole containers at the terminal

Depending on how many porthole containers are involved, different methods can be used to cool them during storage.
For a smaller number of containers it is possible to use "clip-on" units, e.g. the "Fridgemaster". The clip-on unit is a 20-ft or 40-ft container fitted with a built-in, completely self-contained cooling aggregate. The porthole containers are coupled direct to this clip-on unit.

Another system used for a small number of containers is the "Halltherm Minicore". Here the cooling aggregate is installed inside a steel frame measuring 6 x 6 x 8 ft (1.83 x 1.83 x 2.44 m). The cooling unit is protected against water by detachable panels which cover the top and sides of the frame. Just like the "clip-on" unit, the Minicore is a completely self-contained and independently operating cooling installation.

The unit comprises 2 compressors and an air-cooled condenser, together with an air-cooler and



Halltherm Minicore

the required control equipment. It can be transported by crane or forklift truck and is then connected up to the mains electricity supply at the terminal.
Supply and discharge couplings for the cooling air are located on both sides of the unit. Either one container or two can be connected up to the unit. To ensure that a good connection is obtained with the container at all times, the couplings can be extended electro-mechanically by a further 30 cm. The installation offers flexible and simple operation because the double circulating air cooler is connected up to 2 compressors.
The compressors can operate either in combination or separately. As a result, this provides not only effective automatic temperature control regardless of whether one or two containers are coupled to the installation, but also makes it possible to couple up two containers with different transport temperatures.

Where bigger numbers of containers are stored, one of the systems described below is used.

The central system

If the terminal is equipped to receive large numbers of containers, a central cooling installation will be present in the building or close to the terminal. From this installation insulated cooling lines run above ground or underground to the container storage site. In this case the porthole containers are connected up to the piping network with the aid of pneumatic couplings in the same way as on board a ship.

The Unicore system

For the storage of large numbers of containers Hall-Thermotank International Ltd. has developed the Halltherm Unicore system. The cooling installation and the control system are built inside a 20-ft ISO container.
From the air coolers located at both ends of the container, insulated supply and discharge ducts run to a 40-ft-long metal structure. The air ducts pass along both sides of this framework and are

Halltherm Unicore

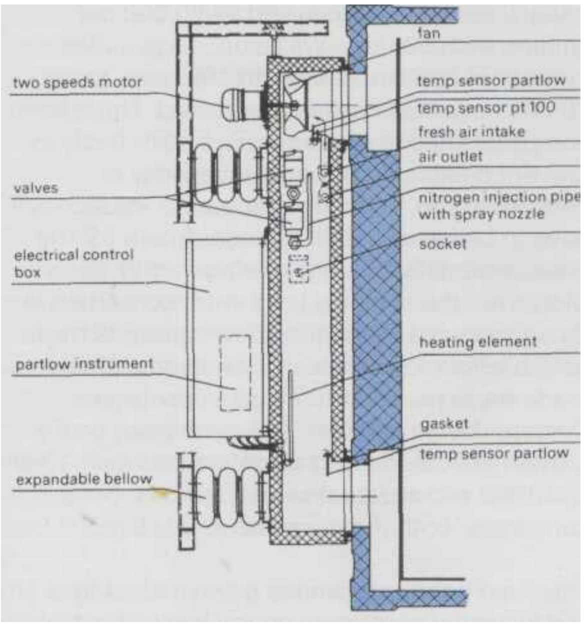
fitted with the required inlet and outlet couplings. The photo gives a clear picture of the layout of thisinstallation.

Each air duct has its own air cooler, which means that the temperature required for a specific container can be controlled independently of the temperature in another air duct connected up to the same cooling system.

As can be seen from the photo above, the containers can be coupled up to both sides of the framework and can also be stacked 2 or 3 high if portainer or gantry cranes are present.

The nitrogen system

In some terminals the porthole containers can also be coupled up to a liquid nitrogen installation. The liquid nitrogen is stored in a tall insulated tank. A two-tier steel structure is erected alongside the tank. The Press-On Units are suspended from this framework. A pipe runs from the tank via the steel framework to supply liquid nitrogen to the Press-On Units.
The suspended Press-On Units can be moved vertically so that they can be linked up both to 8-ft containers and to containers with a height of 8'6". A straddle carrier conveys the container to the installation, after which the unit is raised to the required height. The gastight seal between the unit and the container is obtained by means of the expandable bellows which are pressed against the portholes under nitrogen pressure.



Cryo Press-On Unit

CKT W x 8' x 8' 6" Reefer container

Development of the integral container

The development of reefer container transport started with porthole containers. In those days the design of the integral containers had still not been developed to the extent that they could be used on a wide scale.
The integral container then offered a solution solely in cases where a limited number of reefer containers had to be transported or where an on-shore installation was unsuitable for the receipt of porthole containers.
It was only in the second half of the 1970s that the transport of cooled products in integral containers really started to grow. In those years it was mainly the Japanese who stimulated the transport of cooled products in such containers.

Before we discuss the design and construction of the integral container in greater detail, we must first explain some of the relevant terminology:

Integral container:

A reefer container equipped with an independently operating cooling unit which needs to be connected up to the electricity network. The container is fitted with air conditioning equipment and can maintain any required temperature between -25°C and +25°C at an ambient temperature of -2G°C to +50°C.

ISO:

International Standards Organisation.

ISO container;

This is the basic standard design for a thermal container and its test standards are laid down in ISO 1496/2.
To summarise, the characteristics of an ISO container are as follows:

(a) of durable quality and sufficiently robust to withstand frequent use;
(b) specifically constructed for the transport of goods by one or more transport modes without transhipment of the cargo inside the container;
(c) fitted with devices which facilitate transfer from one transport mode to another;
(d) built in such a way that it is easy to load and unload;
<e] with a cubic capacity of at least 8 m^3 (282 cu. ft).

TEU:

Twenty foot Equivalent Unit. The container with standard dimensions of 8' x 8' x 20' is the internationally accepted unit. The TEU is a unit of calculation. Regardless of the actual length dimensions of a group of containers, their total capacity is expressed in TEUs. In other words, the total capacity is expressed in terms of 20-ft containers.

FEU:

Forty foot Equivalent Unit. A 40-ft container is referred to as an FEU. **Note:** 1 FEU = *2* TEUs.

In addition to the ISO, there are other organisations which have drawn up regulations governing the construction of containers and/or the transport of goods in containers. The most important organisations are:

USCG: The United States Coast Guard
ANSI: The American National Standards Institute
CSC: The Agreement on the International Convention for Safe Containers
ATP: The Agreement on the International Carriage of Perishable Foodstuffs
TI: Transfrigoroute International.

Containers are also inspected and certificated by the well-known classification bureaus such as Lloyd's Register of Shipping, Bureau Veritas and the American Bureau of Shipping.
The approval requirements of these bureaus are largely based on the ISO standards but they also set specific requirements relating to the insulation, the cooling unit and the control equipment.

Growth of the world fleet of integral and insulated containers

World-wide there are 6 million TEUs. Of these, some 300,000 units are reefer containers. In recent years there has been no noticeable increase in the number of porthole containers, but between 1985 and 1989 the number of integral containers increased by 20,000 per annum. In 1990 there was a decrease in the number of containers built. In 1991 only some 10,000 new TEUs were constructed. The leasing companies had fewer containers built, firstly to prevent creating a further overcapacity of containers and, secondly, because a solution will have to be found within the near future for the environmentally unfriendly refrigerant R 12. Moreover, the shipping lines were concerned in those years that economic developments might possibly lead to a full-scale recession and this made them reluctant to invest in containers. Despite this pessimism, however, there was a growth of 20% in integral reefers between 1990 and 1992 and an increase of 6% in insulated containers, both measured on a TEU basis.

The table below shows the growth of integral and insulated containers on the basis of actual containers, regardless of size.

year	Integral	Insulated
1980	51 800	58 600
1983	73 200	68 200
1986	104 300	70 700
1990	185 000	70 000
1992	222 000	74 000

During 1992-1993 world reefer container output was largely stable at around 60,000 TEU per year. The global manufacture of refrigerated containers reached a new high during 1994, when production rose to 70,000 TEU.

The manufacturers are not pessimistic about the developments for the coming years. At the moment it is estimated that 50% of all perishable products are carried in reefer containers. Expectations are that this percentage is certain to increase in future. A further growth is also forecast in demand for 40-ft containers and 40-ft "high-cube" units in particular.

The two leading builders in South Korea, Hyundai Precision and Industry (HPI) and Jindo Corp. constructed 30,000 TEU during 1994, which accounted for almost 43% of all the refrigerated containers built in 1994. Some 20% of Korea's production consisted of 20-ft containers and the 80% balance comprised 40-ft standard (8' 6") and high cube (9' 6") reefers.
The production of reefer boxes in Japan amounted to 13,000 TEU in 1994 and the combined output of reefer boxes in Taiwan and Singapore amounted to approx. 10,000 TEU.
In that same year the collective production of reefer containers in Europe was 15,000 TEU.

The most important reefer builders in Europe are: Graaff (Germany), Morteo (Italy), Finsam (Norway), W.H. Davis (UK) and Maersk Container Industri (Denmark).
Maersk Container Industri (MCI) is based in southern Denmark at Tiniev and up to 1994 it concentrated solely on the production of dry freight containers. In 1995 it constructed a new line to manufacture reefer containers. The reefer bodies will be produced with steel outer cladding, lined internally with aluminium.

The best-known reefer producers in the Far East are:
Evergreen Heavy Industrial Corp. (EHIC) in Taiwan and Nippon Fruehauf in Japan. The latest reefer manufacturing lines have been installed in Malaysia (Scan Reefers) and at Pangaji Mario Refconindo in Indonesia.
In northern China the new Yantai-Ace Reefer Container (YARC) factory has been operational since mid-1995. Yantai-Ace is located close to Qingdao and is receiving technical/marketing assistance and financial backing from Ace Engineering and Co., of South Korea.

Container construction and equipment

Choice of materials

Generally speaking, the skeleton and the floor sections are made of stee . For the internal and external cladding and the roof it is possible to choose between multiplex (plywood), glass fibre, stee or aluminium. Formerly, more widespread use was made of GRP (glass reinforced plastic) for the external cladding.
Nowadays stainless steel is generally used for the internal cladding, whilst the external cladding is made from aluminium sheets or from some type of steel such as mild steel, Corten steel or, by preference, high grade stainless steel. Some manufacturers use aluminium both for cladding and for structural components.

Steel and aluminium each have their own specific benefits and drawbacks.
The great advantage of aluminium is that it is lighter than steel. This means that the container's own (tare) weight is lower, thus permitting a bigger cargo weight (payload).
The advantage of a steel construction is the container's longer lifetime, the reduced risk of damage and thus less maintenance. As already mentioned, there has been a preference in recent times for the use of high grade stainless steel because its weight is lower than that of mild steel.

The recent sharp rise in the price of aluminium has encouraged the trend towards a bigger production of stainless stee reefers. According to the reefer producers there is also a trend on the part of the shipping lines to opt for stainless steel outer cladding.
We would note here That the world market prices of both aluminium and stainless steel have risen

in recent years. The price for aluminium ingots rose from around US$ 1,000 per tonne at end-1993 to more than US$ 1,600 at end-1994. It could exceed US$ 2,000 per tonne by end-1995. At the beginning of 1995 the market price of stainless steel amounted to about US$ 2,100 per tonne. Obviously, the cost of the material and economic aspects will continue to play a major role in the choice of materials in future and this applies specifically to the use of high grade stainless steel.

Insulation

For the insulation which is fitted between the internal and the external wall the predominant material used is polyurethane foam. Sometimes polystyrene foam or polyester GRP panels are also used. Because of the space taken up by the insulation and the air ducts some 20% of the effective loading capacity of a reefer container is lost. In addition, after about 6 years, the heat transmission coefficient (K) of the insulating material is reduced by 30% because of ageing of the material and, above all, as a result of moisture absorption.
In recent years in particular, attempts have been made to improve this situation. To reduce the adverse effects of moisture diffusion, polyurethane foam has now been manufactured with a higher density.

The Yantai-Ace Reefer Container factory (YARC) in China applies "Styrofoam" panels in its containers. Styrofoam panels consist of pre-formed polystyrene sections. This method was originally developed for Swecom in Sweden. In this process the reefer panels are constructed around specially profiled polystyrene sections. The advantages of polystyrene over polyurethane foam are the panel's greater mechanical strength and its smaller propensity to absorb water.

All manufacturers of new insulating materials that come on the market are in principle seeking to achieve one and the same objective, i.e. low hydrophilic properties and a reduction of the insulation thickness of the walls whilst retaining the original strength.
The insulation thickness of the walls is generally approx. 75 mm and that of the doors is 100 mm.

Table: Properties of selective blowing agents suited for reefer insulation manufacture

Product	CFC11	HCF22	HFC134a	HCFCUIb	HCFC142b	HFC152a
Ozone Depletion Potential	1.00	0.05	0	0.11	0.06	
Global Warming Potential	1.00	0.34	0.256	0.15	0.36	0.03
Molecular Weight	137	87	102	117	101	66
Boiling Point (°C)	23.8	40.8	-26.5	32.0	-9.2	-24.7
Gas Conductivity (mW/m/°K at 25°C)	7.8	9.6	14.5	7.8	12.9	14.7
Flammability	no	no	no	no	yes	yes
Prices before duties (DM)	2.8	4-5	25-30	4-6	8-10	15-20
Content in polyurethane foam (pbw)	6-14	4-6	4-6	4-6	10	-

Data courtesy of Container and Equipment Sales Ltd.

By applying modern insulating materials it has been possible to reduce these thicknesses to 67 mm and 77 mm respectively.

Polyurethane foam, as used for insulation purposes, was formerly blown using R 11 (CCl_3F). R 11 had long been regarded as the best blowing agent available to the reefer industry and its qualities were proving hard to beat. Today, however, R 11 is almost past history. From January 1995 its manufacture and importation have been banned within the EU. A worldwide ban, as dictated by the Montreal Protocol, will take effect from January 1996 (see also Chapters 20 and 21). Practically all the reefer builders have now switched to full use of R 141 b, with only a very few container manufacturers opting for the R 22 foaming process for their newly-built reefer containers.

As the table shows, the kilogram price for R 141 b is higher than that of R 11, although the price difference is becoming increasingly favour-able as a result of higher turnover (approx. US$ 2.50 per kg). We can also see from the table that R 141 b closely mimics the properties of R 11.
The manufacturers claim that there is a small loss of thermal efficiency of about 5% in the manufacture of reefer panel insulation if R 141b is used instead of R 11. Against this, however, the latest findings derived from accelerated testing have shown that the insulating qualities of R 141b-blown foam actually improve with age and could, within a few years, offer a better performance than comparable R 11 foam.

However good the favourable properties of R 141 b may be, the table shows that we still have a problem because R 141b only represents an interim solution. A glance at the table shows us that R 141 b has an OOP of 0.11 and is therefore still destructive to atmospheric ozone and features on the list of endangered HCFC chemicals. Under EU legislation a total ban on its manufacture is scheduled by around 2015. The Montreal Protocol stipulates an end to its production by 2030, commencing with a 35% cut in manufacturing by 2004.
Although only 15 kg of R 141 b is required to foam an entire set of 40-ft reefer panels and though the reefer boxes manufacturing industry uses just a few hundred tonnes per annum, the manufacturers - with an eye on the future problems - are looking to the chemical industry to come up with suitable alternatives to R 141b.

Some research work has meanwhile been conducted and one of the obvious long-term candidates is water/carbon dioxide. Water/carbon dioxide processes offer a mechanical strength that is comparable to that of foams blown by R 141 b and R 11. However, insulation made from processes using water yields significantly poorer levels of thermal insulation, resulting in a heat loss of about 19%. It is possible that in the future ongoing research efforts will find means of improving these poor thermal properties. If this is not the case, then the reefer panel sections will have to be designed 20% thicker and the capacity of the machinery will have to be increased.

The "greener" reefer container

Ever stricter environmental requirements are also making themselves felt in the world of containers.
In 1992/93 the French shipping group Compagnie Generale Maritime (CGM) placed an order for the construction of 100 20-ft containers. These containers were the world's first CA (*controlled atmosphere)* containers equipped to operate with the "greener" (= more environmentally acceptable) refrigerant R 134a. The containers supplied to CGM incorporate Carrier Seacold 320-type machinery. The compressor used in this type of machinery is fitted with the highly durable discus valve which, unlike most refrigerant compressor valves, will operate with any halocarbon coolant, including R 12, R 22 and R 134a.

Carrier Seacold's compressor suppliers have developed a method of using chlorine-free R 134a gas in their 320/340 series of reefer containers without significant loss of refrigerant capacity. While R 22 has one-twentieth of the ozone depletion potential (ODP) of R 12, the coolant known as R 134a is generally accepted to have no adverse effect on the ozone layer.
Carrier Seacold claims to have been the first in the market with this technology and believes that its older refrigeration systems can be inexpensively converted to the use of the new gas when environmental regulations are enacted to control the use of chlorine-based refrigerants.
R 134a is described as a breakthrough for the reefer container industry, since it is a coolant which can function under a wide range of operational conditions.
Production of R 134a on a commercial scale was started by ICl and DuPont in 1991. Although it contains no chlorine and therefore has no ODP, the gas has a global warming potential (GWP) of 0.28. The expectation is that, once zero-OOP refrigerants have become mandatory, legislation against the use of refrigerants with a GWP will almost surely follow. In the meantime, as R 134a does contribute to global warming, great vigilance and efficiency must be observed during repair and maintenance procedures on equipment using this gas.

To summarise, we can state that HCFC 141 b for insulation blowing and HFC 134a as a refrigerant for newly-built containers are here to stay for a while, as they are the only suitable solutions currently available. As regards the refurbishment of reefer containers running on the old CFC 12, the choice is to convert to either R 22 or R 134a. Opting for R 22 does not seem so likely, as its phase-out will probably be speeded up over the next few years. The same also applies to the blends, e.g. HP62, which also contains some R 22 (see Chapter 21). At the moment, however, customers are not particularly eager to have their reefer units refurbished. Obviously, they will hang on for as long as they can, waiting to see if something better comes up.
Only a few customers have converted R 12-charged containers to R 22, while conversion from R 12 to R 134a is at the moment not taking place on a large scale.

CGM's order for one hundred 20-ft containers was followed up by an order for six further containers incorporating the "PACAS" system. "PACAS" stands for Prism Alpha Membrane Controlled Atmosphere System. These PACAS "boxes" rank amongst the most expensive cargo containment equipment deployed by CGM. If operated in paralle with the Carrier Seacold reefer machinery, PACAS will slow the respiration rate of fruit and other produce and thereby increase its lifespan and maintain its quality. We shall be discussing this system in greater detail in a later chapter.

Totally CFC-free containers

At the end of 1992 the shortsea operator Bell Lines placed an order for fifty 40-ft containers which had been designed to reduce CFC usage to an absolute minimum. The first 49 containers in this series were fitted with ThermoKing CF111 refrigerating units operating on 134a fa non-CFC refrigerant).
As part of its environmental development policy, Bell Lines agreed with the container manufacturer - the German-based company Umformtechnik Hausach - that the final unit should be constructed to totally CFC-free standards, This final unit was to be further developed so that it incorporated what is described as the "ultimate in environmentally friendly refinements". Its features include insulation using non-CFC gas as a blowing agent, resulting in an insulation efficiency that is close to that used in earlier units.
Other "greener" characteristics are: the paint used for the container exterior is water-based rather than spirit-based, which means that no solvents are released into the atmosphere during manufacture or during the paint-curing process. Since early 1993 this "truly environmentally friendly" container has been in use on the Bell Lines service between Continental Europe and Ireland and is believed to be one of the first such "truly green" containers to be operated by an international company.

Sandwich technology

In modern container manufacture widespread use is today made of what is known as the

Comparison of cladding/lining materials for sandwich panels

		shock and blow resistance	resistance agains! LO'fo&ion anrj ageing	di^usion lignlne-ii	wtighf	reparable ness	cleaning
ff KI u rt	mild sieel i 2rrm	•••	•	•••	•	•	•••
	stamles'! stfei 1 0 mm	•••	•••	•••	•	•	•••
	aluminium 1 3mm	•	•••	•••	•••	•••	•••
	QRP 2 Sum	•	•	•	••	•••	•
	GRP/Plywooa 90mm	••	•••	•	••	••	•
m c fi	slainless aleel 0 7 mm	•••	•••	•••	•	•	•••
	aluminium 1 2mm	•	••	•••	•••	•••	•••
	GRP 3 5 mm	•	•	•	••	•••	•

••• very good •• good • sufficient/low

Table: Graaff GmbH, Germany

"sandwich" technology. High-density polyurethane foam is injected between the panels via the "one-shot in-situ foaming" technique (a method developed by the firm of Graaff GmbH, Germany). These "sandwich panels" vary in size and can be as big as 3 m wide and 15 m long. In the case of sandwich construction, too, the internal and external wail can be made either of the same material or of different materials. The advantage of this construction is that no stiffening, such as stringers or spacers, is used between the walls, which eliminates possible heat transmission by conduction between the walls.

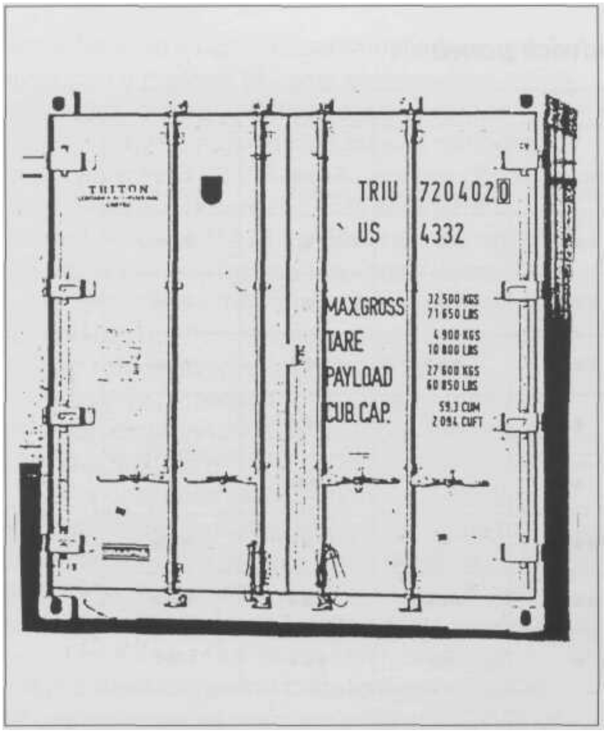
The use of the sandwich construction and certainly also the improved insulating materials have a favourable effect on the K-value. With an insulation thickness of 76 mm and a plate width of 2.5 m the K-value amounts to 0.24W/m^2 K.
The normal practice in making calculations is to take the heat leakage value for a 20-ft container as 20 to 22 kcal/h °C and that for a 40-ft container as 38 to 40 kcal/h °C.
The advantage of the modern container, therefore, is that the wall thickness is less, whilst the K-value remains sufficiently high. As a consequence, the payload is increased and the tare weight reduced.
The sandwich construction results in a iower heat leakage, bringing a saving of about 20% on energy costs as compared to containers of conventional construction.
Another major advantage is that these containers are simple to repair "section by section". In the event of damage only the damaged panel needs to be repaired or replaced.

The above table gives a comparison between the various materials used in the sandwich construction.

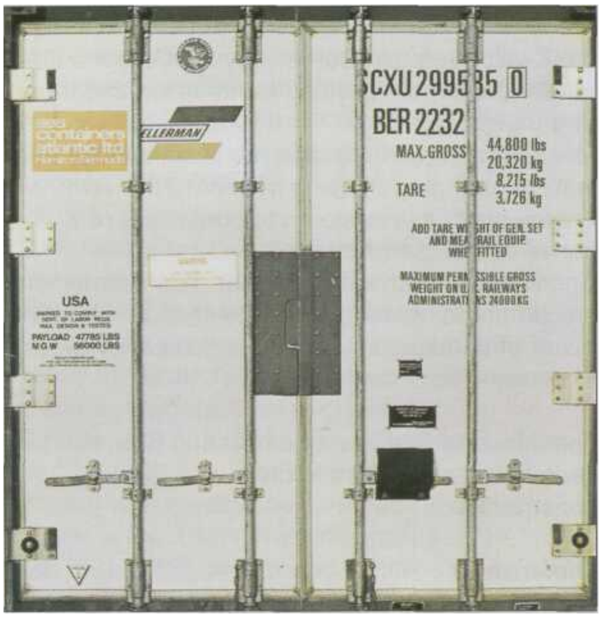
Dimensions

A 20-ft container is 6.06 m long and a 40-ft container is 12.19m long. In both types the width amounts to 2.44 m (8') and the height is usually 2.59m (8'6").

Although standardisation is a precondition for working efficiently with containers, there are still some container shipping lines which use non-standard dimensions. Examples are the "Super



20-ft reefer containers



40-ft stainless steel clad reefer container

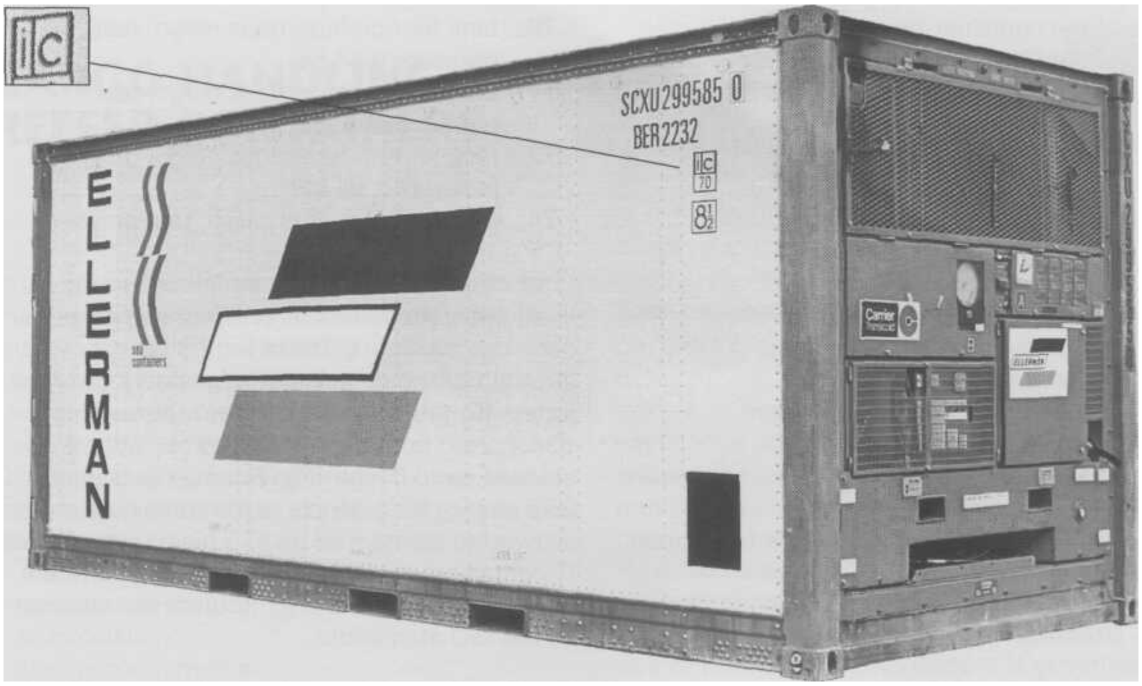
Cube Box", which is 13.75 m long, and what are known as "High Cubes", which are 2.9 m (9'6") high.

Cargo capacity

For a 20-ft general cargo container the payload amounts to about 20 long tons and for a 40-ft general cargo container it amounts to about 30 long tons (1 long ton = 1,016 kg).
For reefer containers these cargo capacities are approx. 20 tonnes and 25 to 30 tonnes respectively.
Before a classification certificate is issued for a container, the container has to undergo various cargo weight trials. The permitted cargo capacity is not only mentioned on the certificate but is also displayed on the loading door.

As we can see from illustrations, the loading door states that the total weight (Max Gross or MGW) amounts to 32,500 kg. This is also given in lbs (71,650 LBS). Shown below that is the weight of the empty container itself (the tare weight). In this case the tare weight amounts to 4,900 kg.

A clarification of these terms:
MAX GROSS (MGW) = TARE + PAYLOAD (weight of cargo)
PAYLOAD (NET) = MAX GROSS - TARE.



An "1C" container

Markings

As can be seen from the container depicted below, a container not only carries the logo and name of the container's owner or leased user, but also a combined code consisting of letters and numbers.
This code contains the following information:
- the owner of the container;
- the container's country of origin;
- the dimensions of the container;
- the purposes for which the container may be used.

The container shown carries the following code on the side: SCXU 299585 (0)
BER2232.

This code represents the following information:
The first three letters (SCX) are the code which denotes the owner (in our case: Sea Containers).
The fourth letter indicates what type of unit is involved. The letter U indicates that it is a container. A letter T is used to denote a trailer.
The remaining digits in the top line of the code represent the unique registration number for that container.
The letters BER indicate that the container is registered in the Bermudas.

The four-digit code which follows and which should be carried by every ISO container, can be decoded as follows:
The digit on the extreme left shows the length of the container:

2 means a 20-ft container
4 signifies a 40-ft container.

The next digit is the code for the container height:

0 8 foot (8') high;
1 8 foot (8') high with tunnel*;
2 8 foot 6 inches (8'6") high;
3 8 foot 6 inches (8'6") high with tunnel;
4 more than 8'6" high;
5 more than 8'6" high with tunnel;
6 half-height (4' to4'3");
7 half-height (4' to 4'3") with tunnel;
higher than half-height but lower than 8 foot;
lower than half-height.

*'with tunnel' means that the container is fitted with a tunnel, usually consisting of plastic (vinyl) or canvas chutes fitted along the ceiling to serve as air ducts for the top air delivery system.

Some of the container types recognised by the ISO are listed below. The meaning of the final two digits in the four-digit code is as follows:

- 00: dry cargo, standard
- 01: dry cargo, open sides
- 10: ventilated, standard
- 15: mechanical, ventilated
- 20: insulated, standard
- 22: insulated, heated
- 30: cooled by gas evaporation, equipment integrated
- 31: mechanically cooled, equipment integrated
- 32: capable of cooling and heating, equipment integrated
- 40: cooled/heated with removable equipment, externally fitted
- 41: cooled/heated with removable equipment, internally fitted
- 70: tank for non-hazardous cargo, test pressure 0.44 bar
- 71: tank for non-hazardous cargo, test pressure 1.47 bar
- 72: tank for non-hazardous cargo, test pressure 2.94 bar
- 74; tank for hazardous cargo, test pressure 1.47 bar.

In addition, the letters 1C or IT are sometimes seen on containers. These letters indicate the strength of the container. If containers carry the letters 1C, this means that they may be transported both by ship and by rail and may be stacked up to 6-high. An IT container is much less strong; for example, such containers are only allowed to be stacked up to 3-high. In brief, these IT containers are destined for a totally different type of transport and are therefore not covered by the ISO standards.

CARGO HANDLING AND STORAGE IN REEFER CONTAINERS

In the previous chapter we saw that, thanks to changes in the container's construction and improvements in the insulating material, not only a bigger payload volume was obtained but also savings in energy consumption,

The technical improvements which have been incorporated in container construction since 1980 mainly relate to:

- temperature control;
- air circulation;
- energy consumption;
- remote monitoring;
- CA storage.

Modern marine containers not only emit less noise than their predecessors, but the equipment has also been made more easily accessible, thus facilitating inspection and repair work. The most important improvements, however, are to be found in the area of temperature control, partly as a result of the many regulations issued in this area.

The modern integral container can be used to transport products at any desired temperature between -20°C and +25°C. In the case of temperatures higher than -4°C the temperature can be regulated accurately to within 0.2°C.

Let us make one'point perfectly clear straight away: a modern container is not designed to handle the rapid cooling-down of products. Its cooling capacity is inadequate for that. If fruits with a high respiration rate, such as mangos and avocados, are loaded in a warm condition, the container's cooling unit does not even have the capacity to extract sufficient heat, which means that warming up cannot be prevented.

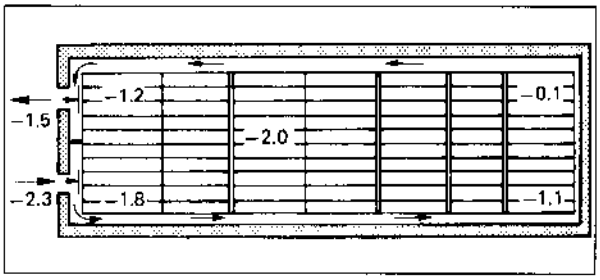
[1]) United States Department of Agriculture

[2]) Shipowners Refrigerated Cargo Research Association, Cambridge, U.K.

Temperature gradient inside the container

In view of the strict temperature requirements which may be set, especially by the USDA[1]), the temperature at every point inside the container must deviate as little as possible from the prescribed transport temperature.
However, even inside a container with properly pre-cooled and well-stowed cargo, allowance still has to be made for a temperature gradient. The size of the temperature gradient is governed by various factors, but chiefly by the age and condition of the container and, more specifically, by the number of air changes per hour (a.c.h.).
The temperature gradient inside the container can be reduced by increasing the number of air changes.
The SRCRA[2]) has conducted a lengthy and extensive investigation into this. We will not discuss this in more detail but simply give one practical example.

In a reasonably well maintained container, properly loaded with pre-cooled meat, the air delivery temperature amounted to -2°C and the outside air temperature was +18°C.
After the cargo had reached a constant temperature, measurements showed that the difference between the incoming and outgoing



Temperature (°Q in a simulated lamb cargo in an ambient temperature of 75 °C.

air still amounted to 0.6°C and the temperature difference between left and right in the back of the container amounted to 1 °C.
Inside the container the average temperature gradient between the front and the back amounted to approx. 0.8°C.
Apart from the container's age, another major cause of heat leakage is, of course, the temperature difference between the cargo and the outside (ambient! air. The type of packaging also plays a role.

International regulations

In a previous chapter we have already referred to the special quarantine requirements which some countries, such as Japan, New Zealand, Australia and the USA, set in respect of imports of certain products.

United States

Well-known examples are the USDA regulations which lay down rules for the number of days during which fruit has to be pre-cooled at a prescribed temperature before it is allowed to be unloaded in the U.S.A.
The U.S. regulations on the handling and transport temperature of perishable goods are set out in a manual issued by the USDA's Animal and Plant Health Inspection Service, under instruction 319.56 2d, and also in the "Plant Protection and Quarantine Treatment Manual", section VI, T 107-T 109).

This second USDA document, the "Plant Protection and Quarantine Treatment Manual" (PPQ), is essential reading for reefer container operators. It lists requirements relating to the type of container which may be used to ship fruit to the U.S.A. and gives instructions on pre-cooling and on the positioning of the temperature recorders.Only the most important of these regulations are summarised below.

- Type and series must be approved by the USDA.
  (The requirements can be found in PPQ Treatment Manual, M 390,614).
- Before loading is started, the container must be pre-cooled down to the "treatment temperature" or lower.
- The fruit must be pre-cooled down to the "treatment temperature" or to a uniform temperature which is no higher than 4.5°C.
- The fruit must be loaded into the container directly from the room in which it has been pre-cooled, so that the temperature of the fruit cannot increase further during loading or during transport of the container to the ship.
- Only one type of fruit is allowed to be carried in each container.
  The fruit must be packed in boxes of the same type.
- The temperature sensors and recorders that are used must be of a USDA-approved type.
  The temperature recorders must be calibrated and must be inserted between the fruit during loading.
- The temperature must be recorded in at least three different places:
  (al One sensor must be placed in the return air duct at the front of the cargo.
  (b) In a 40-ft container 2 pulp sensors must be placed at a distance of about 5 ft from the back of the cargo.
  The sensors must be inserted into the cargo at half its height, with one sensor in the middle of the row and the other sensor in a box on the wall side of the container.
- It must be possible for the recorder to be read from the outside of the container.
- The temperatures must be recorded every hour and, before the fruit is cleared through customs, the printout of the temperature records must be handed over to the PPQ officer.
- Apart from the recorder sensors referred to above, the container must also be equipped with a type T thermocouple wire sensor. This sensor is inserted in the fruit in the direct vicinity of one of the recorder sensors.
  The ends of the sensor wire are located outside the container so that a mobile temperature recorder can be attached to them.
  When loading starts, the temperature shown on the recorder sensors is compared with the temperatures registered on the external temperature recorder.

Europe

The EU (European Union, formerly the European Economic Community (EEC)) has issued several

directives in its attempts to achieve standardised regulations for the production, trade and transport of foodstuffs.
The most important regulations for our purposes can be found in the Quick Frozen Food Directive (89/108 EEC). This directive defines quick frozen foodstuffs as: foods which have undergone a freezing process in which the crystallisation range was passed through as quickly as possible.
The temperature of quick frozen foodstuffs must amount to minus 18°C or lower at all times and at all points inside the product.

The directive also gives detailed instructions on how to take a sample for temperature control:

(a) Within a space of 3 minutes and with an accuracy of +/-Q.5°C, the temperature recorder must have reached 90% of the temperature difference between commencement of measuring and the final readout.
(b) If measuring takes place in an ambient temperature in the range between -25°C and +40°C, the deviation in measuring accuracy must not exceed 0.3°C.
The temperature recorder must give a readout that is accurate to the nearest 0.1°C.
fc) If the probe (measuring pin) cannot be inserted in the frozen product, a tight-fitting hole must first be drilled in the product.
Before measuring starts, both the drill and the probe must be pre-cooled.
(d) The probe must be inserted to a depth of 2.5 cm. If this is not possible, then to a depth which is equal to at least 3-4 times the diameter of the probe.

The EU has also issued directives on the use of temperature recorders during both storage and transport of quick frozen products,

Some of these regulations are as follows:
1. In the storage spaces and also in the means of transport, approved temperature recorders must be fitted to check the internal air temperatures at frequent and regular intervals.
2. The temperature records thus obtained must be dated and kept for one year.

Other important EU directives include:

(a)Fresh Meat Directive (64/433 EEC)
This states that, after slaughter, the carcas must be cooled as quickly as possible to a core temperature of 7°C or lower.
The prescribed temperature for meat offal is 3°C or lower.
The meat must at all times be stored at these temperatures or lower.

(b)Poultry Meat Directive* (77/7 78 *EEC)
This contains regulations on the health of the meat and on the equipment to be used in the slaughterhouse.
One of the rules states that fresh poultry meat has to be cooled down to 4°C as quickly as possible.

(c) Minced Meat Directive (88/657 EEC)
This directive lays down regulations on the processing of meat and the prescribed temperatures during processing.
Cooled processed meat must be stored at 2°C or lower and frozen processed meat must be stored at -18°C or lower[3]).

Other regulatory organisations

In an earlier chapter we mentioned some of the organisations which supervise the construction of containers and/or issue regulations on the transport of frozen and cooled cargoes.
An example of one such organisation is the ISO (International Standards Organisation).

It would be impossible here to discuss in detail the many organisations which have drawn up rules governing the construction of containers or the carriage of goods in containers. But there is one organisation which is just as important as the ISO and which we therefore cannot pass by:

The ATP (Agreement on the International Carriage of Perishable Foodstuffs) has drawn up rules for the international transport by road of certain products which are subject to spoilage. In addition, this useful institution has issued generally accepted standard rules relating to the insulation and cooling equipment used in containers and refrigerated trucks.

[3]) See also Marine Refrigeration Manual, Chapter 18 Mechanical freezing of foodstuffs, and Chapter 19: Carrying conditions for animal products

The countries which are signatories to the ATP agreement are: Austria, Belgium, Bulgaria, the CIS Republics, the Czech Republic, Denmark, Finland, France, Germany, Italy, Luxembourg, Morocco, the Netherlands, Norway, Poland, Slovakia, Spain, the UK and the USA.

Let us make the following points clear about this Agreement:

1. The Agreement is intended in principle for international transport within Europe.
2. An "ATP container" which has to be transported by sea over a distance of more than 150 kilometres to reach its destination is not covered by'the ATP regulations during that voyage.
3. ATP prescribes maximum temperatures for specific cooled and frozen products. Cooled fruit and vegetables are not covered by the ATP regulations.

The maximum transport temperatures prescribed by the ATP for the most common products are:

(a) Quick frozen fish and other quick frozen foodstuffs	-18°C
(b) Frozen butter and edible fats	-14°C
(c) Poultry and rabbits	-12°C
(d) Frozen meat and other frozen foodstuffs	-10°C
(e) Cooled butter and meat products	- 6°C
(f) Cooled dairy products, chickens, rabbits	+ 4°C

Notes:

1. Lower maximum temperatures are applicable for shorter storage durations, e.g. -11°C for butter and -15°C for fish.
2. At the moment the ATP prescribed maximum core temperature for frozen meat is -10°C. This will probably be reduced to -18°C in the near future.
3. The above-mentioned maximum temperatures apply to every point in the cargo and may not be exceeded during loading, unloading or during actual transport.
4. However, during certain technical operations (e.g. defrosting of the evaporator) the temperature in part of the cargo is allowed to increase for a short period to a maximum of 3°C.
5. It should be remembered that the temperatures listed above are maximum temperatures. In practice the transport temperatures will usually be much lower.

Lastly, a few brief words about the Transfrigoroute International (TI|. This group, which represents more than 20 countries, has as its objects the promotion and further development of the transport of perishable products.

For this purpose the TI cooperates closely with the IRU (International Road Transport Union) and, of course, also with the EU and the ATP and other international regulatory organisations in the refrigerated transport sector.

Control of the transport temperature

In the case of frozen cargoes the aim of using low temperatures is to inhibit the growth of micro-organisms. In the case of a "living" cargo like vegetables or fruit the aim of cooling is to slow down the senescence of the product.

When fruit and vegetables have been harvested, their supply of sugar, water and minerals is cut off but the product still continues to breathe, grow and ripen. To obtain the energy required for their metabolic processes, these harvested products must draw on the reserves they have built up during their growth. The speed at which maturation takes place governs the senescence of the product.

The important factor to note, therefore, is that the respiration and other metabolic processes which take place after harvesting are governed not only by the type of product and the time of harvest, but above all by the storage temperature and the storage air.

Accurate maintenance of the desired temperature for "living" products during storage or transport is extremely important if we wish to achieve optimum shelf life. The temperature must be kept as constant as possible, since temperature fluctuations cause stress which in turn leads to moisture loss and faster senescence of such products. As can be seen

from the foregoing, accurate temperature control is essential in the case of cooled cargoes.
The storage temperatures can be accurately maintained by reducing the cooling capacity to such an extent that an exact balance is created between the heat load and the required storage temperature. As will be known, the compressor is driven by an electro-motor, which means that the compressor runs at a constant speed. Reducing the cooling capacity whilst allowing the compressor to continue running at the same speed can be achieved in the following two ways:

1. By allowing some of the compressed hot gas (discharge gas) to flow back via a bypass to the evaporator.
2. By keeping the suction valves of one or more compressor cylinders in the open position so that these cylinders will still suck in the gas but will also pump it back again.

There are also other, less frequently used methods, e.g. changing the rate of revolutions of the electro-motor or temporarily stopping the compressor (on/off control).

Air circulation systems

Two methods can be used to circulate the cooled air through the cargo space of a container:

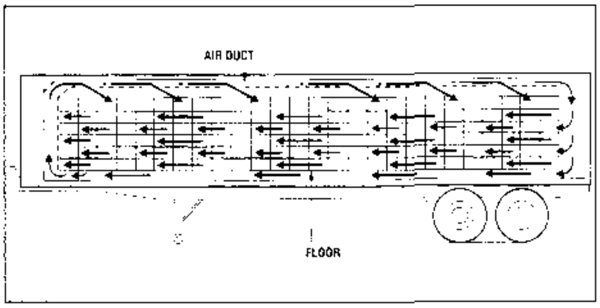
1. *Bottom air delivery.*
2. *Top air delivery.*

In *integral marine containers* the *bottom air delivery method* is generally applied. This is not only the most commonly used but also the most effective method.

The *top air delivery method* is much less commonly used. This method is sometimes applied in refrigerated trailers, especially for pallet transport, and in some reefer containers (Sea-Land),

If frozen cargoes are stowed, the method used is of minor importance, as the frozen cargo is loaded and transported in the form of "block stows".

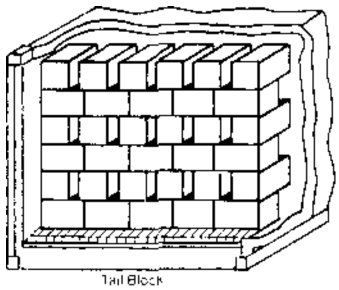
The situation is different for "living" cargo. Since these products breathe and give off heat, the type of air circulation method in fact plays a crucial role. Later on we will be discussing in greater detail the stowage of the cargo in a marine container. At this point let us briefly look at how the products have to be loaded in a reefer container if the *"top air"* method is used.



Top air delivery reefer

As we can see from the illustration above, *"top air delivery"* means that the air is drawn in along the floor under the pallets and fed through the evaporator. The evaporator is located at the front end of the container or trailer. A plastic (vinyl) or canvas air duct - also referred to as a "gooseneck tunnel" - runs from the evaporator underneath the ceiling to about two metres short of the loading doors. The air cooled in the evaporator is blown via this air duct across the top of the cargo to the back of the reefer container. A powerful fan ensures that the cooled air flows through the cargo at a sufficient speed.

As we all know, hot air rises. In this method, therefore, cooled air is blown through the cargo in counterflow to the warm rising air. The important point to note is that this system requires a different method of stowage. In this case the cooled cargo has to be stowed in such a way that horizontal ducts are created between the rows of boxes so that the return air can flow back through the cargo to the evaporator. One stowage pattern



Tail Block

that is frequently used for this purpose is the "Tail Block" stow which is pictured here.

As can be seen from the figure, the first layer is placed on the floor with no gaps between the boxes and the next layer is stacked on this in such a way that horizontal channels are left open. Obviously, no boxes must protrude into these channels. If you look through the channel from the back of the container, you should be able to see the front bulkhead.

Naturally, no boxes should protrude at the back either and sufficient clearance must also be left at the back to allow the air to flow back unimpeded to the evaporator.

In some reefer containers which use this air circulation system, a second partition made of wire netting is placed at some distance from the back wall. If such a partition has been fitted, the boxes can be stowed up against it. If no extra partition has been installed, it is also possible to create a "funnel" for the return air by placing several pallets on their sides (vertically) between the back wall and the boxes.

To ensure good air circulation, the boxes must be stowed to leave 25 cm clearance between the top of the cargo and the ceiling of the container. One exception to this is formed by the boxes in the top row which are located immediately against the outside wall of the container on both sides of the air duct. This row may be stacked to a distance of 10 cm below the roof.

As we mentioned earlier, products which do not generate any heat, such as frozen cargoes, are "block stowed". In the case of such cargoes the aim is in fact to leave no gaps at all between the individual boxes and as little space as possible between the cargo and the container wall. When cargoes of this type are being carried, the air must circulate evenly AROUND the cargo so that heat penetrating from outside through the container wall can be extracted as quickly as possible via the evaporator.

However, it is necessary to leave sufficient space between the bottom of the cargo and the container floor. The same applies to the top of the cargo.

Generally speaking, the clearance between the top of the cargo and the roof insulation amounts to approx. 8 cm. If the internal cladding is corrugated, the boxes can be stowed right up against the side walls.

Ventilated containers

Although we are principally discussing cooled and refrigerated cargoes, it is perhaps useful to point out that there are some "living" products which, though they do not require cooling, can only be transported if they are ventilated.

The ventilated containers used to carry these products can be subdivided into two groups, i.e. containers with passive and forced ventilation.

The container with passive ventilation is not insulated and is not fitted with a cooling unit or with mechanically powered fans. To ventilate the inside, the container is fitted with special ventilation openings.
The air circulation is created in a natural way by convection and as a result of the pressure difference between the air inside and outside the container. Consequently, the temperature inside the container changes more or less in line with the temperature of the ambient air. This is what makes this type of container so suitable for the transport of products like coffee and cocoa beans which might otherwise suffer condensation damage because of temperature fluctuations.

Containers with forced ventilation are fitted with one or more mechanically powered extraction fans. In this type of container the number of air changes ranges between 30 and 40 per hour. These containers are well suited for the transport of, say, onions. But melons (honeydew) are also frequently shipped with success as ventilated cargo in containers of this type.

At the end of the previous chapter we discussed the meaning of the final two digits in the four-digit code for ISO containers. In the ventilated container category the final two digits in the code have the following meaning:

10 = Standard ventilated, ventilation opening smaller than 25 square cm per running metre container length.

11 = Standard ventilated, ventilation opening bigger than 25 square cm per running metre container length.
15 = Container fitted with a mechanical ventilation system installed inside the container.
17 = Container fitted with a mechanical ventilation system installed outside the container.

The integral container

We can distinguish between two types of integral container:

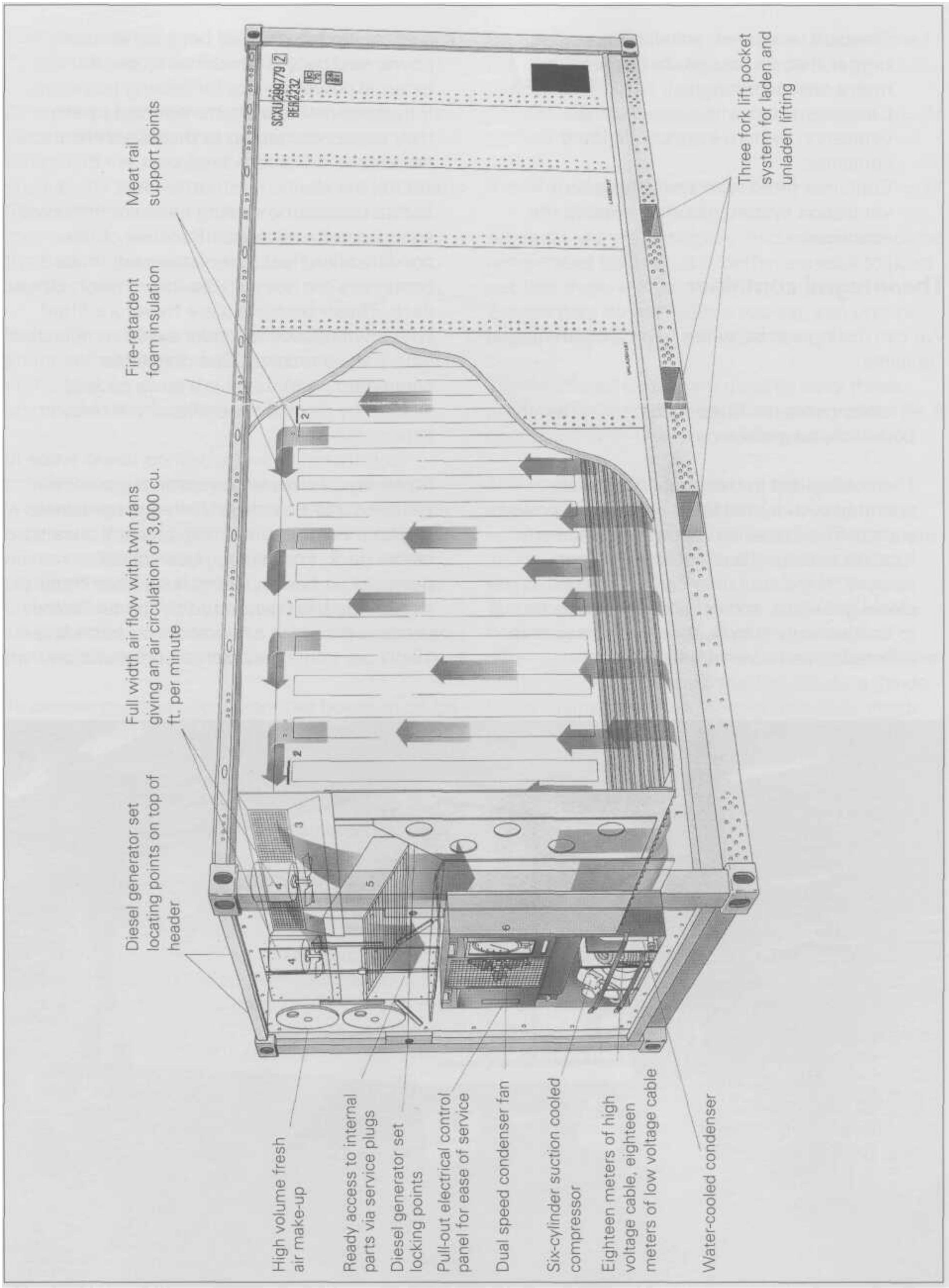
A A reefer container fitted with a permanently built-in diesel generator.

The cooling unit in this container can be operated without requiring an external power source. This container can be cooled at any location without the aid of other power sources. If the container can operate using the diesel generator and can also be connected up to an electricity supply, then the container is referred to as *universally* applicable.

B A container which does not have its own power source and which has to use an externa power source for cooling purposes. If these containers are transported by ship, they are connected up to the ship's electricity network.

In most cases the cooling units are fitted with an air-cooled condenser. Because of the condensation heat that is released, these containers are not suitable for transport below deck. These containers are therefore fitted with a water-cooled condenser in combination with a liquid receiver. The condenser is connected up to the ship's brine cooling system by flexible hoses fitted with fast-action closures.

Nowadays, however, on some big container vessels ("dry box ships") integral containers can be transported not only on deck but also below deck. For this purpose special, powerful air flow systems have been fitted to extract the heat generated by the air-cooled condenser (which can amount to as much as 10kW per container). Some containers are



Air flow across the full width (3,000 cu. ft/minute) fitted with a water-cooled condenser which can also be cooled with seawater.

On a storage site the container can be plugged in to the mains electricity. If there is no electrical power source or if it is not sufficient, the container can also be connected up to a "Power Pack". The "Power Pack" developed by Sea Containers is a transportable electrical generator installed inside a 20-ft ISO container. It has been specifically designed to be placed on board ships which do not have sufficient electrical power or to serve as a power source at depots where there are no link-up facilities to the mains electricity supply.
Two independently powered diesel generators supply electricity (at 230 or 460 V) to the 36 connector points of the "Power Pack".

If the container has been provided with the relevant fittings, it is possible during road or rail transport to attach a removable "Clip-On" diesel generator to the front end of the container to provide power for cooling"). Mowadays the "underslung" diesel generator is also frequently used. This air-cooled generator can be fitted within 20 minutes to the underside of the chassis on which the container is transported.

"Bottom-top" air delivery

On the drawing the arrows indicate the air circulation movement through the cargo and the cooling unit. As in most cases, the container has a T-section floor.

The space between the aluminium T-sections serves as the air delivery ducts (1). The cargo is loaded up to the "leadlines" which are marked at various places on the side walls (2). In the top of the cargo bulkhead there are grills through which the cooled air can pass (31. Powerful fans (4) ensure that the air, which has picked up heat whilst passing through the cargo, is blown via the space above the cargo and passed through the evaporator (5).

In the evaporator the air is cooled down to the transport temperature and fed through the air delivery space to the air ducts formed by the T-sections underneath the cargo. Also visible in the drawing is the temperature recorder (6|. In a modern container a data logger will also be fitted at this point to measure and record the temperature of the circulating air.
For measuring the temperature the container is fitted with two thermostats. One thermostat is located upstream of the evaporator in the return air and the other is placed at the point where the cooled delivery air flows into the container's cargo space.

The coolant circuit

The cooling of the cargo is achieved by allowing the liquid refrigerant to evaporate in the evaporator.

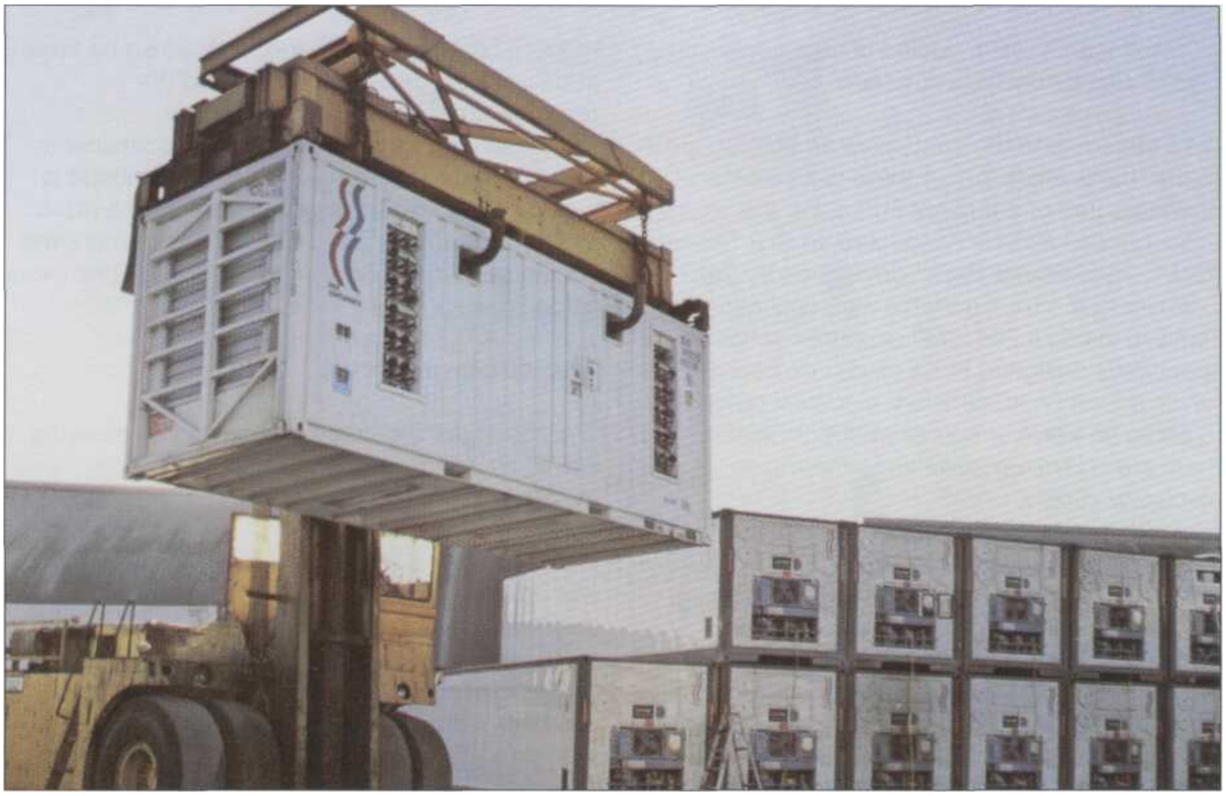
Via a regulator valve a liquid cooling medium is admitted into the evaporator. This regulator valve, also known as an expansion valve, is controlled by an adjustable thermostat. After the circulating air has absorbed heat from the cargo, it transmits this heat in the evaporator to the liquid cooling medium, which causes the liquid to evaporate. The compressor quickly extracts the gas formed in the evaporator and this creates low pressure in the evaporator. In the compressor the coolant gas is condensed until it reaches condenser pressure. At this higher pressure and temperature, the gas flows into the condenser tubes. If an air-cooled condenser has been used, the gas transmits its heat to the ambient air which is blown through the condenser by a powerful fan.

This causes the gas to liquefy again. Some containers are fitted with both an air-cooled and a water-cooled condenser. In such cases the water-cooled condenser can often also operate using both salt water and sweet water.
Obviously, in the case of a water-cooled condenser the heat is transmitted to the water. The figure shows the individual components of the cooling unit which we have just described.

Thermostatic expansion valve

As described earlier, the liquid cooling medium is admitted into the evaporator via a thermostatic expansion valve. The purpose of the expansion valve is to admit just the right quantity of liquid

"} See *also: Marine Refrigeration Manual, Chapter T3: Comatnerisation in reefer shipping*



Fitting a "Power Pack" to containers which have just been hoisted off the ship

A "high cube" reefer container with clip-on diesel generator for use during road transport which is needed to utilise the entire evaporator capacity. Upstream of the valve the liquid has a high temperature and pressure and downstream of the valve, on the evaporator side, a low pressure prevails. Because of this pressure difference the liquid changes into gas with a low temperature and pressure when it is admitted into the evaporator.

The air extracted from the cargo space and blown through the evaporator can then release its heat by transmitting it to the cold gas in the evaporator tubes. If the temperature in the cargo space increases, the liquid admitted into the evaporator will evaporate sooner.

If we want to utilise the entire evaporator, the regulator valve must admit more liquid. Naturally, the reverse also applies: if the temperature in the cargo space decreases, the liquid in the evaporator will take longer to evaporate and the regulator valve will have to admit less liquid. The thermostatic expansion valve is operated by the difference between the pressure in the evaporator and the temperature-induced pressure in the sensor. The sensor, which is basically a small reservoir, is located outside the evaporator on the return air line. This reservoir is (usually) filled with the same coolant as is used in the cooling unit.

The expansion valve is divided into two parts by a membrane. A capillary tube links the sensor to the upper part of the valve. The vapour pressure of the liquid in the sensor, i.e. also above the membrane, is governed by the return air temperature. This temperature practically corresponds to the temperature of the gas at the outlet of the evaporator. The space underneath the membrane is connected to the evaporator. In this space the prevailing pressure is the evaporator pressure which corresponds to the evaporator inlet temperature of the cooling medium.

Nowadays electronic expansion valves are also used. The operation of such a valve is likewise based on the temperature difference between evaporation intake temperature and return air temperature.

Air circulation

When we speak of 90 air changes per minute, this means that - where the cargo space is empty the air is circulated at such a speed through the space that the air inside the cargo space will be completely replaced 90 times every hour. If the cargo space is loaded, the number of air changes will of course have to be higher. A higher number of air changes not only makes it possible to adjust the temperature accurately but also provides a guarantee that "dead pockets" have been sufficiently ventilated.

In principle, however, air circulation is a necessary evil. This is especially true in cases where there is a needlessly high number of air changes, since this will simply lead to even greater dehydration of the product.

When the cargo is being cooled, roughly 700 cubic metres of air will have to be circulated for each kW of cooling effect. If the temperature difference between the incoming and outgoing air amounts to only 1°C, the number of air changes may be reduced.

Switching to a lower rate of revolutions not only brings an economic benefit but the fans will also produce much less heat. As an illustration: if we reduce the fan speed to 75% of normal, the heat generated will be 42% of that produced at top speed, whilst a switch-down to 50% of the speed will mean that the heat produced amounts to a mere 13% of that released during full-speed operation.

Undermount generator set from Carrier Transicold

It will be clear that the heat which is released by the fans must ultimately be extracted by the cooling installation, which requires additional energy. This is why constant efforts are being made to find a speed control enabling better regulation of the evaporator fans and also to find more efficient fan motors,

Airventilation

When "living" cargo is being cooled, we need not only air circulation but also air ventilation. As will be known, the respiration of "living" cargo creates various combustion products, including $C0_2$ (carbon dioxide). The shipper may require that the $C0_2$ content in the cargo space should remain below 0.5% or even lower. It is still simpler to measure the CO_2 content than the ethylene content (C_2H_4). The underlying principle, therefore, is that if the $C0_2$ content is kept at a low level, the ethylene content will remain low as well. To prevent an excessive concentration of $C0_2$, ventilation is required.

Fresh air can be admitted automatically via an opening, or via pipework of suitable width, which is open to the outside (ambient! air and is connected to a point where the lowest pressure prevails on the return air side of the fan. The air which is polluted with an excess $C0_2$ content can flow out through an open pipe fitted on the delivery side of the fan.

Clearly, the quantity of fresh air which has to be admitted depends entirely on the product and specifically on the amount of $C0_2$ it produces. That is why there is no easy answer to the question "How much fresh air should be admitted?". For example, in the case of living plants, apples, bananas, kiwifruit and lettuce a lot of fresh air must be admitted, whilst pineapples, aubergines, berries, grapes, etc. can make do with little fresh air,

Another important question here is whether or not the cargo has been pre-cooled. As a general rule for container cargo 1-2 cubic metres of fresh air per t/h must be admitted, which is equivalent to 1-2 times the empty container volume per hour.
In both cases this converts to roughly 20 to 50 cubic metres of air per hour for a 20-ft container. For most types of fruit this is more than sufficient, though flower bulbs, for instance, require as much as 80 cubic metres of fresh air per hour.

The total cold load

As explained above, the heat that has been absorbed from the cargo by the circulating air (field heat) is transmitted to the cooling medium in the evaporator. As we have meanwhile seen, the circulating air will also have absorbed some heat from various other sources.

The required cooling capacity is therefore determined by the following factors;

1. ***Field heat:***
   the heat which is released when the product and its packaging are cooled down from loading-in temperature to transport temperature.

2. ***Radiant heat:***
   heat which penetrates the cooled cargo space via conduction and radiation.

3. ***Fan heat:***
   the heat generated by fans. The electrical energy used to power the fans is converted into heat. This heat is transmitted to the circulatingair.

4. ***Respiration heat:***
   the heat produced by a "living" product as a result of its breathing process.

5. ***Fresh air ventilation:***
   the fresh air which has to be admitted to remove gases such as $C0_2$ has to be cooled down to the temperature of the cargo space.

6. ***Defrosting of evaporators:***
   in cases where low evaporation temperatures are used, the evaporator will have to be defrosted severa times a day.

The condenser extracts the heat which the evaporator has absorbed from the cooled cargo space. The electrical energy required for this is converted into heat which in turn must be extracted by the condenser.

To summarise this briefly:
Condenser capacity =
evaporator capacity (cooling capacity) + energy supplied to the compressor.

Remote monitoring

Despite the advances achieved in refrigeration machinery and in the related electronic equipment, it is still a labour-intensive and sometimes even an impossible task to make a visual check of the proper operation of a large number of reefer containers which may be stacked up to 3-high. Certainly in view of today's reduced crewing levels and also the reduction in employee numbers at storage sites, there is a need for the temperature control of the reefer containers to be regulated from a centrally installed monitor.
To make remote control possible, the reefer control technology sector has gradually changed over to electronic control units for regulating compressor capacity and evaporator injection. Nowadays, sophisticated electronic temperature control systems have been developed by various firms. These new systems also record the temperature (data logging).

The fast-moving progress in micro-electronics has resulted in a new generation of digitalised controllers (PLC controllers! which can be operated and regulated by means of a computer program. The set temperature and the incoming and outgoing air temperature are digitally displayed on a modern data logger.

In some cases other relevant data can also be retrieved, such as the number of hours during which the compressor has been operational, or the number of air changes, or the maintenance data for the container or its component units, etc,

Countless possibilities exist for obtaining relevant data about the temperatures and the air composition, but they all depend on the type of data capture system which the container is equipped with and on the possibility of transmitting these data to the central monitoring unit(CMU).

Despite all these possibilities for capturing and storing data via the data logger, today's reefer containers are still fitted with a modern version of the chart recorder. The information provided by the data logger represents the situation at one given moment in time, whilst the chart gives a picture at one glance of the entire refrigeration process during the voyage.
Microprocessor-based temperature control may have made it possible for the temperature in an entire group of containers to be regulated from one central point, but its actual application may still encounter a number of practical problems.

Though it is impossible to stop the onward march of technological progress, the implementation of remote monitoring is being slowed down not only by its high costs but also because of its incompatibility with existing systems. The problem is that no agreement has been reached on which frequency can best be used to transmit the data to the monitor. The battle is between single-frequency transmission at approx. 55 kHz or broad band transmission in the range between 50 kHz and 450 kHz.

In the USA people would prefer the general application of the single-frequency system. The reason is that the "narrow" band is highly selective and the broad band is more susceptible to interference and false signals.

In Europe the advocates of the broad band system claim that the narrow band system is outdated. According to them, the broad band system is not only cheaper but also offers more possibilities. In addition, the signal emitted need not be so very accurate, since the tolerance is much higher because of the wider frequency.

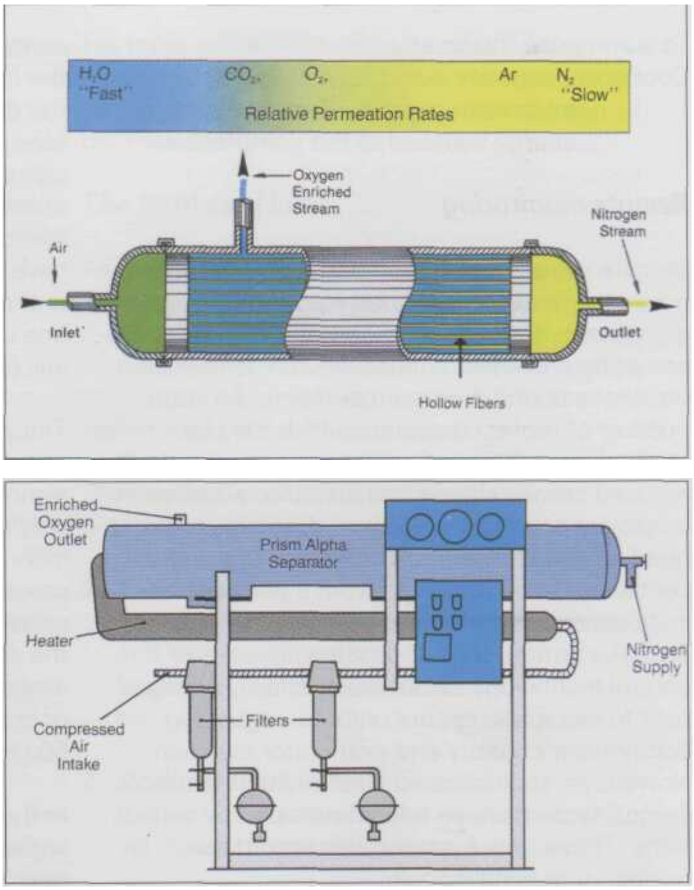
For the time being both systems will probably continue to be used alongside each other. It will be clear, however, that this will cause some slowdown in the further development of remote monitoring, which may have an adverse impact on the number of containers which can be carried on a ship or stored at the terminal.

Composition of the storage air

The maturation process of "living" products is very much dependent on the storage temperature and the composition of the air in the place of storage.

Roughly speaking, atmospheric air consists of 21 % oxygen (O_2), 0.03% carbon dioxide (CO_2), with the remainder consisting chiefly of nitrogen (N_2).
By altering the composition of the air, attempts are made to slow down the product's respiration rate and thus delay its senescence. For this purpose the CO_2 content is increased and the O_2 content is decreased. Obviously, this can only be done within limits.

Too low an oxygen content of the air will cause the product to suffocate. Similarly, an excessive CO_2 content will also cause suffocation of the "living" product, since it will be impeded in its release of the CO_2 it breathes out.
Generally speaking, respiration will be endangered during storage if there is a risk that the oxygen content may move to below
1 % and/or the CO_2 content may exceed 6%.
Most perishable products not only require an optimal storage temperature but also an optimal composition of the storage air. If the products are stored in a space in which not only the temperature but also the composition of the air can be regulated, then this is referred to as CA (Controlled Atmosphere) storage.



PRISM Alpha Membrane Separator

Various possibilities have been devised for achieving a rapid reduction in the oxygen content in the air. The simplest method is to inject pure nitrogen, in a liquid or gaseous state, into the storage space. This forces the air out of the storage space and creates an air mixture with a lower oxygen percentage. Though this is a simple method, it is too expensive to be economically applied on a wide scale. If this method is used in container transport, there are also other drawbacks, such as the weight of the liquid nitrogen, the space occupied by the liquid gas cylinders and the need for supplies of nitrogen to be available in the ports of call.

CA containers

In a separate chapter we shall be returning in more detail to CA storage, its purpose and effectiveness. Here we shall merely discuss the application of CA storage in container transport.

Cooling with the aid of cryogenic refrigerants, such as nitrogen, is widely used in the United States in particular, since the price of nitrogen is relatively low in that country.

In the case of CA storage in containers we need to make a clear distinction between containers in which the cargo is cooled by liquid nitrogen, and containers which, though equipped with a cooling unit, are also cooled by nitrogen injected into the cargo space by the "PRISM Alpha" system which will be discussed later on.

An example of a system which is based solely on the use of liquid nitrogen is the "Polarstream" system (British Oxygen Co.). In this system an insulated cylinder with liquid nitrogen at a slight excess pressure is installed inside the container. The liquid nitrogen is fed through a line to the spray system, which is fitted underneath and along the entire length of the container roof, and is then sprayed into the container via nozzles. After the cargo has been loaded, the required transport temperature is set with the aid of a thermostat.

A solenoid valve, which is placed in the line and is controlled by the thermostat, regulates the quantity of nitrogen to be admitted. The moment the liquid nitrogen enters the container, the nitrogen droplets evaporate and expand 700 times in volume. The heat required for this is extracted from the heat of the cargo. It takes about 30 minutes for the cargo to be cooled down from the loading-in (ambient) temperature to 0°C.

Properties of nitrogen

1. Gaseous nitrogen is colourless, odourless and tasteless and slightly lighter than air at the same temperature.

2. Liquid nitrogen is odourless and colourless and has a boiling point of -196°C. One litre of liquid nitrogen yields about 700 litres of gas (at room temperature).

3. Nitrogen is non-flammable, but cylinders of compressed nitrogen may explode violently if overheated, e.g. as a result of fire.

4. Nitrogen is chemically inert (i.e. no reaction is possible with other compounds except at high temperatures and high pressure).

5. Liquid and cold gaseous nitrogen can cause serious burns ("freeze-burns") if they come into contact with the skin or the respiratory organs.

6. Nitrogen will not sustain life and has a suffocating effect because of the reduction in the oxygen content.

7. Nitrogen in itself is not toxic!

In the case of frozen cargoes the temperature of the refrigerant sprayed from the nozzles may be lower than -20°C. Contact with this spray brings a risk of burns (caused by freezing). The loading door of a CA container is therefore fitted with a safety cutout which switches off the spray system when the loading door is opened. Obviously, you should only enter a CA container or a CA storage area after it has been sufficiently ventilated.

MA container

In addition to the CA containers described above, there are also MA (Modified Atmosphere) containers. Such a container is closed immediately after it has been loaded and is then hermetically sealed and injected with a nitrogen-rich gas mixture.

One of the companies which applies this system is "TransFresh", of Salinas, California (U.S.A.). This firm has 5 service stations along the American coast. The containers in which this system is applied are constructed in such a way that they are virtually airtight and can be resealed in a virtually airtight condition after being loaded. Before they are loaded, their airtightness is checked again at the loading station. After loading, the required gas mixture is injected through specially designed openings. The entire operation lasts 40 minutes, after which the container is ready to be transported by ship.

This system yields good results, especially for the transport of tomatoes and strawberries. But the storage time is very limited when this method is used: 12 days at most. However, this type of container can also be fitted with remote control for automatic regulation of the required oxygen and CO_2 content inside the container.

20' x 8' x 8' 6" Reefer container with CA

Where such equipment has been installed, this container will obviously be classed in the CA container category.

Apart from the containers described above, various container manufacturers also have other types on the market. In principle, however, all of them are based on the same system and they will therefore not be discussed further here.

The nitrogen separator

The development of product transport in a CA container only got properly under way after a nitrogen separator became commercially available at reduced prices (in 1988-1989). Such a nitrogen separator not only eliminated the need to take along a supply of liquid nitrogen, but also made it possible for CA storage to be applied in seagoing transport on a wider scale and on an economical basis.

The separator allows each container to have a fresh stream of nitrogen throughout the journey whenever the O_2 and CO_2 sensors activate the nitrogen generator in each container.
In 1986 Permea, Inc., then a subsidiary of the Monsanto Group but now a wholly owned subsidiary of Air Products & Chemicals Inc., developed the "PRISM Alpha" membrane separator which is pictured on page 114.

Method of operation

The PRISM Alpha separator is theoretically a very simple instrument which operates on the principle of the different permeability of materials for specific gases. Inside the separator jacket there are thousands of very thin, permeable hollow-fibre membranes. A compressor takes the ambient air, compresses it and forces the compressed air through the hollow-fibre membranes in a 100-150 psi range.

The separation of gases takes place within each hollow-fibre membrane. The speed at which a gas permeates the porous walls of the solid structure is not the same for every gas. That is why a distinction is made between "fast" gases, such as water vapour, carbon dioxide and oxygen, and "slow" gases like nitrogen.

As the compressed air is forced into the hollow membranes, the "fast" gases will permeate through the walls and leave the separator in the form of an oxygen-rich gas at a lower, almost atmospheric pressure, The "slow" gas (nitrogen) leaves the separator at a reduced pressure compared to when it flowed into the separator. It is estimated that the pressure drop between the inlet and the outlet is about 5%.

The circuit

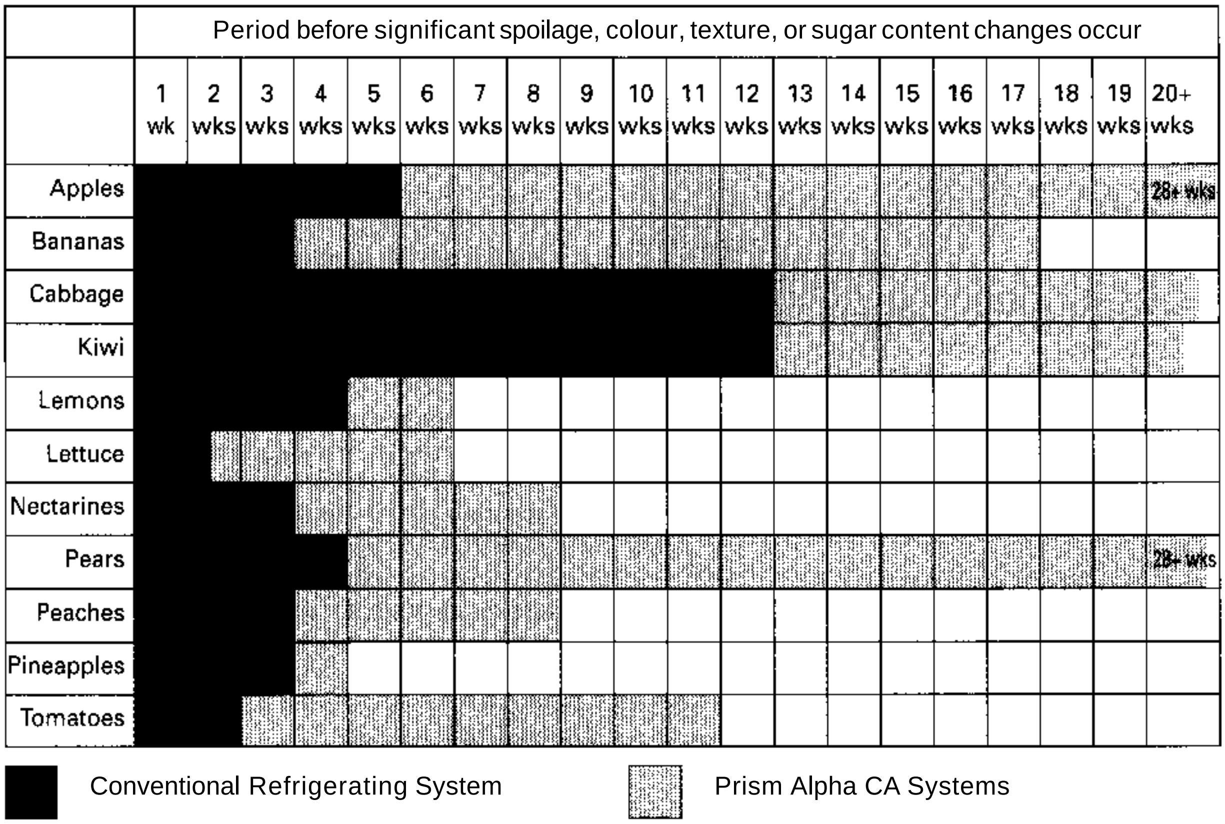
The ambient air is first compressed to approx. 7 bar, The compressed air is then passed through a number of filters to remove dust and oil particles. Then the compressed air is fed through a heater, after which the air is forced into the separator at a constant temperature. In the membranes the oxygen is separated from the nitrogen and the oxygen-enriched gas is vented off to the outside air. The virtually pure nitrogen (98-99%) is injected into the container, so that the oxygen percentage in the storage air is reduced by displacement.

The PRISM Alpha system is also used in other sectors of industry which require a supply of pure nitrogen. When this system is used in a container, the compressor pressure amounts to about 7 bar and the composition of the air consists roughly of 98% nitrogen and 2% oxygen.
In 1987 the first integral container fitted with a PRISM Alpha membrane separator was put into service for trials.

The first trial cargo consisted of a batch of Granny Smith apples which were transported on a 6-week voyage from New Zealand to the U.K. and were unloaded there in good condition.
The second trial involved a mixed cargo of nectarines and blueberries shipped from New Zealand to California. Because of engine damage the ship only arrived in California after 28 days. Prior to that time blueberries had never been transported by ship over such a long distance. Despite the delay, this highly perishable cargo was unloaded in excellent condition.

The early trials during 1987-1988 indicated that economical shipments of highly perishable

Typical extended storage life with Prism Alpha System



cargoes can be achieved in reefers equipped with "nitrogen flushing" systems.
In 1989 Prolong Systems, Inc. (USA) began retrofitting standard 20-ft and 40-ft reefers with CA systems. Prolong chose Carrier's NT model as its standard and created the first economical CA system for reefers where no cubage was lost, nothing protruded from the nose of the reefer and all components were fitted into the "picture frame". The mixture of 0_2 and $C0_2$ was monitored, adjusted and recorded by a microprocessor-controlled system.

Nowadays several container leasing companies can offer both 40-ft and 20-ft containers equipped with the PRISM Alpha system or the Medal separator (DuPont/Air Liquide) system. The advantage of the PRISM Alpha system is that it has no moving parts outside of the air compressor, which means that it requires little maintenance. In addition, its weight is relatively low and its dimensions are limited so that it can be integrated in the cooling unit section of an integral container without occupying extra cargo space.

The advantages of CA storage are that it slows down both maturation and senescence of the products while also retarding the growth of moulds and certain bacteria. Another important benefit is that CA storage reduces the ethylene production and/or the sensitivity to ethylene gas. CA storage is therefore an especially effective method for apples, pears, bananas, mangos, papayas, strawberries, peaches, nectarines, plums, tomatoes and cut flowers.

The storage life of the products listed opposite is more than doubled by CA storage. However, we must remember that the storage times listed in tables can only provide an indication, since the storage life is primarily dependent on the ripeness and health at the moment of harvesting. If poor quality products are placed in CA storage, the outcome ("outturn") will be a disaster - along the lines of the computer user's maxim GIGO: "garbage-in, garbage-out".

The table below shows the CO_2 and 0_2 contents for several products and the recommended temperature of the storage air.

Recommended controlled atmosphere conditions

Commodity	Temp. (°F)	O_2	CO_2
Apples	31-38	1.5-3.0	1.0-5.0
Bananas	55-57	2.0-5.0	2.0-5.0
Cabbage	32-40	2.5-5.0	2.5-5.0
Kiwi	31-32	1.0-2.0	3.0-5.0
Lemons	55-59	5.0-8.0	<10.0
Lettuce	32-40	1.0-3.0	0-2.0
Nectarines	32-40	1.0-2.5	3.0-5.0
Pears	29-31	2.0-2.5	0.8-1.0
Peaches	32-40	1.0-2.5	3.0-5.0
Pineapples	46-55	2.0-5.0	5.0-10.0
Tomatoes	53-68	3.0-5.0	2.0-3.0

CA systems for 20-ft and 40-ft refrigerated containers

The "Prolong" system

Prolong Systems, Inc. (Oregon, USA) has integrated a completely self-contained (and patented) CA system into the Carrier 69NT20 and 69NT40 refrigeration models. Requiring no additional box space and weighing only approx. 165 Ibs, this CA system is designed to operate in conjunction with the reefer unit so as to provide precise atmosphere control as well as effective temperature control and humidity maintenance. The CA compressor operates on 380/460V, 3-phase, 50/60 Hz power, while the CA microprocessor controller operates on 190/230V, single-phase 50/60 Hz power provided by a step-down transformer. This CA system requires only 0.8 kW and 1.2 kW of power for a 20-ft and 40-ft CA system respectively.

Prolong's CA systems utilise Permea Prism Alpha separators, manufactured by Permea, Inc. These separators generate nitrogen (N_2) on demand which, when piped into the refrigerated container, dilutes the oxygen level to reach a low set-point. Prolong's CA controller continually monitors the 0_2 and $C0_2$ concentrations and adjusts their levels towards the set-points by varying the volume and purity of the nitrogen introduced into the container.
In the Prolong system the microprocessor continually monitors, controls and records all CA functions throughout the journey. All CA parameters can be set during a pre-trip inspection without extensive training or knowledge of controlled atmosphere systems. The CA controller regulates the CA compressor, air heater, drain solenoids, $C0_2$ solenoid, and bypass solenoid as necessary to maintain the CA set-points within the pre-selected parameters.

The accuracy of the CA controller is ensured by air calibrations which are automatically carried out hourly and a manual gas calibration (performed during pre-trip inspections). The 0_2 and $C0_2$ set-points are easily programmable throughout the 0-20% range.

The "PACAS" system

The container manufacturer Graaff (Elze, Germany) designed the "PACAS" CA container in

Carrier's NT40 Refrigeration Unit, with C/A Designed by Prolong systems, inc.

cooperation with Permea, Inc. (USA). "PACAS" is an acronym for: PRISM Alpha membrane Controlled Atmosphere System.

In addition to the previously described PRISM Alpha nitrogen separator and a microprocessor plus monitor to regulate and control the air in the container, the PACAS system is made up of the following components:

1. an air humidifier with control system for humidifying or drying the atmosphere in the container, plus a 25-litre water tank, pump, and measuring and control equipment.

2. a PC (personal computer) to regulate and control the storage air and collect the relevant data. These data are stored in the computer's RAM. The computer can provide readouts covering a period of up to 50 days. The system is also fitted with sensors to measure the oxygen and $C0_2$ content and the degree of humidity in the container. A computer-controlled valve makes it possible, if required, to use some of the enriched oxygen which is normally vented to the outside air. This valve also ensures that the required nitrogen percentage is maintained.

3. a $C0_2$ storage system. This allows $C0_2$ to be added at between 0 and 15% of the volume. The $C0_2$ is obtained from liquid $C0_2$ cylinders with a total capacity of 30 kg.
   The cylinders form a permanent part of the system. The required $C0_2$ percentage is injected into the container via a solenoid valve. The computer measures and regulates the exact percentage of $C0_2$. For products requiring a higher $C0_2$ percentage, such as fish or meat, extra $C0_2$ cylinders can be taken along. These cylinders are placed in the cargo space against the container bulkhead.

Pressing one of the keys on the PC gives an instant display of the composition of the gas. The $C0_2$ and oxygen contents and the degree of humidity can also be displayed at the press of a key. If a change is required in the composition of the N_2 and CO_2 air mixture, the $C0_2$ control key must be pressed. This displays the $C0_2$ value. The key should then be kept held down until the required composition has been reached. The

computer also shows when it is time for routine maintenance or when component parts need to be replaced.

The CA unit is virtually maintenance-free. However, the sensors and filters do have to be checked every year. The compressor only requires maintenance after 8,000 hours of operation. The approximate weight of the unit is 400 kg and its power consumption is less than 2.5 kW/h. During the first day and a half the unit will be utilised at 100% capacity, after which the required gas ratio will have been attained. Depending on the product being transported, the actual operating time can then be reduced to 30-50%.

The production capacity for N_2 (at 98% purity) amounts to 3.6 m^3/h. The PACAS system can be built into an integral container in the space under the cooling aggregate without any loss of cargo capacity.

At the beginning of 1993 the liner operator Compagnie Generale Maritime (CGM) bought six 20-ft reefer containers fitted with the PACAS system. CGM had been conducting sea trials with other CA systems since 1991. The company opted for the Seacold/Graaff combination on the strength of its high-precision control and the wide spectrum of uses which it had to offer by comparison with other equipment.

Initially, Graaff GmbH and Prolong Systems (USA) retrofitted CA systems into existing containers with refrigeration systems made by other companies. Graaff has sold some systems to carriers such as NedLloyd and CGM, while Prolong sold to companies such as Cool Carriers and CKT (Rotterdam).

It is fair to say that the few nitrogen-flushing CA systems built by Graaff and Prolong have opened the door to a potentially large market for long-distance shipments of perishables in refrigerated containers.

CA containers are, of course, also commercially available.
The CKT-group is a specialist in advanced container technology, particulary used in rail and road transport, shipping, the (petro)chemical industry, and in oil and gas related projects on- and offshore.
Based in Rotterdam, CKT operates throughout the world. The core business of the Group's four divisions are engineering, 1MB, Part supply and container Rental.
CKT rental owns a large fleet of reefer containers and operates in targeted niche markets. There sizable CA activities are based on many years of experience in cooperating with Prolong systems Inc. Its existing CA-fleet features Carrier Transicold machinery.
500 of these CA systems, integrated in the popular NT refrigeration units, are being assembled by Carrier Transicold at its Singapore plant and increased production is being forecasted due to a growing demand.

Regardless of which container manufacturer is involved, the principle of the CA system is the same in all cases. Perhaps the air compressor may be located in a different place (e.g. between the fans in the evaporator section of the cooling unit), or new possibilities may have been found for reducing the weight of the unit even further, which would of course benefit the effective payload. Other major improvements which have already been applied in practice relate to the regulation and control of the humidity and the $C0_2$ content in the cargo space.

The building price of this type of CA container is some $ 6,500- $ 7,000 higher than that of a conventional integral container. This is of course reflected in the leasing prices for the containers. However, this higher price is more than offset by the economic advantage of being able to harvest the product at a later time and still bring it to market in a ripe and fresh condition.
In addition, the extension in storage life plays a major role, especially since it means that products which formerly had to be airfreighted can now also be shipped by sea and arrive at lower landed cost.

Tectrol CA system

The Tectrol CA system is supplied by TransFresh Corporation of California, USA. Tectrol is a trade name registered by TransFresh Corp. for a mixture of N_2 and $C0_2$ which is widely used for MA and CA applications in reefers.

The Tectrol CA module can easily be added to or removed from a standard 40-ft container. In 1994 the Taiwanese shipping line Evergreen decided to install the Tectrol CA system in 500 new 40 ft reefer boxes. Tectrol systems have also been fitted in 300 new reefer boxes for NYK of Japan as well as in 100 reefer boxes for the Japanese shipper Mitsui OSK Lines (MOL).

Besides the orders from Asian carriers, TransFresh received two further major orders in 1994: one was from the US carrier Sea-Land to equip 1,500 reefer containers with the Tectrol system, whilst the second substantial order came from Maersk Line, of Denmark.
At the beginning of 1995 more than 12,000 reefer containers throughout the world were fitted for Tectrol CA operation.

THE DEVELOPMENT OF CONTROLLED ATMOSPHERE STORAGE

Atmospheric air contains roughly 79% nitrogen (N_2), 21 % oxygen (O_2) and 0.03% carbon dioxide (CO_2). As we have seen, the ripening process of fruit during storage can be retarded by modifying the composition of the storage air, i.e. by raising the CO_2 percentage and lowering the O_2 percentage.

During storage the maturation of fruit is dependent on:

1. the temperature of the storage air;
2. the oxygen (O_2) content of the storage air;
3. the carbon dioxide (CO_2) content of the storage air;
4. the product's sensitivity to ethylene (C_2H_4).

Quality loss during storage is influenced by:

1. the dehydration of the product;
2. the development of micro-organisms.
3. the failure to remove respiration gases, e.g. ethylene, acetaldehyde, etc.

In the CA (Controlled Atmosphere) reefer container, the oxygen content is reduced by admitting liquid or gaseous nitrogen into the cargo chamber. Reducing the oxygen content by replacing the oxygen with liquid nitrogen may be a simple method, but is too expensive for large-scale use. That is why big coldstores use a different method to obtain the required air composition for CA storage.
First, they achieve a rapid "pull-down" of O_2 using liquid N_2, then they maintain the desired levels of O_2 and CO_2 by flushing the coldstores with fresh streams of nitrogen obtained from large nitrogen generators.

Normal CA storage

Particularly in the early days the method used for CA storage was what we refer to as "normal" or "ordinary" CA storage. This method takes advantage of the fact that the respiration of fruit converts oxygen into carbon dioxide. Inside gastight cells, the CO_2 content produced by the breathing (respiration) process is allowed to increase. The O_2 content is reduced to an equal extent. An increase of, say, 4% in the CO_2 content will reduce the O_2 content to approximately 17%.
Note that the combined total percentage of carbon dioxide and oxygen always remains at 21 %. The percentage of nitrogen (N_2) remains unchanged and is just the same as in the ambient air: 79%.

The required air condition can be maintained simply by admitting fresh air into the storage space via a special manual feed system.
However, this system is far from ideal: in fact it takes weeks before the desired air composition is obtained. Ultimately, though the CO_2 content will have been increased, the O_2 content will still not have been reduced enough to provide much benefit.

Scrubbed CA storage

In ordinary CA storage the total combined percentage of O_2 and CO_2 always remains at 21 % with a nitrogen content of 79%. A better system is one which enables the O_2 and CO_2 percentages to be controlled independently of each other. This also makes it possible to achieve a higher nitrogen percentage. This system is known as scrubbed CA storage. In this case, too, the product's respiration consumes oxygen and produces CO_2 gas. Suppose that the required air composition is: 4% CO_2, 2% O_2 and 94% N_2. If we wish to maintain this condition, the surplus CO_2 must be extracted as soon as the CO_2 content threatens to move above 2%. This can be done by placing loose lime in the cell or by using a hydrated lime scrubber or an activated carbon (charcoal) scrubber.
Activated carbon absorbs CO_2. Any shortage of

oxygen can be simply remedied by circulating fresh air through the cell.

Gas burner with scrubber

The drawback of the systems described, however, is that reducing the oxygen content takes much too long. Especially in bigger coldstores a system is needed in which the 0_2 and $C0_2$ contents can be regulated independently of each other and in which the required air composition can be achieved in the space of a few days. To lower the respiration rate of the products, the oxygen content is reduced as quickly as possible after the cooling-down period. To reduce the oxygen content, this system uses a gas burner fitted with a scrubber or with ammonia crackers. The gases created by burning propane or natural gas contain a low percentage of 0_2 and a high percentage of CO_2. After combustion, however, the low-oxygen air still contains 12 to 13% CO_2 and is contaminated with various gases from the cell air. That is why the combustion gas has to be passed through a gas scrubber. Before the gas is admitted into the cell, it is first cooled down using water.

To prevent suffocation of the products, the gas burner *(Tectrol burner)* can only be operated once the storage temperature has been achieved. Incidentally, the Tectrol burner also always requires a warm-up time of several hours before the installation can start extracting oxygen from the air. Once the burner is operating, it still takes about 40 hours before a cell with 100 tonnes of products and 21 % oxygen has been reduced to a 5% oxygen content.

CA-container

Usually the content is not reduced to below 5% 0_2. Once that percentage has been reached, the respiration of the products themselves will reduce the oxygen content to the required level.

Ammonia cracker

The oxygen content of the storage air can also be reduced very rapidly by using an ammonia cracker. The disadvantage of an ammonia cracker is that it is a complicated machine which takes up a great deal of space.
The machine operates in two stages. In the first stage ammonia gas at a temperature of 900°C is converted into the elements hydrogen and nitrogen.
In the second stage the hydrogen reacts with oxygen and forms water vapour. The air is sucked in from the storage chamber and the oxygen in that air is used for the combustion process. The gas is enriched with nitrogen and, after being cooled with water, is fed back into the storage chamber.

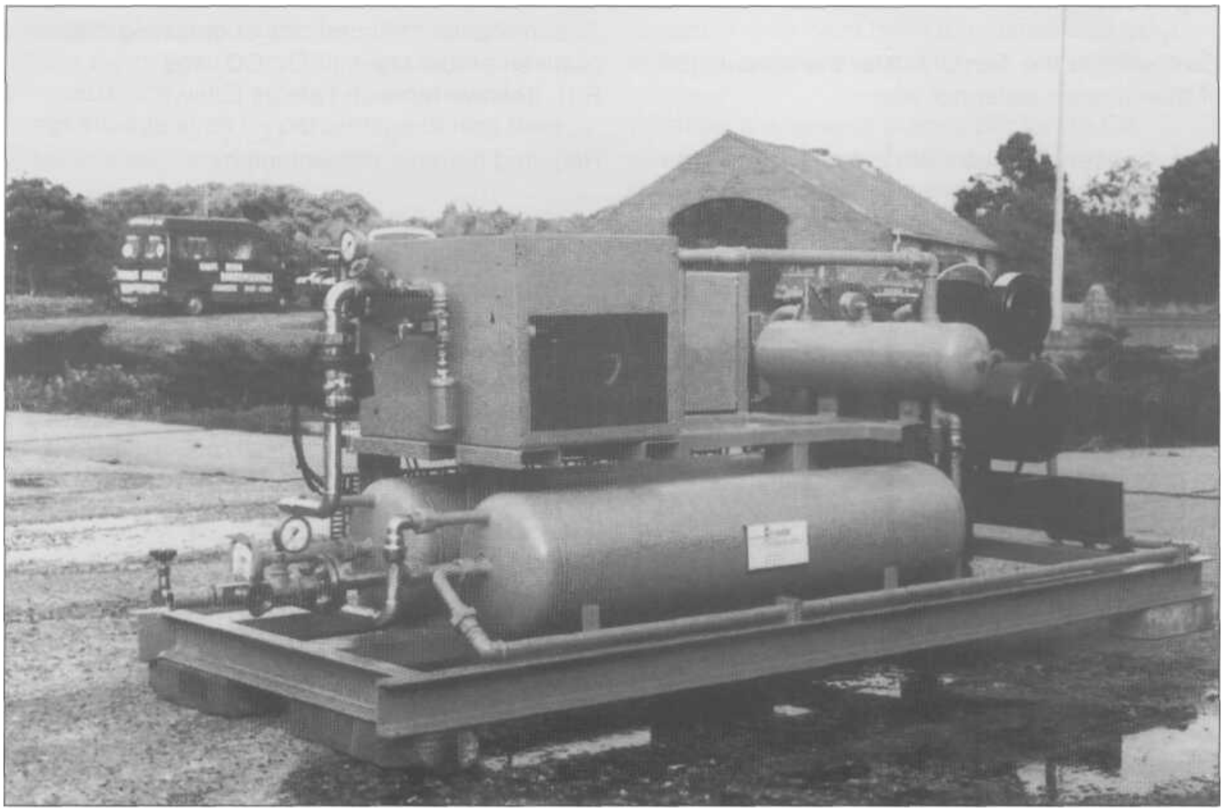
Nitrogen separator

In a previous chapter we discussed the principle of the nitrogen separator in detail. Briefly, it heats up compressed air to 40°C. This air is then forced through membranes. 'Fast' gases such as oxygen, carbon dioxide and water vapour pass through these membranes more quickly than the 'slow' gases like nitrogen. In this way the nitrogen is separated from the oxygen and both gases are then available for use. In our case we are interested in the nitrogen, since CA storage is basically nitrogen storage.

The nitrogen separator is frequently used nowadays in coldstores and wholesale fruit auctions.

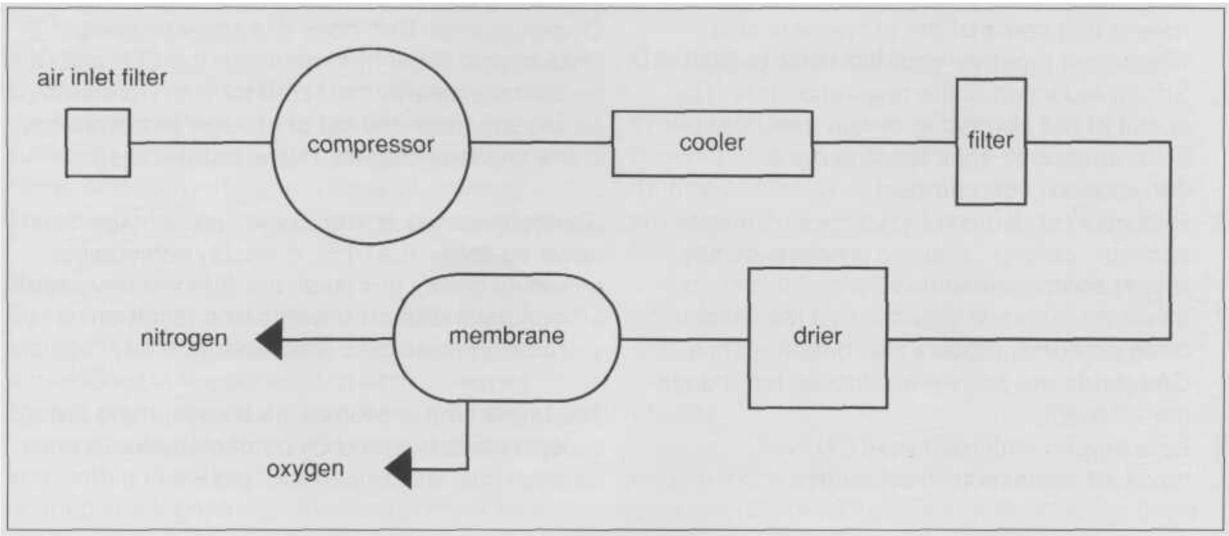
Once the products have been cooled, the nitrogen separator can be used not only to bring the storage air to the required CA conditions but also to maintain those conditions. When used in coldstores, the separator serves solely to create a CA condition. An activated carbon scrubber is then used to maintain the CA condition because it has a much lower energy consumption.

Nitrogen generator



The nitrogen generator consists of a compressor, filters, air drier, separating membranes, electrical control and the necessary instrumentation.
Compressed air is passed through a filter where oil and water droplets and oil vapour are removed.
The air is then dried in the air drier in order to achieve a maximum efficiency of the membranes.
Oxygen and nitrogen are incompletely separated from each other in the membranes.

Diagram showing the operating principle



Advantages of the nitrogen separator

Compared to the *Tectroi* burner the advantages of the nitrogen separator are:

1. A nitrogen separator will create the required composition of the storage air twice as fast as a Tectroi burner (gas burner).
2. Though the Tectroi burner does indeed produce oxygen-poor air, the air.contams 12 to 13% $C0_2$ and other pollutant gases. The nitrogen separator, however, immediately produces pure nitrogen, depending on the setting, e.g. 97% N_2 and 3% 0_2.
3. A nitrogen separator does not use any propane, butane, ammonia or natural gas, which means that the system is 100% environmentally friendly. Further advantages are that the nitrogen separator has no moving parts and is also safer because no fire is involved.

The advantages of CA storage

1. Substantial extension of the storage time for some products, without loss of quality and whilst complying with the international standard penetration norm.
2. Quality improvement of the fruit, especially apples and pears.
3. Maintenance of fruit firmness, especially in kiwis.
4. Inhibition of ethylene production thanks to the low temperature and the low oxygen percentage. (Use of a nitrogen separator means that some of the ethylene is also filtered out together with the other gases).
5. Strong reduction in the respiration rate. The speed of the circulating air can therefore be lowered as well, thus slowing down dehydration of the product.
6. Reduction of certain physiological damage such as *"chilling"* in some products or, say, russet *spotting* on lettuce.
7. Inhibition of mould growth. Just like other living products, moulds also breathe. Thus, CA retards the growth of moulds, but it does not kill them.
8. Low oxygen with moderate $C0_2$ will, however, kill insects in coldstores.

Recapitulation

To summarise, the methods of obtaining the required percentages of O_2, $C0_2$ and R.H. (relative humidity) are as follows:

Required nitrogen percentage by:

(a) injecting pure nitrogen gas or liquid nitrogen from cylinders or storage tanks;
(b) burning propane in an open-flame burner or in a burner with a catalyst;
(cl using a nitrogen separator fitted with fibre membranes.

Increasing the $C0_2$ percentage by:

(a) injecting $C0_2$ gas;
(bl respiration of the fruit itself.

Reducing the 0_2 percentage by:

(a| admitting fresh air or injecting a gas;
(b) using loose lime;
(cl fitting activated carbon or lime scrubbers;
(d) fitting water scrubbers.

Increasing the R.H. by:

(a) injecting mist droplets;
(b) admitting steam;
(c) evaporating water, etc.

The composition of the storage air

The storage duration can be extended by increasing the $C0_2$ percentage and reducing the 0_2 percentage. But: does this apply to every product and is the ratio between the $C0_2$ and 0_2 percentage always the same for every product? As we saw from the list of storage temperatures in the previous chapter, this is not the case.

Generally speaking, the oxygen percentage must never be lower than 1 %. If the 0_2 percentage moves to below this level, the fruit will develop off-odours and/or off-flavours as a result of suffocation (anaerobic respiration).

The upper limit is 5% but, as always, there are exceptions to this: the 0_2 percentage for lemons, for example, is between 5% and 8%.

In CA storage a distinction is made between Low Oxygen (LO) and Ultra Low Oxygen (ULO) Storage. LO storage describes the situation where the oxygen percentage has been reduced to approx. 2%. ULO storage is understood to mean storage at an 0_2 percentage of less than 2%.

The $C0_2$ percentage is likewise subject to limits. For many types of fruits such as bananas, pears and tomatoes the general rule is that, if the 0_2 percentage falls below 2% and/or the $C0_2$ percentage climbs above 5%, the fruit will not ripen or will show irregular ripening. For many types of fruit the $C0_2$ limit is 5%. If this limit is exceeded, bananas may suffocate whilst some apple varieties will suffer brown discoloration in their flesh (pulp).

In most cases the recommended CA storage conditions for apples are between 1.5% and 3% 0_2 and 1.8% to 3.0% $C0_2$. The storage temperature is between -1 °C and 4°C. The storage temperature is dependent not only on the variety but also on its susceptibility to *"chilling"* injuries at the cellular level.

Here again, however, there are exceptions: for instance, the $C0_2$ percentage for pears during CA storage is between 0% and 1 %, but the limit for lemons and pineapples is up to 9%.

A high $C0_2$ percentage inhibits bacterial growth. To prevent the development of *Botrytis rot,* therefore, a $C0_2$ percentage of as high as 10-15% is used for strawberries and cherries!

Although CA storage at low temperature and low 0_2 slows down the effect that ethylene has on the ripening of fruit, there is still a need for sufficient ventilation with fresh air, particularly in cases of lengthy storage. This is of especial importance for apples, pears and kiwis.

Note:
By no means all products are suitable for CA storage. The main products which qualify are those listed in the previous chapter, such as apples, pears, strawberries or kiwifruit. The same in fact also applies to cooled meat such as beef and lamb and poultry. For many other horticultural or agricultural products CA storage has a less favourable effect or no effect at all. These crops include cauliflower, carrots, beetroot, melons, grapes (if they have been fumigated with $S0_2$), radishes, potatoes, etc.

Whether it is wise to place a product in CA storage is indicated in various brochures and temperature lists, e.g. in the Shipping Guide for Perishables, published by Sea-Land.

Modified Atmosphere

In our discussion of the MA container we pointed to the fact that the only difference between MA and CA storage is that in CA storage the composition of the air can be regulated and controlled.

MA storage is sometimes used during the palletised transport of strawberries. In this case the bottom of the pallet is first lined with plastic sheeting, after which the pre-cooled cases of strawberries are stowed on the pallet.
A polyethylene cover sheet is pulled over the cases and tape or liquid wax is then used to create a gastight seal between this sheet and the plastic underlay. Then the air is extracted from inside the cover and gas with the required composition is blown in.

As discussed previously, products can also be packed in such a way than an MA condition is created inside the packaging. This applies, for instance, to bananas shipped in 'banavac bags' or cherries shipped in cases with polyethylene liners.

Carbon monoxide

When products are transported in MA or CA containers, a small percentage of carbon monoxide (C01 is sometimes also added to the storage air. In such cases the CO is obtained from gas cylinders.
Carbon monoxide is a colourless, tasteless and odourless gas. It is flammable and highly toxic (e.g. carbon monoxide poisoning). The explosion limits are between 12.3% and 74% of the air volume.

Adding 2-3% carbon monoxide prevents discoloration of lettuce. But, just like $C0_2$, there are also advantages and disadvantages attached to the use of CO. Though a few per cent of CO will prevent discoloration in lettuce, the carbon monoxide will specifically cause brown patches on the lettuce leaf if the CO_2 percentage in the storage chamber exceeds 2%. The recommended values for CA storage of lettuce are therefore: 2-5% O_2, 0% CO_2 and 2% CO.

CO also inhibits the influence of ethylene, causing the product to ripen less quickly. But if CO is used in an air composition with a reduced O_2 percentage and/or an increased CO_2 percentage, then this good characteristic is largely cancelled out again! However, for products which are highly sensitive to ethylene, such as kiwis, it still does have some effect even under such conditions.

Nitrogen separator in reefer shipping

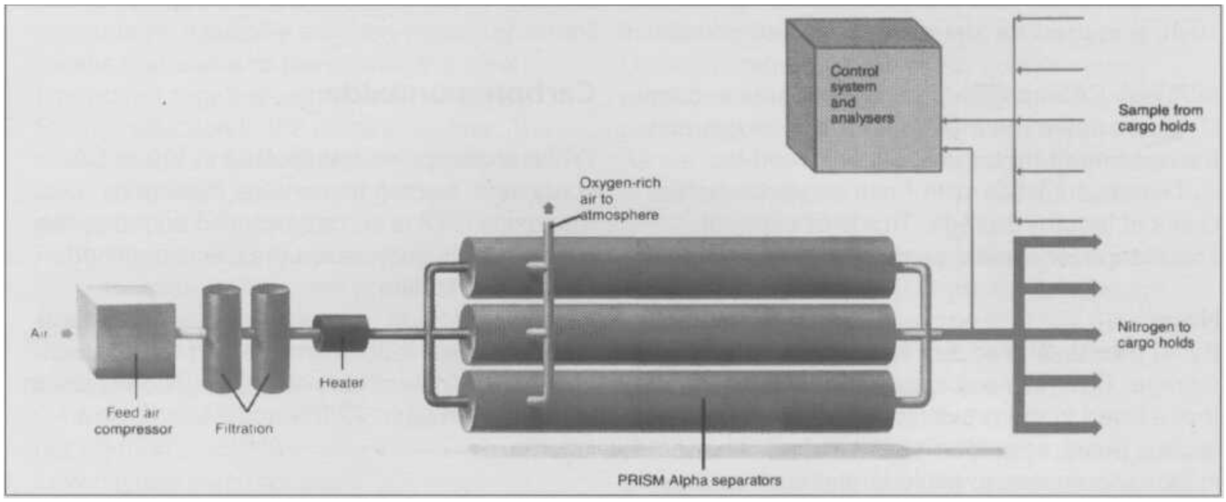
Surely, a simple machine like the nitrogen separator could also be used on board a reefer? All it would require would be a gastight refrigerated compartment and a few fittings. Since reefer voyages last several weeks at most, we need a method which will enable the required CA condition to be achieved within a few days. It is also important that the cargo is already pre-cooled when supplied. CA storage can in fact only commence after the fruit has been brought down to the transport temperature if suffocation of the fruit is to be prevented.

As mentioned earlier, the separator is used in on-shore installations for rapidly creating CA conditions, but in such cases an activated carbon scrubber is sometimes used to maintain the CA storage conditions. The reason for this is the saving on energy costs, but this argument plays a subordinate role on board a ship.

Incidentally, the hold does not need to be absolutely gastight, since an extra supply of separated gas can be used to remove the air that has leaked inside. The only problem is that a fixed, permanent installation will not pay its way on every voyage. Not only because the installation is useless on a ballast voyage or for frozen cargoes, but mainly also because not all types of fruit are suitable for CA storage.

This is why Permea, Inc., using hollow fibres called "Prism Alpha", has designed two types of CA systems, i.e. one in the form of a containerised transportable unit in a 20-ft container, and another which can be airlifted after arrival at destination to be used at source in another reefer ship.

The special CA unit can be flown out by air in a specially designed 10-ft airfreight container. These airfreight containers are designed in such a way that they fit exactly in the cargo hold profile of a Boeing 747 or a DC 10 (see photo page 127). The unit pictured here weighs 4,500 kg and is simple to operate by connecting it up to the shipboard electricity network.



Simplified flow diagram

The major fruit exporting organisation, the New Zealand Apple and Pear Board, pioneered shipboard CA storage of Cox's Orange Pippin and Granny Smith apples on the New Zealand to Europe route. This method is meanwhile also being used for other types of fruit, thus adding yet another dimension to the reefer trade.

The operation of such a containerised unit is described below. A unit of this type is capable of maintaining CA storage conditions for 150,000 cases of apples. Obviously, all the cooling chambers to be conditioned must be made virtually airtight. In itself, not an easy task, as official approval requires that the pressure drop from 0.75 to 0.50 inch water column in a hold must take place in less than 3 minutes.
When making a hold airtight, therefore, the following points must be borne in mind:

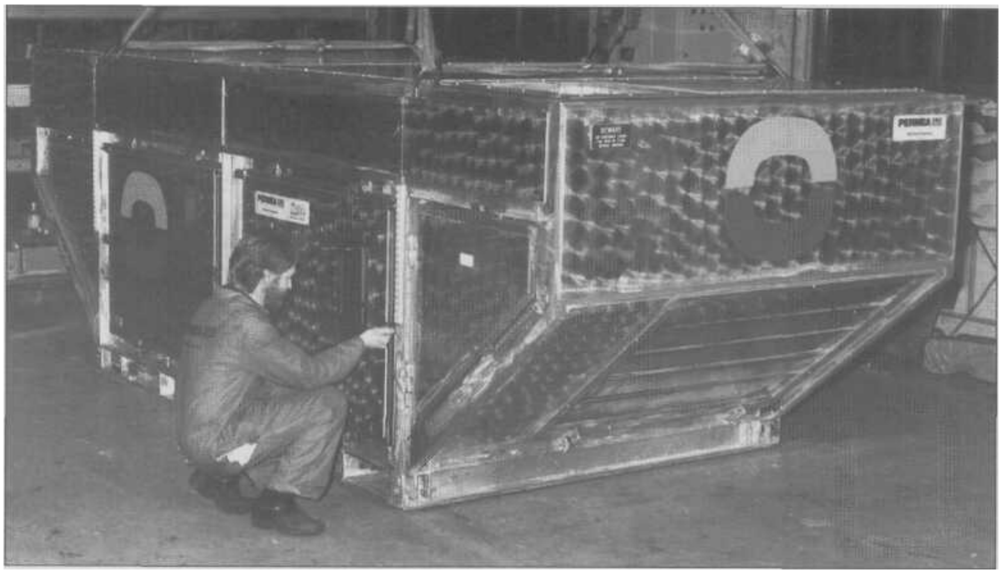
1. the rubber seals of hatch covers and banana doors must be in good condition;
2. the banana hatchways, which provide access to the hold, must also have an effective seal;
3. the deck houses through which air ducts pass must have a gastight seal;
4. the water seals of the scuppers must be filled;
5. the air vents on bilge sumps and cooler wells must be provided with covers;
6. if a CO_2 fire extinguishing piping system is fitted, this must be sealed off; the same applies to the CO_2 measuring system;
7. the air inlets and outlets in the hold must be fitted with a gastight seal.

After the hold has been made gastight, its tightness is tested either using a test fan or compressed air. An effectively functioning pressure gauge must be fitted for control purposes. Hoses are then fitted between the unit and each cooling chamber. Two thin hoses are used for measuring purposes and a thicker hose of approx. 1 inch diameter is used to feed in the nitrogen. The system also incorporates a pressure/vacuum valve which serves as a safety cut out if a vacuum occurs during cooling-down and also extracts the oxygen and carbon dioxide from the hold when nitrogen is admitted.

The unit

For marine applications the CA unit has to comply with the following requirements:

- it must be designed as a complete stand-alone unit, requiring only hose connections to the hold, an electrical supply connection and the necessary contacts for the sampling of O_2 and CO_2 in the holds;
- it must be transportable;
- the unit must regulate its programmed settings completely automatically;
- the unit must be completely seaworthy and it must be possible to install it on deck.



Typical Prism Alpha CA system in air transportable container

The air drawn in by the screw compressor is compressed to approx. 10 bar. This compressed air is passed via oil separators, filters and water trap to the membrane separator, where the air must first be heated to approx. 45°C to ensure an improved operation of the separator. A higher temperature could damage the hollow-fibre elements.
Depending on the throughput, the oxygen percentage created after separation of nitrogen and oxygen will be between 2% and 5%. This quantity of oxygen is fed via solenoid valves and hoses to the relevant holds. The surplus oxygen that is released is allowed to escape into the outside air.
The unit contains a measuring section with a computer and a control section, whilst the compressor and cooling air fan each have their own separate start-up panel. This section also houses the calibration gas cylinders which are filled with nitrogen containing 5% $C0_2$ but no oxygen. Via a sampling pump the measuring unit regularly takes a reference sample from these gas cylinders to check out its own setting. Any deviations are recorded and an alarm is triggered if the set limits are exceeded.

At pre-programmed time intervals air samples are also taken from the compartments linked to the system and a printer prints out the values on paper. In addition, portable O_2 and CO_2 meters are used to take manual samples each day.

If the required oxygen percentage is approx. 2% but if measurings show that the 0_2 percentage in the hold is moving above 2.1 %, then "low flush" nitrogen with 2% 0_2 is admitted into the hold,
If the measurings show that the 0_2 percentage is lower than 1.8%, then "high flush" nitrogen with an 0_2 percentage of 5% is fed into the hold.

The alarm is activated if the 0_2 percentage moves below 1.5% or above 2,8%. In this way the hold air can be kept within the set 0_2 percentages. However, it may take five days before the unit has reached the range in which it can start to regulate the oxygen composition.

Regulating the $C0_2$ content also requires alternate use of high flush and low flush nitrogen, but the primary control is formed by the regulation of the 0_2 percentage. The preset alarm levels will trigger a visual and acoustic alarm so that the required measures can be taken.
Obviously, various safety features are also incorporated for the compressor and for monitoring the air temperature, etc.

Operating data

0_2 percentage 1.8 to 2.1, alarm low at 1.5% and high at 2.8%.
$C0_2$ percentage 1.9 to 2.1, alarm high at 2.8%.
"low flush" flow of N_2 with 2% 0_2 = approx. 100 m^a/h
"high flush" flow of N_2 with 5% 0_2 = approx. 300 m^3/h
The temperature of the air upstream of the separator is between 40°C and 50°C.
The temperature of the cooling air at the outlet is between 80°C and 100°C.
The N_2 outlet pressure is between 0 and 3,5 bar.

CA equipment

In addition to the nitrogen generator, CA equipment consists of the following components:

1) ***Pressure and vacuum relief (P.V.) valve***
The P.V. valve serves to limit abnormal positive or negative pressure levels caused by the hold temperature and the amount of N_2 gas fed into the hold.

2) ***Injection pipe***
The injection pipe supplies N_2 gas to the hold in order to reduce 0_2 and $C0_2$ levels. The end of the pipe is led to the suction side of the cooling fan in the cooler room.

3) ***Re-circulation pipe***
The re-circulation pipe improves the efficiency of N2 gas generation and makes it easier to control the carbon dioxide level in the CA hold.

4) ***Sampling pipe***
The sampling pipe extracts CA gas from the cargo hold and feeds it to the 0_2 and $C0_2$ analysers which calculate the 0_2 and $C0_2$ concentrations. The end of the pipe is located in the return air wire netting in the cooler room. Sometimes a second sampling pipe is also incorporated to control the pressure in the cargo hold.

Safety

Because of the extremely low oxygen percentage in the CA holds and possibly also in the deckhouses as a result of leakages, the most stringent safety precautions must be observed at all times when entering these areas. Inside the unit there is a compartment containing respirators but, even if a respirator is worn, it is still inadvisable to enter these areas. All hazardous areas must therefore carry warning notices and be effectively sealed against unauthorisedaccess.
Before the vesse can be unloaded, the relevant areas must be very well ventilated for a prolonged period. Before performing work in these areas, the air in the storage chamber must be inspected using portable meters on which the oxygen percentage can be read off. These meters must emit an acoustic alarm signal if the oxygen percentage is 19% or less.

CA provisional rules

The first successful trials with the Prism Alpha system very soon made it clear that CA storage will find more widespread use in reefer shipping in future. In response to this Lloyd's Register of Shipping (LRSi ih London has therefore compiled what are known as the "CA Provisional Rules".

These Rules are divided into 8 sections and are applicable to every gas system used for CA storage, regardless of whether the system is permanently on board or transportable. The Rules are regularly updated to take the latest technological developments into account. The main aim of LRS was to provide rules to promote the safety and reliability of the installations. That is why certain components of the installation which may work loose or which require extra maintenance are duplicated. As much as possible, the Rules are laid down only for the main outlines of the system, so that the compilers can rapidly introduce new ideas and developments.

The procedure for obtaining a CA classification follows the same lines as are customary when applying for classification of the cooling installation.

The following notations which may be found on a CA certificate include the following:

(CA) During measuring of the air leaks the CA holds were found to be airtight and are fitted with connecting points for taking gas samples. The (CA) notation indicates that the vessel is suitable for linking up with a CA system.
The test results are stated on the certificate.

(..% O_2) This notation is awarded to ships fitted with a gas installation which has sufficient capacity to compensate for air leakage from a CA hold. The minimum oxygen percentage which can be achieved is entered between the brackets in the notation,

R.H. This notation is awarded if the installation is equipped with facilities which enable the R.H. in the CA hold to be increased. The air humidifiers (water evaporators) are allowed to be installed in the engine room as well as in the cargo area.

* The asterisk (*) is awarded if a system has sufficient capacity to reduce the nitrogen percentage to a set value within a predetermined time, whilst all CA systems are operating.

Design plans and data

Section 2 of the Provisional Rules specifies the information and documents which have to be submitted to obtain approval. The General Arrangement Plan, for example, has to show where the CA holds are located and also the layout of the installation. With a view to safety, this relates in particular to the position and type of pressure relief valves and gas feed pipes.

In connection with possible air leakages, information has to be supplied about the hatchway sealing, door seals, conduits for the feed and discharge pipes, etc. In addition, the measuring points for taking air and R.H. samples must be indicated, as well as details about the equipment for measuring air leakages. This section also contains the rules on the design and operation of the air humidifiers.

Cargo area

Section 3 likewise devotes a great deal of attention to safety. It points to the need for effective air seals. Although no indication is given of the permissible air leakage limits, the requirement is set that the conduits through which pipes and cables pass should be of an airtight design.
All entrances to the cargo area must be fitted with safe seals and alarm installations. Warning notices must be posted next to hold seals, manholes and doors which give access to the cargo area. Every CA cargo hold must be equipped with an alarm which is activated as soon as the nitrogen percentage becomes too low. The cargo hold must be provided with at least 2 gas sampling points fitted with filters which enable the air composition to be monitored.
Deck houses and other adjacent rooms must be equipped with a mechanical ventilation system which can be operated from outside these rooms.

Gas system

Section 4 stipulates that the gas system must be designed in such a way that the entire gas charge cannot be lost as the result of one single operator error. The gas system must have sufficient capacity to cope with any unexpected loss of gas from the cargo area. The gas must be able to

flow in at a set velocity and the nitrogen percentage must be reduced within a set period of time.
The gas supply system must be designed in such a way that the pressure of the gas when it flows into the CA hold is no higher than the design pressure of that hold. An alarm must be activated if the gas pressure or the temperature in the CA hold is abnormal, if the gas supply is disrupted or if the nitrogen percentage is abnormal.

This section also stipulates that the ship must have at least 2 oxygen and $C0_2$ analysers with a measuring accuracy of ±0.1%. These gas analysers must be calibrated at regular intervals.

Humidity

Just like in the case of conventional cooled transport of fruit, it is also necessary during CA storage for the relative humidity to be kept as high as possible so as to prevent dehydration.

In most cases an R.H. of 90% or higher is required. This requirement cannot be met in CA storage without making use of a humidifier. Simply feeding in fresh air, the usual method for adjusting the humidity in the hold during conventional transport, is in fact impossible. An additional complicating factor is that the N_2 Qas which is fed in is very dry (dew point -60°C). Section 5 therefore focuses specifically on the air humidification system. The system must have sufficient capacity to create and maintain 90% R.H. in the cargo hold. Regardless of the quantity of gas injected, the R.H. in the hold must not deviate by more than ±5%.

If the air humidifier is permanently installed, the pipes must be fitted with drain cocks so that they can be drained when frozen cargoes are being carried. In addition, the pipes which pass through areas in which the temperature may move to below freezing must be equipped with a heating system.

The air humidifier, which must be of an approved type, must transmit its operating data to a monitor at intervals of at most 4 hours. The readings must be printed out at least twice a day. At a preset, low R.H. percentage an alarm system must be activated.

Safety rules

Section 6 requires the presence of a permanently installed oxygen and $C0_2$ monitor in every cargo hold, gas chamber and enclosed adjacent room, If the nitrogen percentage threatens to drop below 19%, a warning system must be activated which emits both acoustic and visual signals.
Air and ventilation outlets of cargo holds and gas chambers must stand completely clear of the accommodation quarters and the air intakes for the air conditioning fans.

The ship must carry four complete sets of safety equipment which comply with LRS Rules. In addition, a sufficient number of sets of respiratory equipment must be available. These respirator sets must also comply with the further detailed requirements set by LRS,

This section also states that entering a loaded CA hold is prohibited. In emergencies the cargo hold should first be made gas-free before it is entered. The officer in charge must be trained in the use of respiratory equipment and must speak the language of the personnel who are loading and unloading the cargo. He should also be familiar with the safety procedures relating to the entering of CA zones, as are described in detail in the Operational Manual.

Inspection and testing

Section 7 stipulates that, before the CA system is put into operation and before a class certificate with a CA notation can be issued, it has to pass a final test in the presence of a Lloyd's surveyor.

Besides the check on the overall proper functioning of the installation, this test obviously focuses specifically on:

(a) alarm and control systems;
(b) verification of the instruments;
(c) air-tightness of CA holds;
(d) the operation of the humidification system in cases where a CA notation has been awarded;
(e) safety seals on entries;
(f) safety equipment, such as respirator sets and portable nitrogen detector;
(g (the posting of warning notices at entries, hatchways, etc.

Note: It will not be possible to create completely airtight CA cargo holds. It is therefore permissible for air leakage to be compensated for by injecting a certain quantity of gas to achieve the required composition.

Periodical surveys

Section 8 requires that the CA system should be subjected to Periodical Surveys if the class certificate is to be prolonged.
The Annual Survey and the Special Survey take place once a year and once every 5 years respectively.
The purpose of the Annual Survey is to check the overall state of the CA installation.
It is limited mainly to an inspection of the voyage log, control of the safety equipment, seals and entries, the alarm systems, the operation of the gas feed pipes and the hurnidification equipment, etc.
The Special Survey is more comprehensive. To pass this survey the installation may have to be fully or partially dismantled.

1
2
3
4

LOADING THE CONTAINER

Measures PRIOR TO loading

11 Check the proper functioning of the cooling unit.
2) Check the calibration of the temperature thermostat.
3) If a temperature recorder is present, check its calibration as well.
4) Inspect the container cladding for cracks and/or damage. Check all seals, especially the seals and closures of the cargo doors.
5) Check the container for smell and hygiene. Make sure that the drains in the floor are clean.
6) Find out whether the previous cargo was not a "contagious" cargo. The previous cargo may possibly have originated from the petrochemical industry or may have contained undesirable chemicals. The packaging from the previous cargo may also leave behind a penetrating odour, as of course may the cargo itself, for instance citrus fruit or fish.
7) If the container is not properly clean or odour-free, it must be cleaned with a detergent cleaner and warm water. After cleaning, the container must be ventilated.
   In the event of stubborn odours it may even be necessary to steam the container out and then ventilate it.
   If no clean water is available, attempts can be made to dispel the odours by alternately heating and ventilating the container.
81 Before being loaded, the container must be pre-cooled to the temperature at which the cargo is supplied. This will prevent the cargo from absorbing the heat stored inside the container. There is no sense in operating the cooling unit during loading. The important thing to remember is that loading must take place as quickly as possible and that the doors must be closed during pauses in the loading operation. After loading is completed, the cooling unit must be coupled up.
9) Check whether the supplied cargo is suitable for the voyage duration and route. The length of the voyage may affect the product's keepability, whilst the route is important in view of the risk of heat radiation where outdoor temperatures are high. In the case of too-low outdoor temperatures it may even be necessary to heat the storage air.

Measures DURING loading

1) Never accept cargo which may make the container unsuitable for a subsequent cooled cargo.
2) During loading, make several checks on the temperature of the cargo being supplied. Where possible, take these random samples using a thermometer which complies with EC regulations.
   Also check the quality of the cargo.
3) Check for possible damage to the packaging or its contents. In particular, make sure that the cargo has no abnormal odours or moulds. If damage or abnormal temperatures are observed, record these as remarks on the cargo documents.
4) The cargo must not be stacked higher than the "leadline". In any event a clear space of 8 to 10 cm must be left free between the cargo and the roof.
51 Since the air will follow the line of least resistance, the cargo must be uniformly stowed, with no excessive gaps; this will prevent "short-circuiting" of the circulating cooling air.
6| The stowage pattern that has been chosen must correspond to the air circulation system which is being used.

Important points prior to transport

11 Have all documents been received which are necessary for transport and delivery?

2) How many air changes are required?
3) How should the cargo be ventilated?
4) Is the cargo homogeneous or mixed?
5) How high is the cargo's heat production?
6) What is the transport temperature; what critical temperature thresholds apply to this particular cargo?

Stowing the cargo

Bottom-top system

As explained previously, two air circulation systems are used in containers, the most common-one being the "bottom-air" system. In this system air is sucked by fans from the container through the grilles in the front bulkhead and is then cooled in the evaporator. The cooled air is then fed in under the T-bar floor and flows in an evenly distributed pattern into the container.
In the case of cooled cargo the circulation system which has been chosen governs the way in which the cargo has to be stored. In this chapter we shall assume that "bottom-top" circulation has been used in the container.

General rules on stowing

When stowing the cargo a distinction is made between frozen cargo and cooled cargo. For frozen cargo we have to make sure that heat penetrating through the container walls cannot come into contact with the cargo. For cooled cargo both the radiant heat from outside and the heat produced by the cargo have to be extracted. This is why the cooling air must flow around frozen cargoes but *through cooled* cargoes.

Cooled cargoes

In cooled cargoes the respiration heat and the type of packaging play an important role. The respiration heat of vegetables, especially leaf vegetables, is generally much higher than that of fruit. For example, if we compare sprouts with apples, both of which have a transport temperature of roughly between 0°C and 2°C, then we can see from the transport tables that at this temperature the respiration heat of sprouts is 140WA whilst that of apples is 20W/t.

Particularly in the case of products which give off a lot of heat, the boxes must obviously be stowed in such a way that the cooling air can flow through the cargo evenly and without encountering any obstacles. It is therefore important that the boxes containing such cargoes must in any event be stacked in such a way that no ventilation openings are closed off. For both cooled and frozen cargoes it is important that the air is evenly distributed and that there are no big gaps in the stow which might cause the air flow to "short-circuit".
Where the dimensions of the boxes so permit and provided that the boxes have sufficient ventilation openings, as is the case with banana boxes, the stacking pattern can be alternated after each layer or after a couple of layers. This improves the stability of the stack. If the boxes have fewer ventilation openings, e.g. boxes of apples and pears, the stacking pattern cannot be varied and each box should be stacked on top of the other.
If the products are packed in (net) sacks, such as onions, carrots and potatoes, the first layer of sacks should be stowed in an "upright" position, alternated in subsequent layers by one row of sacks in a horizontal position.

To summarise, the loading pattern is determined by:

- the type of container and its equipment;
- the air circulation system used in the container;
- the nature of the cargo;
- the type of packaging material.

Ventilation

Ventilating with fresh air is needed so as to prevent an excessive build-up of CO_2 and to remove unwanted gases. The quantity of fresh air that has to be admitted depends on the CO_2 production of the products and on the air leakage from the container.
Modern containers are equipped with mechanically adjustable ventilators which allow fresh air to be admitted in line with the prevailing conditions. In such cases the storage air can be refreshed between 0.5 and 4 times an hour. If the container can be ventilated, we can find out from

the transport tables how much ethylene the product creates and whether the product is ethylene-sensitive and adjust the ventilation rate accordingly.
A possibility of obtaining a readout of the $C0_2$ content is only offered by modern containers. In cases where this is not possible, ventilation usually takes place on a continuous basis.
In most cases, however, constant ventilation is unnecessary. As a rule of thumb, 1 to 2 m^3 of fresh air per hour must be admitted per tonne of cargo.

Cooling capacity

The cooling unit has insufficient refrigerating capacity for rapid cooling of the products. The refrigerating capacity required to keep the products at their storage temperature amounts in itself to as much as approx. 0.35 kWh per tonne. Lowering the temperature of 1 tonne of products by 1°C requires a further extra capacity of approx. 1 kWh.
However, the capacity of the cooling units is generally sufficient to reduce the temperature of 1 tonne of products by 0.2°C to 0.4°C per hour.

Let us assume that we have loaded 12 tonnes of products and that we want to reduce their temperature by 0.3°C per hour.
The required refrigerating capacity can be found from the following equation:

12 * [0.35 + (1. * 0.3)] = 7.8Kwh.

Assume that the pulp temperature of the products when loaded was 20°C and that the required transport temperature is 2°C. Suppose that the cooling unit is capable of reducing the temperature by 0.2°C per hour. In this case it will take 18:0.2 = 90 hours before the transport temperature has been reached.

For cargo which has not been pre-cooled, actual practice shows that it can take 4-5 days to achieve a transport temperature of approx. 0°C. Because of this lengthy cooling-down time the product loses too much moisture, i.e. weight, and there is also a substantial reduction in its keepability. Because of this and other factors, therefore, it is essential that the products are pre-cooled when they arrive for shipment.

In our theoretical example but just as much when specifying the container's required refrigerating capacity and cooling-down time, allowance needs to be made for the following factors:

- the initial temperature
- the field heat of the product
- the product's respiration heat
- the stowage pattern
- the temperature and R.H. of the outside air
- the type of packaging
- the air leakage from the container.

The principal rule for transport is:

Always comply with the transport instructions. Where decisions have to be taken, always use your common sense.

Frozen cargoes

Frozen cargoes have already been brought down to the transport temperature prior to loading and are stacked using the "block stow" method (see fig. 1).
In a "block stow" the boxes are stacked tightly against each other. The only space that is left is the gap between the outermost boxes and the container walls. Since most of today's containers have smooth internal walls, special attention

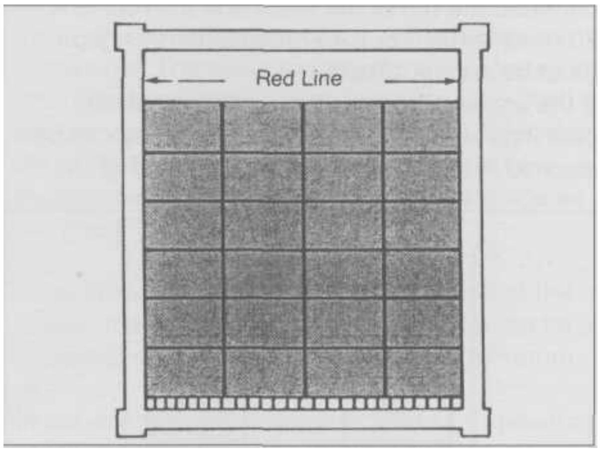


Fig. 1 Stowage pattern for frozen cargo.

must be given to ensuring that the boxes are not stowed tight against the walls. To guarantee effective air circulation around the block there must be sufficient clearance below and above the block. Normally a gap of about 8 cm is left

free between the top of the block stow and the roof.
The stack must be stowed in such a way that the cooling air flows in an even pattern arounc/the block. The boxes must not come into contact with the heat penetrating the container through walls, floor or roof.

Stowing of cooled cargoes

As discussed previously, cooled cargoes are exposed to two heat sources, i.e. radiant heat from outside, and the heat generated by the product. In this case the air must circulate not only around the cargo but, above all, *through* the cargo.
As is the case for frozen cargo, the "block stow" system is also applied here. However, the way in which the boxes are placed within the block is determined here by the product and the shape of the boxes, especially by the number of ventilation openings.

If the container floor is not utilised in full, folded-open boxes must be placed on top of the non-occupied floor space so that the air is forced to flow through the stack. Just like in the case of frozen cargoes, the boxes must not be stowed tightly against the wall. In this case, too, a clearance of about 8 cm must be left free between the top of the stack and the roof of a 20-ft container. For a 40-ft container this gap must be approx. 10 cm.
If the boxes have suitably located ventilation openings and the right dimensions, they can be stacked in a "brick stow" pattern (see Fig. 2).

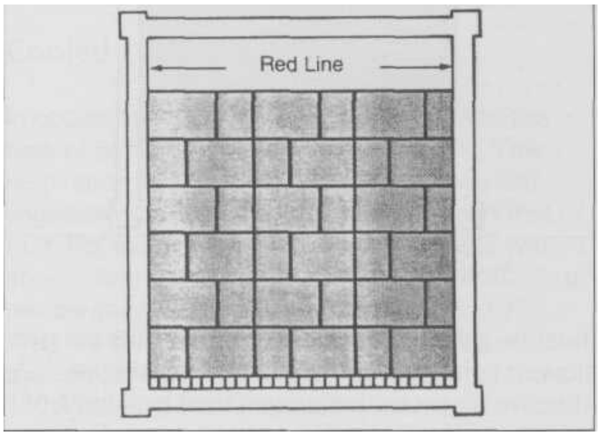


Fig. 2 Boxes in a brick stow - "bottom-air" system.

This boosts the stability of the stack. However, it may also give rise to localised "hot spots" if the ventilation openings do not correspond exactly.

Boxes which have fewer ventilation openings - like those used for apples - must be stowed in an identical pattern, box upon box. The same applies to products which generate a lot of heat, like vegetables.

Palletised cargo

The method of stowing pallets is governed by the dimensions of the pallet and by the internal dimensions of the container. In our examples below, we will assume that pallets with the ISO standard dimensions of 120 cm x 100 cm are to be stowed in a 40-ft container.
The approximate internal dimensions of a 40-ft container are: height 2.20 metres, length 11.35 m, breadth 2.29 m.
The cargo capacity amounts to approx. 57 m^3; payload approx. 23 tonnes. The cooling capacity for a cooled cargo amounts to approx. 6,000 Kcal/hr and for a frozen cargo: approx. 3,000 Kcal/hr.

The most frequently occurring "footprints" of the boxes are 60 cm x 40 cm or 50 cm x 40 cm.

The height of the boxes varies widely. As can be seen from the illustration here, if we place one pallet with its longest side lengthwise in the container and the next pallet with its shorter side across the breadth of the container, it is possible for two pallets to be fitted in exactly (1.00 m + 1.20 m = 2.20 m). In a lengthwise direction, 9 pallets can be placed in one row (9 x 1.20 m = 10.80 m), with 11 in the other row (11 x 1.00 m = 11 m). In total, 20 pallets.To ensure that the pallets are positioned as uniformly as possible, a small gap can be left between them. But take care not to leave too wide a gap at certain points.

As we can see from fig. 3, boxes with a "footprint" of 60 x 40 cm can be stacked five per layer on the pallet. This footprint size allows us to arrange the boxes in two different patterns within each layer. If the footprint is 50 x 40 cm, six boxes can be fitted in each layer. In this case it is not possible to alternate the stacking pattern. If the height of the pallet is approx. 12 cm and that

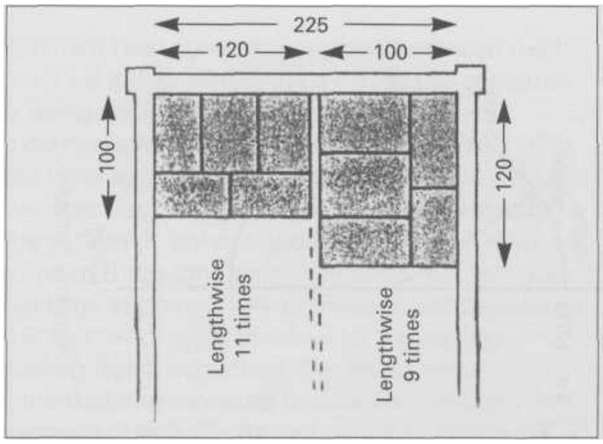


Fig. 3 Stowage pattern for palletised cargo - "bottom-air" system.

of the box approx. 25 cm, then stacking the boxes 8-high will leave just the right amount of clearance between the top of the cargo and the roof.

Since the cooling of palletised cargo takes place more slowly than the cooling of individually stowed boxes, it is important that palletised cargo has been properly pre-cooled when loaded. Especially when used for products which generate a lot of heat, such as avocados, the "block stow" pattern means a very long delay before the transport temperature is attained. This applies in particular to the boxes located in the centre of the block (fig. 4).

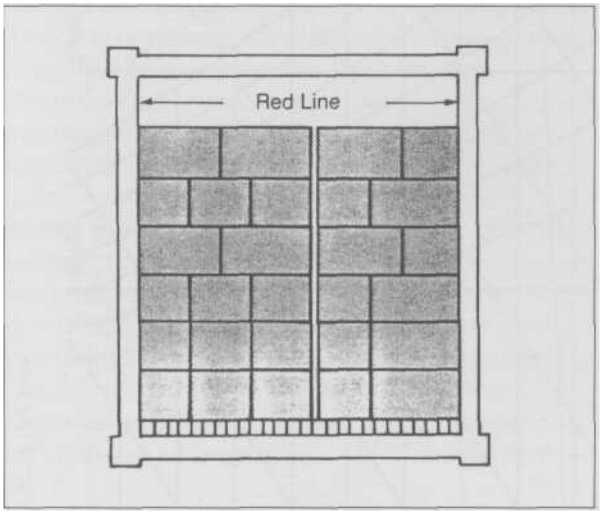


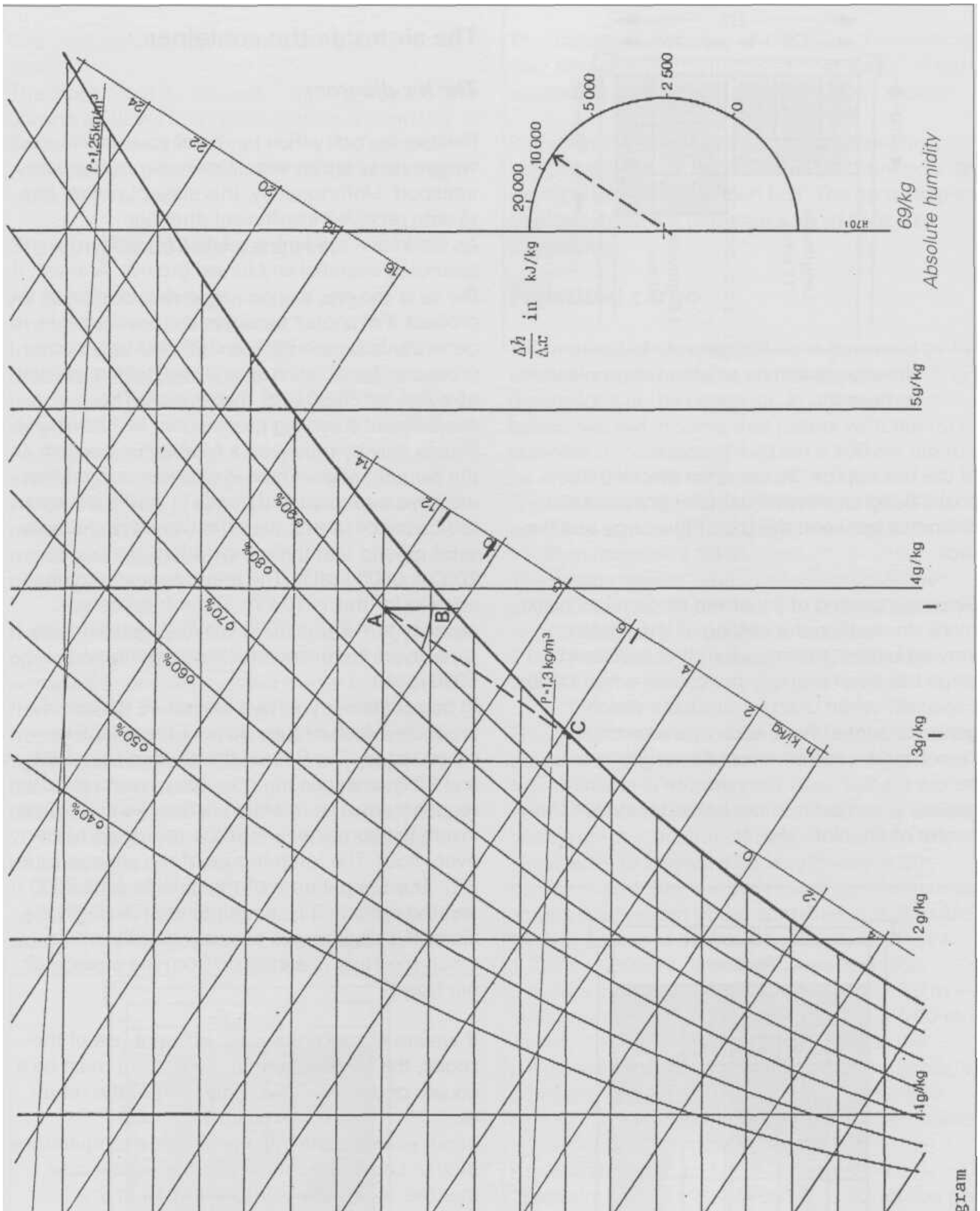
Fig. 4 An alternating stowage pattern ensures uniformity in stows of palletised cargo.

The air inside the container

The h,x diagram

Relative humidity (R.H.) and dehydration-induced weight loss play an important role in refrigerated transport. Unfortunately, this subject matter has to date received insufficient attention.
As we know, too high a relative humidity promotes bacterial and fungal growth. And yet, if the air is too dry, it encourages dehydration of the product. For cooled products the required R.H. is generally between 85% and 95%. Many cooled products, especially fruit and vegetables, consist of water for 80-90% of their weight.The operation of a cooling process can be shown in a simple way by means of a Mollier h,x diagram. In the diagram shown here we have assumed that we have loaded cooled goods in a 40-ft container. Let us suppose that the effective cargo capacity is 57 m^3 and that the refrigerating capacity at 20°C is 6500 kcal/h. The energy consumption needed for this is 10 kW. The refrigerating capacity at -18°C is 3600 kcal/h. The maximum capacity of the evaporator fans amounts to 5000 m^3/h.
In this container we have loaded 15 tonnes of products which occupy 70% of the effective cargo space. The R.H. of the storage air is 90% and 80 air changes per hour have been set as the requirement. The intention is that the air volume inside the container should be refreshed twice every hour. The temperature of the storage air is 2°C. The temperature of the outside air is 20°C and the outside R.H. amounts to 55%. With the aid of the diagram we can now calculate how much moisture is extracted from the storage air per hour.

If we are to make the most efficient use of the cooler, the temperature of the coolant must be a couple of degrees lower than that of the return air.
In our example the storage air has a temperature of 2°C. Let us assume in this theoretical case that the cooler temperature is -2°C. In the diagram point A indicates where the circulating air (2°C; 90% R.H.) enters the cooler. The vertical lines in the diagram are lines of equal water content. At point A we can read that 1 kg of air contains 3.9 grams of water (x = 3.9 g/kg). The curved diagonal lines in the diagram are lines of



h–x-diagram
Absolute humidity
g/kg
1g/kg
2g/kg
3g/kg
4g/kg
5g/kg
Δh/Δx in kJ/kg
20 000
10 000
5 000
2 500
0
ρ=1,25 kg/m³
ρ=1,3 kg/m³
h kJ/kg
A
B
C
40%
50%
60%
70%
80%
90%
°C

constant heat content. For point A we can read: h = 11.8 kJ/kg. Whilst the air from the container is being cooled, its R.H. increases but its moisture content remains constant. That is why we have to follow the vertical line of constant water content (x = 3.9) until this line intersects the saturation curve at point B (R.H, = 100%). At point B the dew point has been reached. Our readings at point B are as follows: temperature = 0.8°C; x = 3.9 g/kg; and h = 10.3 U/kg. As cooling down continues, the air remains saturated and moisture is released. To see what happens during the further cooling process we must follow the saturation curve until the horizontal line of -2°C (isotherm) intersects the saturation line at point C. At point C we can read: temperature = -2°C; x = 3.2 g/kg; h = 5.8 U/kg; andR.H. = 100%.

The difference in heat content (Ah) between points A and B amounts to:
11.8 kJ/kg - 5.8 kJ/kg = 6 kJ/kg and the moisture loss (Ax) amounts to: 3.9 g/kg - 3.2 g/kg = 0.7 g/kg (-0.0007 kg/kg).

By dividing Ah by Ax we find:

$$\frac{\Delta h = 6 \text{ kJ/kg}}{\Delta x = 0.0007 \text{ kg/kg}} = 8571 \text{ kJ/kg.}$$

From this it follows that in our case 8571 kJ are needed to extract 1 kg of water from the air.
The Ax/Ah ratio can also be read off directly from the diagram. To do this, the line connecting A and C must be shifted in parallel to the centre of the circle. The ratio can then be seen on the circumference of the circle.
Two diagonal lines have been drawn in the diagram to indicate the density (p) of the dry air in kg/m^3.
On this line we can read that at approx. -2°C the density (p) = 1.3 kg/rn^3.
From this it follows that:
Ax = 0.7 g/kg <==========> Ax = 0.9 g/m^3
Ah = 6 kJ/kg <==========> Ah = 8 kJ/rn^3

As the cargo occupies 70% of the container space, the air volume is equal to 30% of 57 m^3 = 17m^3.
A rate of 80 air changes/hour means that the quantity of air circulating through the air cooler is 80 x 17 m^3 = 1360 m^3.

Using this figure we can calculate that:
x =1360x0.9 g/h =1224 g/h = 1.224 kg/h
h =1360 x 8.0 kJ/h =10880 kJ/h =10,880,000 J/h.

We know that: 1 kW/h = 3600 kJ and that
1 kcal/h = 4187 J/h.

The required cooler capacity then follows from:

$$\frac{10{,}880{,}000 \text{ J/h}}{4187 \text{ J/h}} = 2598 \text{ kcal/h}$$

The required power consumption is therefore[1]

$$\frac{10{,}880 \text{ kJ}}{3600 \text{ kJ}} = 3 \text{ kW/h}$$

However, the cooling unit also has to handle an additional load because of the air changes. In our case the air admitted from outside amounts to 2 x 57 m^3 = 114 m^3/h. As we can see from the Mollier h,x diagram, chapter 8, the capacity required for this air (temp. 20°C; R.H. 55%) is:
x = 8 g/kg and h = 41 kJ/kg.
As the fresh air flows into the container it will be mixed with the circulating air. Its moisture content (8 g/kg) will remain unchanged until the dew point is reached. From the graph we can see that the dew point is reached at 10.5°C. From this point we have to follow the saturation curve. As the temperature decreases further, moisture is released and this is absorbed by the circulating air. We follow the saturation curve to the point where it is intersected by the -2°C isotherm. At this point we can read that R.H. = 100%;
x = 3.2 g/kg and h = 7.6 kJ/kg.
Between the inflow of the air and its exit from the cooler Ax amounts to 4.8 g/kg and Ah is 33.4 kJ/m^3.
If we assume that the average s.m. (r) of the air is 1.25 g/m^3, then Ax is 6 g/m^3 and Ah is 42 kJ/m^3.
For an air inflow of 114 m^3, Ax = 648 grams and Dh = 4.788 kJ =4,788,000 J.
In total, therefore, the cooler has to extract 1224 g + 684 g = 1908 g/h = 1.9 kg of water per hour.

Relationship between R.H. and temperature

Maintaining the required R.H. level is difficult because the P.H. is influenced by a great many factors, some of which are:
- the number of air changes per hour
- the cooling surface of the cooling unit

- the temperature of the coolant as compared to that of the return air
- the number of times the air has to be replaced
- the temperature and R.H. of the outside air
- the heat transfer coefficient (a) of the product.

In our h,x diagram we can read that 1 kg of air contains 3.9 g of moisture at 1°C and 90% R.H. The value we find for x at 9°C and 90% R.H. is: x = 6.2 g/kg. This demonstrates that R.H. and temperature are indissolubly linked. In our example we saw that the air may contain less moisture as its temperature decreases. This is the reason why, during the cooling of the air, moisture condensation will form on the evaporator pipes or the moisture will be deposited on the cooler in the form of frost. As a result the R.H. of the storage air is reduced. The R.H. of the storage air can be increased again by ventilating with outside air.

As this example has clearly shown, condensation problems are particularly likely to occur in "warm" cargoes. In this case there will not only be deposits of water on the evaporator fins, but the circulating air will also give rise to condensation on the packs. As a result, cardboard packs may be weakened to such an extent that damage is caused. If the products are packed in plastic, condensed water will be left inside the cooled plastic of the pack and will also be deposited on the product.

As the temperature difference between the return air and the delivery air becomes smaller, the P.H. of the circulating air will increase. Roughly speaking, it can be said that if the temperature difference is 1 °C for cooled cargoes, the R.H will be approx. 95%. If the difference is 3°C, then the R.H. is 89% and for a difference of 4°C the R.H. is 78%. To ensure that the R.H. is kept at the required level, therefore, it is important to have the lowest possible temperature drop within the cooler.
However, it remains a fact of life that it is easier to control the temperature than the R.H.
In the case of storage temperatures of just above 0°C the R.H. can be influenced to a certain extent by admitting fresh air or by changing the temperature of the coolant, though this always leads to only minor changes in the R.H.

Most cooled products require a high R.H. Exceptions to this general rule are: nuts, dates, dried fruits, beans, garlic and flower bulbs. Today's modern containers are also fitted with equipment for controlling the R.H.

Loss of moisture and weight loss

The bigger the difference between the temperature of the cargo and the temperature of the cooling air, the greater the dehydration. Since the product releases moisture into the circulating air, more water vapour will be transferred from the product to the cooling air, thus making the weight loss even bigger. At a faster rate of air circulation the boundary layer surrounding the product is replaced more often, which means that a constant moisture evaporation is maintained. The required air-flow speed is therefore determined by the product, the type of packaging and the stowage pattern of the products. As a general rule, the air-flow speed is between 0.2 and 0.5 m/sec.

Moisture loss not only reduces the weight but also adversely affects the taste and quality, and this leads to a less appetising appearance, especially in fruit and vegetables. Storage air which is too dry will encourage moisture loss, and yet air which is too moist will promote fungal and bacterial growth. The quality deterioration resulting from moisture loss is not the same for every product. Leaf vegetables (lettuce, for example} will soon tend to shrivel and lose their fresh appearance if the moisture loss amounts to more than 4%. Packs which prevent dehydration are particularly essential for products which dry out quickly, such as broccoli, parsley and lettuce. During cooled transport the weight loss for apples and pears amounts to about 0.6% per week. For some types of fruit and vegetables the weight loss is much higher. At an R,H, of 75%, palletised boxes of berries lose about 2% in weight per day, asparagus and paprika peppers lose 3.6% per day and beetroots and carrots 1.7% per day.
The weight loss for quick-frozen meat packed in cardboard boxes is 0.05% per week. If this meat is packed in plastic, the weight loss is reduced to 0.02% per week. The moisture loss in cooled meat is much higher, especially during a lengthy

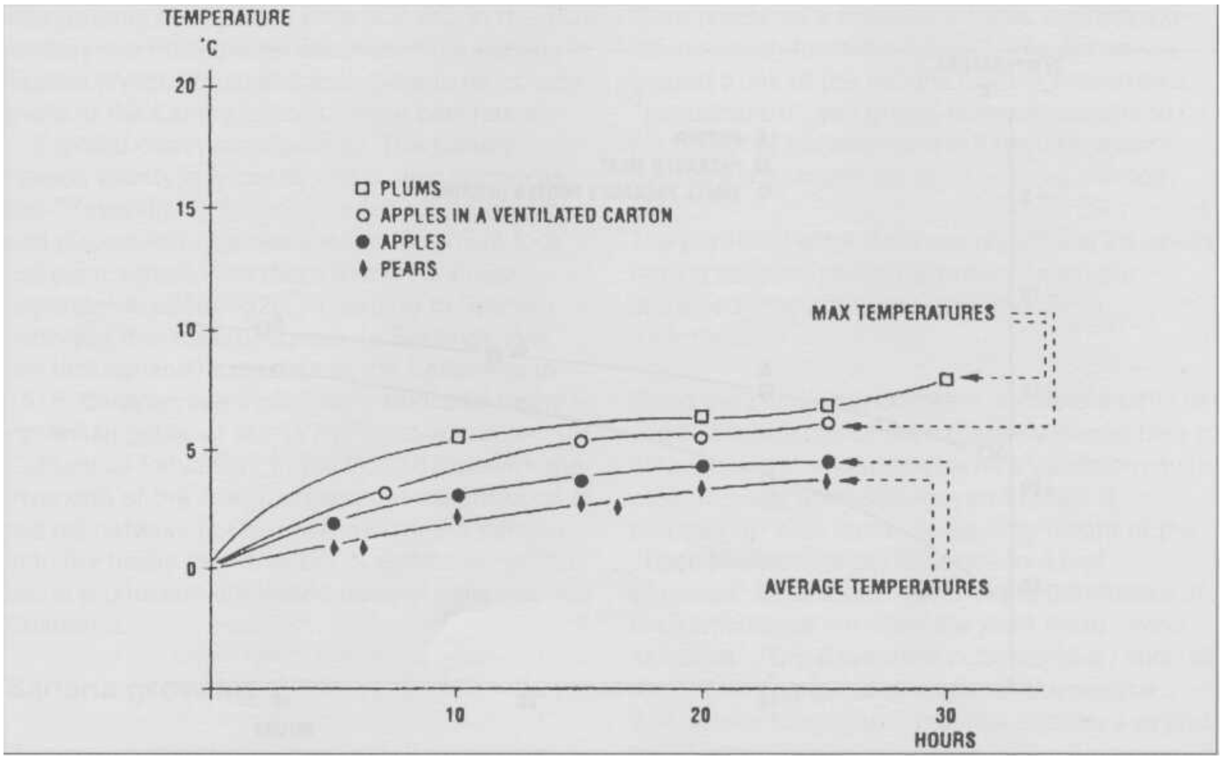
voyage (10 to 14 days). If the meat is not packed in suitable material, the moisture loss can climb to as much as 5%. Effective packaging will cut the moisture loss to 1 %. Rapid pre-cooling prior to loading will minimise weight loss, but slow cooling of the product inside the container will specifically encourage dehydration.
To prevent damage, hanging carcases of meat must be suspended in such a way that sufficient air circulation is guaranteed between the carcases, whilst meat should be hung next to meat and bone next to bone.

To minimise weight loss the products are often packed in cellophane. However, this does result in condensation forming on the inside skin of the pack. To prevent condensation inside the pack, small holes are sometimes punched in the packaging material.

Air circulation

Air circulation is necessary to remove the heat produced by the product as well as any unwanted gases and moisture. The number of air changes per hour is determined by the respiration rate of the product and/or by the speed at which the cargo has to be cooled down. At the start of cooling the temperature difference between the return air and the delivery air is still high (3-5°C). During this period between 500 and 700 m^3 of air per kW of refrigerating capacity circulates through the cooler. Once the cargo has been cooled down, the difference between the return air and the delivery air amounts to approx. 1 °C and the number of air changes can be substantially reduced.
The number of air changes is governed not only by the cargo but also by the type of packaging. The respiration rate is proportionally linked to the temperature. For every 10°C increase in the temperature the respiration rate doubles. Sometimes the respiration rate is even more than doubled! At 10°C, for example, apples breathe 3 times faster than at 0°C. The faster the respiration rate, the greater the quantity of heat produced and the shorter the storage time.

In a modern container the maximum number of air changes can amount to more than 100x the air volume of the empty container capacity per hour. A high number of air changes is required



Temperature change in cooled cargo following failure of cooling unit at outside temperature of 20°C

especially for palletised cargo. However, if the air changes exceed 100/hour, the increase in the heat transfer coefficient of the product will be cancelled out by the insulating effect of the cardboard boxes.
In addition to sufficient air circulation, a uniform distribution of the air is equally important. Uneven air distribution will give rise to "hot spots" and all the related problems they cause.
A good temperature distribution is very much dependent on the capacity of the fans and on the method used to control their operation. Besides the type of packaging, it is chiefly the method of stowage which plays an important role here. That is why the cargo must be stowed as uniformly as possible, with no big gaps between the pallets or between the cargo and the ends of the container.
In practice, it takes about twice as long to cool down fruit packed in tissue paper and/or in non-ventilated boxes as compared with fruit which is packed in ventilated boxes.

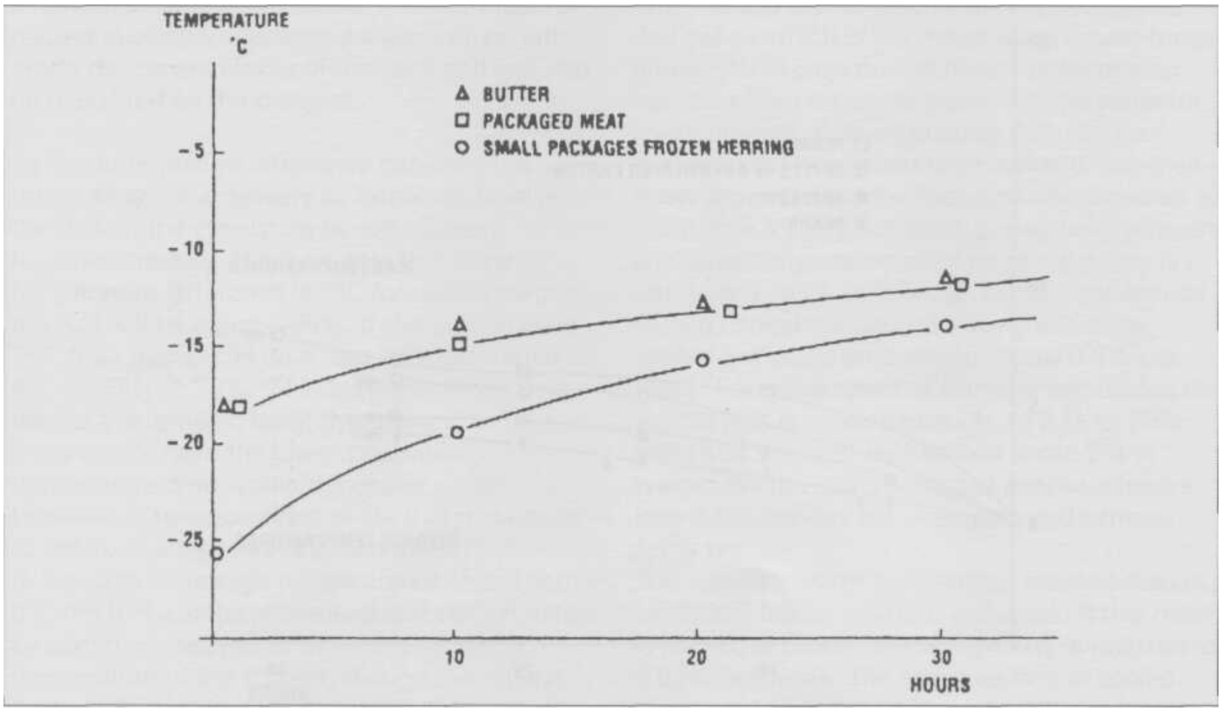
Breakdown of cooler unit

There is a possibility that for various reasons the cooling unit may be non-operational for some time. As a consequence, the temperature of the cargo will increase. The graphs show how the temperature rises for some cooled and frozen products if the machine is non-operational and if the outside temperature is 20°C.
(Source: "The Transport of Perishable Foodstuffs", J. Frith, SRCRA, Cambridge, 1991)

The speed at which the temperature of the cargo increases is determined by:

- difference between inside and outside temperature;
- intensity of the sunlight;
- wind speed;
- heat leakage through the container walls;
- type of product and packaging.

As we can see from the graphs, the temperature of frozen cargoes in particular will increase quickly following failure of the unit. For frozen meat the maximum temperature which is still just about acceptable depends on both current legislation and the commercial demands of shippers and receivers. As a general rule it should be borne in mind that dairy products, but also cooled fish and cooled meat will soon deteriorate as a result of fluctuations in the storage temperature.



Temperature change in frozen cargo following failure of cooling unit at outside temperature of 20°C.

CHAPTER 13

BANANA CULTIVATION

Origins of the banana plant

The banana is the edible fruit of several tropical species of the Musa plant which is a member of the Musaceae genus. The banana is one of the world's oldest cultivated plants. About one million years ago the banana grew in the wild in the jungles of what is now Malaysia and South East Asia. Bananas are believed to have originated there because so many of the varieties and names of the banana can be traced back to that region. The recorded history of the banana dates all the way back to Alexander the Great's conquest of India, the country in which he first discovered the fruit in 327 BC. In about 400 AD Malayan sailors took the rootstock of the plant to Madagascar. From that island it spread to the East coast and the interior of Africa.

Pictures of the banana can be found on Egyptian monuments dating from circa 500 BC. In the 15th century the Portuguese discovered the banana in Guinea (West Africa) and took banana roots with them to the Canary Islands where bananas are still grown commercially today. The Canary Islands variety is Musa sinensis, also known as the "Cavendish". Some decades after Columbus had discovered America the first colonists took the plant across with them to the American continent in about 1520. According to Spanish history, a friar called Thomas de Berlanga took the first banana rootstocks to the Caribbean in 1515. Bananas were officially introduced to the American public at the 1876 Philadelphia Centennial Exhibition. In the late 1870s, with the invention of the telegraph and the construction of the rail network in Central America, the banana industry finally took shape. For details about the world production and world trade in bananas, see Chapter 2.

Banana growing

Bananas can be grown successfully in tropical regions provided there is a nutrient-rich soil and provided they are supplied with sufficient water at the right times via rainfall or an irrigation system. One exception is the "Dwarf Cavendish" variety, which can be successfully cultivated outside the tropics, e.g. on the Canary Islands, in Israel and Egypt.

As we already explained in Chapter 2, the banana is not only a tasty fruit but also a very valuable fruit because it is rich in carbohydrates, minerals, vitamins A and C and a number of B vitamins, most notably vitamin B-6, Bananas not only have a high nutritional value but also contain three kinds of fibre which help to sustain good health and promote good digestion.

The banana plant is a large tree-like herbaceous plant with a milky juice (known as "latex") in all its parts. The plant belongs to the same family as the lily and the orchid. The underground tuberous stem produces a close-set of soft, overlapping leaves which form the "trunk". The above-ground trunk of the banana plant is known as a "pseudostem" and grows within 6 months to its full height of between 2 and 8 metres, making the plant the largest on earth without a woody stem.

The perennial plant does not reproduce via seeds but via sprouts, called rhizomes, which are produced year after year from the same rootstock,

Since the plant's pseudostem consists mostly of water, banana plants are extremely susceptible to "blow downs" caused by severe windstorms. To prevent such wind damage, each plant is propped up with sturdy poles. The height of the "Gros Michel" variety is between 4 and 8 metres. This height is one of the drawbacks of Gros Michel, as it makes the plant more "wind-sensitive". The Cavendish cultivars (cvs.) such as the "Dwarf" grow to a height of only approx. 2 m, whilst the "Giant" reaches approx. 3 m and the "Valery" grows to approx. 3.5 m high on average. The tallest plant in the Cavendish cvs. is the "Lacatan" which grows to a height of 4-5 m. The axil of each leaf contains a bud which may develop into a single flowering shoot consisting of several flower clusters. Each cluster contains 12-20 blossoms arrayed in two rows. In the same year each female flower grows to form an individual banana, which is in fact a berry. The female flower produces the banana fruit without fertilisation or seed formation (via parthenocarpy). As the fruit develops, its weight causes the shoot to grow downwards. By contrast with the downward-growing bunch, the fruit itself tends to curve upwards as it develops. This is the reason why all bananas are curved. Because only one bunch (stem) of fruit is produced by each pseudostem, the plant is cut after harvesting of the fruit so as to allow the following pseudostems, known as the "daughter" and "granddaughter", to develop and flourish. Although a banana plant consists of a large number of leaves (approx. 60), it has only 10-15 functioning leaves. The sizes of the leaves (length x width in cm) are as follows: Gros Michel 400 x 100; Robusta 210x80; and Dwarf 158 x 80. Depending on the cultivar, the surface area of a leaf is between 2 m^2 and 4 m^2.

The following specialised terms are used in banana cultivation;

Finger: Each blossom develops into an individual banana fruit, known as a "finger".

Hand: The entire group of 14-20 bananas, joined together at the crown, is called a "hand".

Cluster: This is a part of the hand and usually consists of 4 to 8 individual bananas.

Bunch: As the stem develops, seven to twelve hands of bananas are formed. A chopped-off stem with a complete set of hands is referred to as a "bunch".

On average a finger weighs 150 grams. If we assume that the average hand consists of 16 fingers and that each bunch is made up of 10 hands, then the entire bunch comprises 160 bananas with a total banana weight of 24 kg. However, a bunch weighing 45 kg or more is certainly not exceptional. This is why it is necessary to support the bunches with props or to attach guys between the crown of the plant and the bases of nearby pseudostems.

Not all bananas are the same. Depending on the cultivar (cv.) they reveal differences in colour, shape, size and taste. The Gros Michel, for example, is a slim banana with a bottle neck top. By contrast, all Cavendish cvs. have a rounded top.

Development and cultivars

Under idea! conditions it takes 9-11 months after planting before the bananas can be harvested. However, this period is also governed by the climate and the cultivar and may under less favourable circumstances extend to as long as 16 months. The same applies to the time from blossoming to harvest. In the tropics this period amounts to between 80 and 90 days but in a less warm climate (sub-tropics) the period from flowering to harvest may be as long as 120 days or more.

There are several hundred different cultivars. Roughly speaking, we can subdivide bananas into two groups, viz. the cooking variety (plantains) and the "dessert" bananas. The plantain, or cooking banana, is a variety which forms part of the daily diet in tropical areas but it is of little significance for the international fruit market. It is the fruit of the plantain *(Musa paradtsiaca)* and is very similar to the dessert banana. This fruit's high carbohydrate content makes it difficult to digest. That is why this banana is not normally eaten raw but, as the name "cooking banana" indicates, after it has been cooked or fried. The plantain has a length of 30-40 cm. Unlike the dessert banana, its hard peel is firmly attached to the fruit peel. The colour of the peel may be green, yellow or reddish.

In recent years the familiar dessert bananas have also been joined on the market by other varieties, such as the apple banana, red banana, baby banana and golden banana.

The red banana, which has a length of approx. 12 cm, is supplied from Indonesia. The fruit has a similar taste to the dessert banana. This variety can be eaten either raw or cooked.

Kenya and Brazil are the main suppliers of the apple banana. This banana has a thin peel and is about 8-10 cm long. The apple banana tastes good and can be eaten as it is (raw).

The golden banana (known locally as " pisang

mas") is 12 cm long. This banana, which is mainly imported from Malaysia, has an aromatic, sweet flavour and can also be eaten raw.
The baby banana, also known as the rice banana or "pisang susu", is imported from Kenya and Thailand. This banana has a thin peel. The fruit flesh has a very sweet taste.
We shall limit ourselves here only to the more important cultivars for our purposes, e.g. the Gros Michel and the Cavendish cvs. In Indonesia and Malaysia the Gros Michel is known as "Pisang Ambon".

Cms Michel

Until the mid-20th century the Gros Michel was by far the most important banana variety in the world banana trade. In those days the fruit was transported in bunches ("on the stem"). Because of the symmetrical, cylindrically shaped bunches, these sterns were extremely suitable for shipping without packaging. The Gros Michel plants are high yielding and the average bunch consists of 9 hands. Moreover, this banana has an attractive colour and a most elegant shape,
Compared with some Cavendish varieties, however, the Gros Michel also has a few drawbacks. One of this cultivar's disadvantages, for instance, is the tallness of the plant. This means that it is exposed to relatively more wind than the Cavendish cvs. and suffers greater damage as a result. The Gros Michel is not only tall but is also a big plant. In simple terms, this means that the planting density of the Cavendish cvs. is much higher. For example, if we compare the planting density of Gros Michel with that of Dwarf Cavendish, then we can see that the number of stems per hectare is 2.5 times higher for Dwarf, i.e. Dwarf's fruit yield per ha is also much higher.
The Gros Michel's principal drawback, however, is that - unlike the Cavendish cultivars - is susceptible to Panama disease. The main reason for the success of Gros Michel in the past was that its cylindrically shaped bunch made it highly suitable for stowage and shipment "on the stem".

Production of bananas and plantains (millions of tons)

	avge. 1979-81	avge. 1986-88	1990	1991
World	37.4	42.7	45.8	47.7
Central America	7.0	7.0	7.0	8.0
Costa Rica	1.1	1.1	1.5	1,6
Honduras	1.4	1.0	1.1	1.1
Mexico	1.4	1.6	1.1	1.9
Panama	1.0	1.0	1,3	1.2
South America	9.0	10.9	11.9	12.5
Brazil	4.3	5.1	5.5	5.6
Columbia	1.1	1.3	1.3	1,6
Ecuador	2.1	2.4	2.8	3.0
Venezuela	0.9	1.0	1.1	1.2
Europe	0.5	0.5	0.4	0.5
Asia	12.7	17.1	18.8	19.1
China	0.3	2.0	1.9	2.1
India	4.4	4.7	6.2	6.4
Indonesia	1.9	2.2	2.4	2,4
Philippines	3,9	3.7	3.8	3.5
Thailand	1.6	1,6	1.6	1,6
Vietnam	0.9	1.4	1.2	1.3
Oceania	1.1	1.2	1.5	1.5
Africa	4.7	5.7	6.2	6.1
Burundi	1.1	1.4	1.6	1.6
Ivory Coast	0,1	0.1	0.1	0.1
Tanzania	1.0	1.3	1.4	0.8
Uganda	0.4	0.4	0.5	0.5
Za'i're	0.3	0.3	0.4	0.4

Source: FAO

Cavendish

As far as exports are concerned, the following bananas of the Cavendish group are of commercial importance: Grande Maine or Giant Governor; Petite Maine or Dwarf Cavendish; Robusta; Poyo; Valery; and Lacatan.
Unlike the Gros Michel, a bunch of Cavendish does not have a symmetrical shape. If Cavendish is shipped unpacked "on the stem", this irregular shape of the bunch will cause damage to the bananas. Since bananas have been transported in the form of detached hands in boxes from about 1960 onwards, the shape of the bunch scarcely plays a role of significance nowadays, However, the most important benefit offered by all Cavendish cvs. is that they are resistant to Panama disease.
Two of the principal Cavendish cvs. are "Dwarf" (Naine) and "Robusta". The "Dwarf", as its name implies, is the smallest banana in the family. The

"Dwarf" can readily withstand a cooler climate and is mainly grown in subtropical regions, e.g. on the Canary Islands, in Egypt, Southern Australia and Brazil.
In Africa and the West Indies a much more frequently found cv. is the "Robusta". In Central America (United Fruit Co.) the "Valery" clone was for many years the favourite variety but that has now been replaced by other clones such as the "Giant", also known as the "Grand Maine".
Other Cavendish cvs. include the "Americani". The "Americani" is mainly grown in the French-speaking regions of Africa.

Crowing conditions

In addition to possible diseases and pests, an important role during the fruit's growth and further development is also played by a number of other factors, e.g. temperature, rainfall, wind, number of hours of sunshine, and the soil condition. It would take us far beyond the scope of this chapter to discuss all these factors in full. We will therefore confine ourselves to a few general comments on each. For a more in-depth study of the growing conditions for bananas, we refer to the list of literature references included at the end of this book.

Elevation

Banana plantations are chiefly located in low-lying areas in the tropics. Given a suitable soil structure and the right humidity, however, bananas can also be grown in these regions on higher ground or on hillsides provided that the humus layer is good. The disadvantage of cultivation at higher elevations is that the growth cycle is prolonged and that there is an increased risk of chill injury because nighttime temperatures are too low. As mentioned earlier, the latter does not apply to the Dwarf cultivar, which can also be grown in subtropical regions.

Temperature

The banana develops best at an average monthly temperature of approx. 27°C. At temperatures above 36°C growth comes to a standstill and the risk of "sun-scorch" increases. If rainfall is evenly spread over the growing period, then an average precipitation of 120 mm per month is required to ensure good growth in tropical regions.
Obviously, the required rainfall is also governed by the actual surface geography of the growing area and the number of hours of sunshine. On a sunny day the plant will evaporate more water than on a cloudy day, whilst the water given off by the plant during a completely overcast day will even be half the quantity released during a sunny day.

Tropical cyclones

Another important factor is the effect of the wind on the growth of the banana plant. Wind speeds in excess of 25 km/h can have an adverse effect, not only because the leaves may be badly damaged but also because the pseudostem may be uprooted and the operation of the root system disrupted. Ultimately this will also have a detrimental effect on the development of the fruit.
Wind speeds in excess of 60 km/h will cause considerable damage, but winds gusting at 100 km/h or more (as occur specifically during tropical cyclones) are disastrous and bring a very high risk of destruction of the entire plantation. Tropical cyclones are known in East Asia as "typhoons", in America as "hurricanes" and in the North West of Australia as "willy-willies".
These tropical cyclones are born in the latitudes between 5" and 10°, i.e. in the area where the trade winds normally blow. Although these cyclones have their origins at low degrees of latitude, they do not occur at all in the latitudes below the 5th parallel. Early in its development the cyclone tracks westwards. After a while its course usually veers towards the pole, which means that the hurricane mostly heads towards the United States and the typhoon towards the coasts of China and Japan.
As we can see from the above, the banana-growing regions which may be hit by cyclones include: Central America, the Windward Islands, the West Indies, Taiwan and the Philippines.
Regions which are cyclone-free include Brazil, Ecuador, Colombia, Panama, Cameroun (the Gulf of Guinea) and Indonesia.

Type of soil

Another factor is the condition, structure and texture of the soil. Apart from good drainage, an important role is also played by the right ratio between the salt content, pH degree, and the balance between N (nitrogen), P (phosphorus), K (potassium) and Ca (calcium). Broadly speaking, a fertile soil consists of a mixture of sand, clay and humus. Using modern-day fertilisers, poorer types of soils can in many instances be converted into a good, nutrient-rich soil for banana cultivation. Because of the plant's weak root system, however, it is important that the ground should be free of stones and that the soil layers should be porous enough to permit the roots to penetrate easily.

The degree of acidity or alkalinity of the soil is another crucial factor. Acidity is the opposite of alkalinity and a substance which is neither acid nor alkaline is described as "neutral". The degree of acidity or alkalinity of a substance is expressed numerically in the form of its pH value, with pH 7 representing neutrality. Figures below pH 7 denote increasing degrees of acidity; figures above 7 stand for increasing levels of alkalinity. The best soil for bananas and other fruit crops will have a pH reading of between 6.5 and 7.5. Real trouble only starts to arise where the pH is below 5 or above 8.

Banana tree

Banana plantation

Potash (K = potassium) is the principal fruit-forming fertiliser. If the potash in the soil is insufficient in relation to the soil's nitrogen content, fruits will tend to be poorly coloured and lacking in flavour. Potash also has a striking effect on foliage; potassium deficiency will in fact give rise to scorched leaves.

Drainage

A banana plant has an extensive root system. The roots can grow as far as 4.5 m in a horizontal direction. However, the plant's vertical roots are not deep, having an average depth of 30 cm, whilst the finer roots {of 1-5 mm in diameter) may go down to at most 50 cm below the surface. The roots are extremely fragile and, though they require a moist soil, they will not tolerate stagnant water. Good drainage is therefore essential. The drainage system is usually constructed at a -soil depth of 80 cm to 1 metre.

As can be seen from the above brief descriptions of the various factors which may influence the growth of the plant - and ultimately also the quality of the fruit - bananas need not necessarily be identical in quality throughout the year, even if they originate from one and the same district.

BANANA DISEASES AND PESTS

Panama disease

As already explained, the Gros Michel was the leading variety of banana up until 1960. Between 1920 and 1955, however, most of the Gros Michel banana production was destroyed by the serious disease of soil-borne fungal wilt incited by strains of *Fusarium oxysporum,* more commonly referred to as Fusarial wilt or Panama disease.

By the late 1950s commercially attractive clones of bananas resistant to Panama disease were readily available. All the Cavendish cvs. were also found to be resistant to Panama disease. Nowadays, therefore, Cavendish cvs. such as the "Dwarf Cavendish" and the "Giant Cavendish" account for virtually the entire production of bananas exported from Central and South America as well as from many other banana-growing countries.

Sigatoka disease

General aspects

Sigatoka leaf spot is the most damaging and most costly disease affecting bananas, with potentially very serious consequences for the entire banana-growing industry. Though many banana cvs. are resistant to Sigatoka, the Cavendish cvs. are unfortunately a notable exception. This serious disease occurs in all banana-growing regions, apart from in Israel and the Canary Islands.

When we refer to Sigatoka leaf spot, we have to distinguish between three related pathogens:

(a) Sigatoka:	*Mycosphaerella musicola*
(b) black Sigatoka:	*M. fijiensis var. difformis*
(c) black leaf streak:	*M. fijiensis*

It is far from easy to tell the three types apart and, since the effects on the plant and the prevention methods are identical, the disease is generally referred to simply as "Sigatoka". Sigatoka is not a disease of the fruit itself, but purely a leaf-spotting disease which results in premature necrosis of large parts of the plant's total leaf surface. In severe cases, however, the disease will also have an impact on the quality of the fruit.
On a plant which has not yet produced its first bunch, the initial symptoms will usually be seen on the third and fourth leaves on which light yellow or green/yellow stripes will form. These stripes grow broader and develop to approx. 10 mm long and approx. 1 mm wide, after which they form a brown spot. After some time the centre of this spot dries out and assumes a grey colour. The result is a collection of more or less rounded spots with a grey-coloured centre and brown edges. By the time the bunch has emerged, these stripes, spots or both will have expanded downwards from the youngest unfurled leaf through to the oldest upright leaf.

In the case of "black leaf streak" small speckles develop on the underside of the third or fourth leaf. These speckles grow to become reddish brown streaks some 20 mm long and 2 mm wide. The colour of the streaks then changes to dark brown, almost black, after which they also show through on the upper side of the leaf. As in the case of black Sigatoka, these streaks expand until they form spots. Where the infection is severe, the great many streaks form a mass which, when it is water-soaked, causes a large part of the leaf to take on a black colour. Several weeks after the black patches have formed, the leaves die off. The symptoms of Sigatoka are indistinguishable from those of black leaf streak. As mentioned earlier, it is impossible to tell the three diseases apart on the plantation. The only reliable method is to make a microscopic examination.

Diseased leaves either fall from the plant naturally or are removed via deliberate defoliation. Particularly in the past a decision was soon taken to cut entire leaves off the diseased plant. However, it is not always necessary to remove the whole leaf. Sometimes it will suffice if the individual leaf blades are cut back from the tip until the necrotic tissue has been removed. The idea underlying this "limited surgery" is that it is better if a greater photosynthetic area is preserved on the plant. Besides, in view of the disease control techniques which are now available and which afford near-complete protection against the il -effects of Sigatoka infection, there is no sense in cutting away the whole of a leaf in cases where it exhibits no more than a few square centimetres of necrotic tissue.

Rain, humid weather and high temperatures promote the rate of development of the disease. Against this, however, dry periods or low levels of overnight dew counteract the development of the disease spores. Even though the disease may cause serious defoliation in some cases, the plants will be able to recover again during a drier period, especially if good fertilisers have been applied. Humidity in the plantation can be reduced by good drainage, via removal of suckers and by ensuring that the plants have sufficient space to grow in.

A sound banana plant has 12 or more healthy functional leaves. Defoliation, whether deliberate or disease-induced, leads to a considerable reduction in fruit yield per hectare. The number of functional leaves at the time of harvest is crucial for the further development of the fruit. In Central America the general rule is that, to guarantee a reasonable development of the fruit (both before and after harvesting) the plant should still carry at least seven leaves at the time the fruit is harvested.
Since the loss of leaves causes a significant decrease in photosynthesis, severe Sigatoka infections may mean that the size of the bunch and of the individual fingers is smaller than normal. The fruit from a diseased plant is physiologically more mature than its physical size would seem to indicate. The bananas on such a plant are therefore harvested at an earlier time than normal so as to rule out the risk of premature ripening during transit. This earlier harvesting will in turn reduce the yield per hectare.

Sigatoka disease: possible effects on the fruit

If steps are not taken to counter Sigatoka disease in good time, the consequences for the fruit may be as follows:

(a) premature ripening;
(b) increased susceptibility to chill injury;
(c) buff-coloured pulp;
(d) off-flavour and abnormal smell.

However, if one of the above-mentioned symptoms is observed upon outturn of the bananas at the port of destination, this cannot automatically be attributed to the effects of Sigatoka disease. Any incidence of premature ripening alleged to have been caused by Sigatoka has to be investigated at the despatch end. In most cases Sigatoka disease is limited to a certain country or district. In January 1994 the black Sigatoka fungus affected the Geest crop in Costa Rica. The wholesalers suspected that the disease was also present in Fyffes brand bananas supplied from Honduras and Guatemala. Though the Irish Fyffes group emphasised that their crop had not been affected by the fungus, sales of Fyffes bananas were none the less hit and there was even a negative impact on the Fyffes share price.
In the meantime, however, intensive research in the relevant fields has provided the means for countering what was once referred to as the Sigatoka scourge. Perfectly adequate methods of controlling leaf disease in bananas have been

available for many years and these methods are generally utilised - and with great effectiveness - in all the major banana-growing areas.

Brief history of Sigatoka disease

The disease in its original form was first described by a plant pathologist (Zimmermann) who was working in Java in 1902. However, its more common name of Sigatoka derives from a more detailed account of the disease following a study conducted in the Sigatoka district of Viti Levu (one of the Fiji Islands) in 1912. From that year until quite recently the incidence of the disease was reported from ever more banana-growing regions around the world. By the early 1970s, however, satisfactory methods of control had been found. This meant that the principal effect of Sigatoka was on the cost of production, rather than on the biology of the plant itself or the bananas it produced.
This position of satisfactory containment of the disease was first seriously threatened in 1963, when what was clearly a potentially much more serious type of Sigatoka-like leaf necrosis first attracted commercial attention. As it happened, this was again in Fiji. This form of the disease was found to be caused by a different species of *Mycosphaerella,* which was then given the name *M. fijiensis* Morelet. Morelet also dubbed it "black leaf streak", the intention being to make a distinction in everyday speech between the new disease and Sigatoka, but this good intention failed singularly. Growers everywhere soon started referring to black leaf streak as "black Sigatoka". Today, the disease incited by *Mycosphaerella fijiensis* is therefore referred to almost universally as "black Sigatoka" or just plain "Sigatoka", another reason being that in areas where it has become endemic, it has virtually displaced the earlier disease. We will therefore follow the common growers' convention and refer to all forms as "Sigatoka".

Nature, effects and control of Sigatoka disease

Sigatoka is a disease of banana leaves; to the best of our knowledge there is no record in the scientific literature of the pathogen having been recovered from a banana fruit and certainly textbooks are unanimous in stating that it does not attack the fruit. In certain circumstances death of the leaf tissue can result in physiological disorders in banana fruits, but such disorders should, strictly speaking, not be described as "disease". Readily visible symptoms of the disease take the form of necrotic spots, variable in both colour and shape, on the leaf blades. In the extreme case the spots coalesce, with resulting destruction of a large part, or even the whole, of the affected leaf.

The effect of Sigatoka on the plant is the loss of photosynthetic area, resulting in loss of yield and delayed maturity. From time to time it has been postulated that diseased leaves may produce one or more phytotoxins which are translocated to the fruit, where they are said to be responsible for those discolorations of the vascular strands of the pulp which are characteristic of fruit which has developed on plants very severely affected by Sigatoka. To the best of our knowledge, however, no scientific investigation has confirmed the existence of such toxins. The appearance of these discolorations is certainly not dependent on the synthesis of any toxin in the leaves of the plant. Apart from Sigatoka, there are numerous other explanations for such symptoms, just as there are for the unexpected early ripening of harvested banana fruits.
Control of Sigatoka has to take into account the different ways in which the various incitant fungi produce and release spores. *Mycosphaerella musicola* is spread principally (but not wholly) by asexual spores which are produced externally to the infected leaf, whilst the spread of *M. fijiensis* is largely (although again not wholly) via sexual spores which develop inside the leaf. Control

measures are thus aimed at preventing or suppressing the production and/or germination of spores and at killing established fungal structures, whether on the leaf surface or within the leaf blade. To achieve all of these aims and to guard against the possible development of fungal strains resistant to the fungicides in use, the common practice is to use a variety of chemicals applied either in rotation or, if compatible with one another, together in a single spray.
Present-day methods of Sigatoka control depend crucially on the use of two dissimilar types of fungicide - one acting systemically by translocation within the plant, and the other by direct action against spores or other fungal structures exposed on the leaf blades.
The oldest systemic fungicide used for Sigatoka control is petroleum oil. It was, and still is, extremely effective. For a decade it gave commercially acceptable control of Sigatoka caused by *M. musicola* when used entirely on its own. But the suspicion that it had undesirable (if relatively small) physiological effects on the plant led to it being used at reduced rates, but in conjunction with direct-acting fungicides, commonly dispersed in an oil/water emulsion.
When the systemic chemical benomyl was introduced in 1975, it was found to be very effective against Sigatoka, but only when used in conjunction with oil. Tridemorph, a semi-systemic introduced in 1980 and particularly effective against f/y/ens/s-incited Sigatoka, also seems to require oil for complete effectiveness, as does propiconazole, a systemic introduced in 1984 and also now in widespread use.

Table 1 at the end of this section on Sigatoka lists the proprietary materials which are currently used in the plantations under the control of Uniban. Uniban, the Union de Bananeros de Uraba S.A., is the single largest banana growing organisation in the Uraba region of Colombia. As can be seen from that table, the products of all the classes described above are utilised for control purposes. There is nothing exceptional in that fact: it is the common practice adopted by very large scale producers throughout Central and South America.
Most fungicides are expensive. But, if applied indiscriminately, some of them (oil, in particular) do more than simply increase the cost of disease control. They also have undesirable side-effects.

Consequently, much attention has been paid in recent years to the question of how best to determine the necessary minimum frequency of application.
Methods of systematically inspecting plantations, utilising "score sheets" for recording the inspectors' findings and taking account also of meteorological conditions both contemporary and forecast, have evolved from work by some of the plant pathologists currently or formerly engaged in research in the field of Sigatoka control (notably J. Brun, J.D. Dickson, J. Ganry, J.R Meyer, and R.H. Stover).

To give an overall impression of how Sigatoka is controlled, a description follows of the measures adopted by Uniban in the Uraba district of Colombia.

A team of 20 inspectors, most with a relevant technical qualification, inspect on a systematic basis the 12,600 hectares of dessert bananas grown by Uniban members. The whole area is covered routinely in 15 days - an interval sufficiently short as to be entirely adequate for the cover afforded by the fungicidal chemicals in use. The decisions when to spray, and what to spray with, are not based solely on the immediate results of those inspections. All the data for several years past have been collected and computerised and suitable analytical techniques have been developed, so that senior plantation managers can assess the effectiveness of the measures utilised in the conditions in which they were utilised and so refine them in the light of experience.
This approach has been outstandingly successful. At the peak of the initial fijiensis *epidemic* in Central and South America, as many as 40 spray applications had proved necessary per growth cycle in order to control the disease. The advent

Table 1: Phytosanitary materials utilised by Uniban for Sigatoka control

Name:	Manufacturer:	Active ingredient:	Type of action:
Dithane F	Rohm & Haas	Mancozeb	Protectant (water-borne)
Dithane M45	Rohm & Haas	Mancozeb	Protectant (oil or emulsion borne)
Calixin	BASF	Tridemorph	Semi-systemic
Benlate	Du Pont	Benomyl	Systemic
Tilt 250	Ciba-Geigy	Propiconazole	Systemic
Spraytex	Sunko	Petroleum oil	Systemic fungistat, synergistand carrier
Triton	Union Carbide		Emulsifying agent

Note: An anthfoaming agent is also added to mixing tanks when required

of improved fungicides and the use of good inspection and forecasting methods has led to an overall reduction in this figure. Uniban's achievement of only 12 fungicidal applications per growth cycle in the drier months of the year, increasing to 18 applications in the wetter months, is a particularly good score.

The fungicidal chemicals in use are stocked on the Uniban air strip and spray station at Apartado. A sufficient number of airplanes are available to meet all requirements. Three re-charging points are available for simultaneous use.

The airplanes used for spraying the bananas are powerful, large capacity Ayres machines, capable of lifting more than a tonne of spray at a time. This makes them particularly suitable for covering large areas in the comparatively short time available each day. In all tropical banana-growing areas spraying starts at first light and has to stop when the ambient temperature reaches a limiting figure. The use of these large 'planes and of facilities for re-provisioning them at high speed therefore makes very good sense in the Uraba region of Colombia, where the temperature in fact rises very rapidly indeed on most days throughout the year. The airplanes are fitted with the necessary instruments for the utilisation of electronic bout marking, a system which has been installed throughout the entire production area controlled by Uniban.

Even with the very highest standards of disease control, it cannot be expected that every single plant on a 12,600 hectare site (more than 31,000 acres) will remain disease-free throughout its life Some isolated plants may exhibit the n ecrotic patches associated with Sigatoka infection which has developed well beyond its initial stage.

Plants in this condition are almost always associated with locations which, for one reason or another, are difficult to spray - typically because of some feature in the landscape which prevents the spray 'planes from being flown exactly where the pilot would wish (e g. alongside roads, or close to buildings, tall trees, cable lines, and similar obstructions). Similarly, plants which are completely shaded by trees or by other banana plants may not receive their intended spray burden and so become diseased.

In relation to the whole area covered, the number of such plants will always be infinitesimally small, to such an extent that - if any of their fruit is ever included in an export consignment (in itself an unlikely event) - its presence would represent such a minuscule fraction of the consignment that it could have absolutely no effect whatever on the subsequent behaviour of that consignment.

Yellow pulp

Though *"yellowpulp"* is a non-infectious disorder, the reason why we are dealing with it immediately after our discussion of Sigatoka disease is that there is a tendency to conclude that the symptoms exhibited by bananas suffering from yellow pulp are similar to those of Sigatoka disease. The characteristics of bananas affected by yellow pulp are: the fruit pulp has a greyish yellow tint, tends to soften and has a disagreeable odour.

Yellow pulp is already manifest during harvesting. In affected fruits, the pulp - which normally has a dull, white colour - will reveal a yellow, honey-like colour, whilst the pulp in the banana's core may already exhibit some softening. During a lengthy transit time these symptoms will increase further and may lead to premature ripening

Yellow pulp is one of the physiological disorders. Other physiological disorders include *"maturity stain"* which, especially after rainy periods, causes brown/black spots and streaks on ripening fruit and also gives rise to "chilling" injuries.

There are many possible causes of yellow pulp. Mostly it results from a pre-harvest nutritional imbalance. Extra supplements of magnesium and/or calcium during soil dressings prior to harvest can reduce the susceptibility of some fruits to this physiological breakdown

Further causative factors may be; abnormal growing conditions (e.g. excessive shade); defoliation; stress; and drought. In principle, therefore, all the same factors which adversely affect the ripening of the fruit. This therefore includes serious cases of leaf rot, which means that Sigatoka may be one amongst many possible causative factors. As mentioned earlier, Sigatoka can only be identified with certainty as the true cause after a thorough investigation on the plantation.

Banana pests

In Chapter 7 we wrote that, as compared to other tropical fruits, bananas generally suffer few problems because of insect attack. During their growth the bananas are obviously visited by a great many types of insects, but these do not penetrate through to the pulp, which means that any damage is limited to external marks such as pimples and stains on the outside of the peel. When the fruit ripens, these cause brown spots on the peel and, though the eating quality is unimpaired, the banana will look less appetising, which may ultimately have an adverse effect on the price. The sales contract therefore usually contains the requirement that the bananas must be sound, fresh, clean, without any defects, pests and/or damage caused by pests, and without mechanical defects.

In discussing banana pests, we basically need to make a distinction between insects which attack the root system, insects which eat the foliage, and insects which obtain their food from the flowers and/or from the fruit itself.

Generally speaking, few insecticides are used in banana cultivation. Whenever possible, biological control methods are also used to deal with disease and insects. To counteract the effects of some harmful fruit pests, insecticide-impregnated bags are sometimes used. In these cases the manufacturer has injected the insecticide into the plastic during production of the polyethylene. The bags are wrapped around the bunch at an early stage and protect the developing bananas from wind and insect damage, whilst allowing sunlight in. In most cases, however, the planter himself uses a rotary hand duster or an electrically powered blower to apply the insecticide powder to the inside of the bag. Proprietary products used for this purpose include Diaznon, Flusilazol or Thiabendazole.

Nematodes

It is certainly not our intention to discuss all possible banana pests here and so we will restrict ourselves to the most important ones. These very definitely include the nematodes. In general, a nematode is any of the Nematoda, the roundworms, a group variously considered as a phylum, or a class. Of the 10,000 species which occur in the world an important role is played in agriculture and in fruit growing by the eelworm (any small nematode worm of the family *Anguiilulidae).* Eelworms are microscopic in size (1-3 mm), hardly big enough to be seen by the naked eye

These plant parasites are invariably destructive and mostly live inside the plant, either in the roots or the stem. Within the plant they breed in immense numbers, feeding on the sap and hampering normal development, so that growth is checked and stems become stunted and thickened. A great many plants suffer from eelworms but, fortunately, most eelworm species are specific to one type of plant only. If a larger area is affected, then starvation is the only possible means of destroying the pests. This means that no<crop similar to that attacked should be grown on the affected area for three or four years. Otherwise, the solution involves immersing the plants for a long time in water. The rootstocks of some plants can be cleared of eelworms without injury to the plants themselves by immersing them in water at a steady temperature (between 45°C and 55°C, depending on the plant) for a period of 10 minutes. If the water gets any hotter, the rootstocks may be destroyed, while a lower temperature will not kill the eelworms.

In banana cultivation nematodes cause root and rhizome disease. The specific culprit here is the burrowing nematode, *Radopholus similis.* Other nematodes, e.g. root rot nematodes and many other species, do cause damage, but this is nothing like as severe as the havoc wrought by *Radopholus similis.* The root rot damage caused by the burrowing nematode comes a close second only to the previously discussed Sigatoka disease, especially as regards its incidence in all Cavendish cvs. We would note in passing that the Gros Michel is resistant to the burrowing nematode.

Nematodes are a severe problem in practically all banana-growing regions, with the exception of Israel and the Canary Islands. Virgin land on which no bananas have (yet) been cultivated is also free of *Radopholus similis.* The damage is mostly caused by a root rot which expands further to affect the stem. The nematodes themselves do not usually penetrate through to the stem, but certain fungi - specific to the lesion caused by the burrowing nematode - do enter the stem. As a result, the roots are weakened to such an extent that the plant eventually falls over. In fruit cultivation this is referred to as "uprooting". But, even where the plant is not uprooted, the fruit yield will be reduced because of the debilitated root system.

Sometimes the outside of the rootstock (rhizome) is also attacked, but in principle this has no direct effect on the plant itself. However, such rhizome infections will result in a high population

The cutter and the backer at work

of nematodes. These nematodes will in turn attack the emerging new roots. This will disturb the root system and loosen the plant's anchoring in the soil.

Control measures

The biggest loss of fruit yield due to uprooting has been found to occur in poorly drained plantations. Good drainage is therefore essential to combat root rot. In addition, uprooting can be minimised if the plants are supported - immediately after shoots have been formed - with bamboo canes or wooden poles (props) and/or by means of guying with plastic twine. However, it goes without saying that prevention of nematode attack is the first and most important control measure. In tropical regions the principal method used to combat nematodes involves the application of *"nematicides".* In stubborn cases the best solution will be to allow the land to- lie fallow for several years. Another method is "flood fallowing" over a period of several months. Once the land is nematode-free, it is advisable to replant the relevant area with rhizomes which have been immersed in hot water at 53°C for a period of 10 minutes.

Thrips

Thrips are any of the 3,000 small insects of the order *Thysanoptera,* many species of which are destructive to plants. The insect, coloured yellow to black, is small and very narrow in proportion to its length (0.5 mm wide as against 8 mm long).

Most of these insects live off plant juices. A very small number of thrips seem capable of doing quite a disproportionate amount of damage. They cause most problems when the weather gets hot and the atmosphere is dry.

In banana cultivation the specific attacker is the "Red rust thrips". This thrips feeds on the juices from the pseudostem and the banana peel. Thrips feeding causes a reddish-brown staining between the fingers which can sometimes spread to cover the entire length of the affected finger. In severe cases there is even a possibility that the peel may split open. To counter or minimise *red rust,* the bunch is bagged with perforated polyethylene bags when it is 2-3 weeks old.

We would also briefly mention the "Flower thrips" which mainly occurs in Central America and the West Indies. Flower thrips lay their eggs in the peel before the fruit is two weeks old. The oviposition marks (made by the insect during egg-laying) cause raised pimples on the peel. Such raised pimples can therefore be seen at every oviposition site on practically every fruit cluster from Central America and the West Indies. As will be clear from the above, the thrips oviposits before the fruit is bagged. But the resultant blemishes are so insignificant both before and after ripening of the banana that preventive measures are not considered necessary. The conclusion, however, is that the consignee will have to accept these raised pimples on the banana peel as being a natural and unavoidable phenomenon!

In Australia and on the Philippines we also have to contend with a thrips species which causes a corky scabbing of the fruit. These "Corky scab thrips" feed on the juices of the flower buds in their early stages and, subsequently, on the young, developed fruit. To obtain food, the female of the species uses its ovipositor to puncture the peel. Especially on the outermost fingers this gives rise to an uneven peel with brown/reddish stains. These assume the form of the characteristic corky scab once the fruit ripens.

Moko

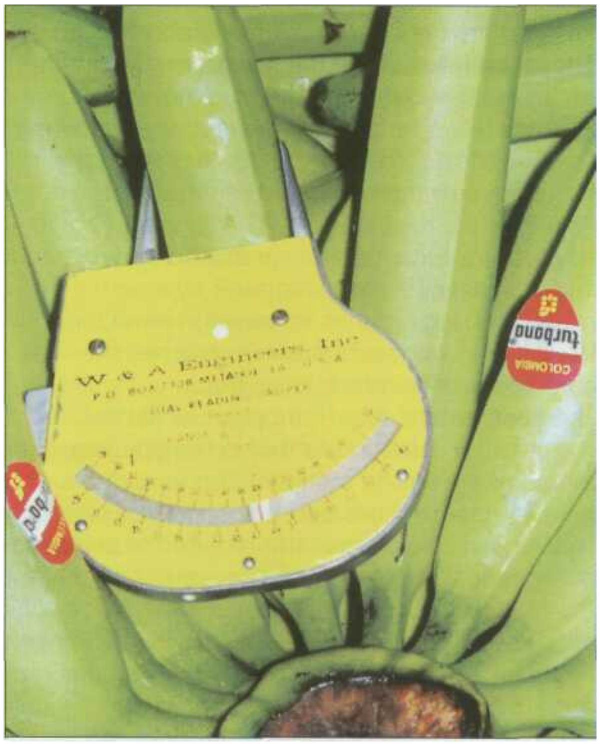
Moko disease or bacterial wilt (incited by *Pseudomonas solanacearum)* occurs in tropical America and Africa. The disease causes wilting and death of the plants infected by the parasite. This disease can also be transmitted by wasps and bees from a diseased plant to a healthy one. The initial symptoms are yellowing and necrosis of one of the three youngest leaves. The disease then spreads to the older leaves. Insects suck the sap from the scars on the bracts which have already fallen off and thus transfer the disease to the plant itself. Ultimately this leads to infection of the fruit and causes several bananas in an otherwise green bunch to turn yellow. The typical feature of a Moko-infected yellow banana is the brown, dry rot in the pulp.

In most cases adequate protection against *Moko* disease can be ensured by periodic inspection on the plantation and, where necessary, by timely sanitation, i.e. the eradication of diseased mats and adjacent plants. All cutting tools used in the destruction of the diseased mats and for pruning must be disinfected after each mat has been dealt with.

POST-HARVEST TECHNOLOGY

Harvesting

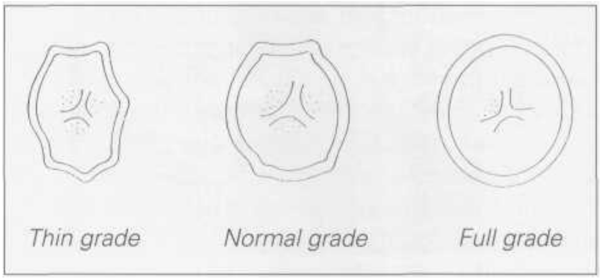
Bananas are cultivated in areas where it is warm and sunny during the day, where there is



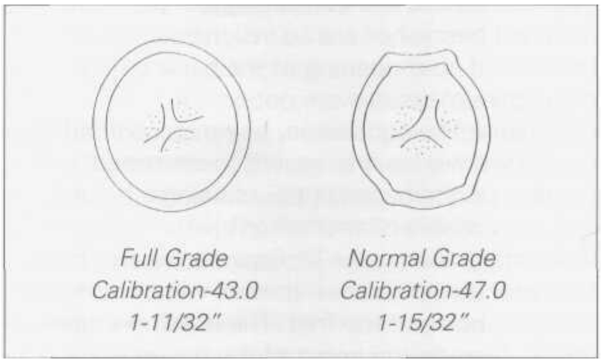
Measuring the finger fullness

sufficient rainfall at the right times, and where the soil is moist, rich in nutrients and sandy.
Banana cultivation is not linked to a particular season. This means that, despite the transport costs, fresh bananas are shipped to market at a reasonable price the whole year round.
The length of time between planting and harvesting of the bananas is dependent on the climate, cultivation practices and the cultivar involved and can vary between 9 and 18 months. Usually, the time between blossoming and harvest is also dependent on various circumstances, notably on the temperature.
Under favourable conditions the time from planting to harvest amounts to 9 months whilst, at average daytime temperatures of 24°C, the time between blossoming and harvest is approx. 90 days.
Each bunch is covered at an early stage in the fruit's development with a perforated polyethylene bag to prevent leaf scarring and ward off pest attacks. The top of the bag is knotted tight by tying a coloured tag around the stalk. By using a different coloured tag for each week, a simple record can be kept of the growing time of each fruit bunch.
The banana inflorescence contains three types of flowers. The first to emerge are the female flowers, the only flowers which produce fruit. Those are followed by the hermaphrodites (of both sexes) and then by the male flowers.
Immediately after the fruit has set, the remaining flower buds are removed so as to prevent the further development of flowers which serve no useful purpose.
After the pseudostem has produced a fruit bunch, it dies off and is replaced by a new pseudostem which has sprouted in its vicinity.
Usually the old pseudostem is chopped off completely once it has borne fruit.
The bananas are cut off the plant whilst still green and are ripened further in the ripening rooms of the selling markets. The time of maturity for cutting is determined by the clone or cultivar and also by the time required to ship the bananas to the customer. For overseas markets the fruit can be cut at between 70 and 90 days after flowering and for more nearby markets at between 110 and 120 days. Maturity can be measured by counting the number of days from "shooting", by inspecting the colour-coded tags or by measuring the diameter of the bananas.

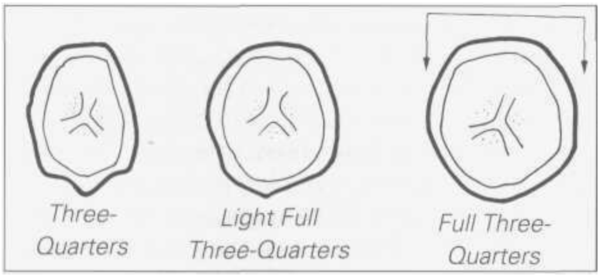
Usually, the ripeness is assessed by looking at the shape of the fingers. We then refer to the "grade" of bananas. In this context, the "grade" is a term used to describe the relative maturity of a banana. The terms used are "thin grade", "normal grade" and "F (= full) grade".



As we can see from the illustration above, the grade is judged by the relative prominence or absence of ridges when the banana is viewed in cross-section. As the pulp ripens, it begins to round out and become better defined, so that it is more easily separated from the peel.
The various stages in the shape of the banana can also be indicated as follows: "Three-quarters"; "Light Full Three-quarters"; "Full



Three-quarters"; and "Full".
If the bananas are destined for export to overseas destinations, they are usually cut when "three-quarters full". However, cutting at this grade does involve making a compromise on weight. In fact, the weight increase between the 80th and 90th day after blossoming is 5 times higher than in the 80 preceding days. The farmer will therefore want to cut the fruit as late as possible. This is where fast transport proves its benefits: it gets the fruit to market on time, with no loss of quality in such late-harvested fruit.



Calibration

Calibration is the measurement of a banana's diameter (either in mm or in 32nds of an inch). This, too, is referred to as a "grade" but it should not be confused with the grades as defined above. The banana's diameter is measured with the aid of callipers. Though the scale of values for the diameter can be expressed in different units (e.g. in mm) the "grade" is predominantly indicated in 32nds of an inch. Generally speaking, the "grade" is understood to mean the diameter of the middle outside finger of a particular hand. The bananas for nearby markets are harvested at grade 44-46, but fruit destined for shipping over long distances must be picked at a "thinner" grade, e.g. 41-43 (3.25-3.41 cm).
We would point out that, as can be seen from the illustration, it is possible that fruit measuring 43.0 (1-11/32") may be "full" grade, while larger fruit measuring 47.0 (1-15/32") may only be "normal" grade and the less mature of the two.
Roughly speaking, Cavendish bananas harvested for overseas markets will be cut from the plant when the finger length is at least 16-18 cm and when each finger has an average weight of 150 grams.

The harvesting process

Harvesting of bananas on the plantation is carried out by two people, i.e. the "cutter" and the "backer". After the props have been removed, the cutter uses a machete to chop partly through the pseudostem at mid-height. The weight of the bunch then causes the stem to bend downwards where it is carefully caught by the backer. The cutter then severs the stem completely just below the bunch.
The bunches, particularly "late-harvested" bunches, are very vulnerable during transport. Most modern plantations have cableways which run from the plantation to the packing station. The backer takes the bunch to the nearest cableway and attaches the foot of the stem to the roller which runs over the cable. A small tractor then pulls a "train" of banana stems via this "aerial tramway", first to an area where they can be temporarily stored in the shade, later to the nearest packing station for further processing. Since an "aerial tramway" involves a substantial capital outlay, the stems are still transported on many plantations by the more traditional methods of carts, trucks or trains.

In some cases the hands are cut from the stem whilst still in the field. If "dehanding" is carried out in the field instead of in the packing station, then the latex flow exuding from the cut surfaces is immediately stopped by covering them with a "crown pad", a small strip of absorbent material impregnated with a fungicide.

Packing station

Upon arrival in the packing house the bunch is checked as to finger fullness, finger length and possible damage marks. Bananas which reveal any damage, e.g. because of insect activity, pathogens and the like, or which have broken fingers, are removed. After that the "dehander" uses a sharp, curved knife to detach the hands from the banana stem. The hands are then placed in the dehanding tank. Here, the fruits are cleaned by flowing water.
It is important that the crown should be severed at the right height. If the hand is cut through too close to the finger neck, the resultant cutting wounds will increase the risk of finger rot caused by fungal growth. Fungi may colonise the withered flower remnants. At a much later stage they may then move into the fruit, causing it to rot. This is the reason why the dead flowers have to be carefully removed from the fingers before dehanding. Upon outturn these dried flower remnants will not only detract from the fruit's general appearance and reduce its consumer appeal but will also form a source of fungal growth, with the result that the flesh at the blossom end and around the vascular bundles as such will later be found to have a black discoloration, or to have rotted.
The dead floral parts are picked out of the dehanding tank by workers known as "selectors". These people also remove

Measuring the finger length

Detaching the hands

Dehanding tank

excessively small or misshapen fruit and divide the hands which are too big into clusters. To prevent further exudation of latex, the fruit is sometimes transferred from the dehanding tank into a "delatexing tank" filled with clean, flowing water. In the delatexing tank the clusters are left to float for a further 20 minutes or so until all the latex flowing from the cut on the crown has been washed off. In a modern packing station the fruit is immersed yet again before it is moved to the packing area. This final immersion bath consists of a solution of alum and fungicide. The alum serves to reduce possible discoloration of the fingers which have been in contact with latex.

Crown rot

We now come to an aspect of crucial importance in the banana transport industry. At the point where the banana is severed from the stalk, a wound is created from which the sap (latex) flows from the green banana. The latex which flows onto the fingers of the bananas causes stains which make the fruit less attractive in appearance. To ensure that the exuding latex is coagulated, the hands are therefore immersed as quickly as possible in the dehanding tank.
Another important function of the dehanding tank is to allow the removal of withered floral parts and dirt. The problem is that fungus spores from the bananas and from the fragments of dead flowers floating in the tank penetrate and infect the cutting wounds on the hands. The result is "crown rot".
In Chapter 6 we already discussed the consequences of crown rot and the measures taken to prevent it. For the sake of completeness we would point out once more that the risk of crown rot is higher if the plant has been grown during a prolonged period of warm, humid weather. For Central America this is typically the period between April and September. If, upon outturn, the mould is found only in the crown top, allowance should always be made for a very rapid further growth of the mould during subsequent ripening.
The risk of crown rot can be countered by taking proper hygienic precautions. Apart from working with clean tools, e.g. knives and other implements, the most important aspect is that the packing stations should be free of discarded fruit waste and that the cascade tanks should be

regularly flushed through with clean water. Sodium hypochlorite or another fungicide is added to the water in the tank to destroy the fungus spores. To prevent mould growth during transit the packing process is completed by dipping or spraying the crown with a benzimidazole solution.
After removal from the water tank, the hands or clusters are labelled with the producer's brand name and are then packed into vented, corrugated fibreboard cartons lined with polyethylene bags or, alternatively, they are packed into "Banavac" bags. Polyethylene bags serve to protect the fruit against abrasion damage and moisture loss. Vacuum-sealed film packaging ("Banavac" bags) creates a modified atmosphere climate which surrounds the packed fruit and thus reduces the risk of *crown rot.*

Anthracnose

As described in Chapter 6, the fungus called *Colletotrichum musae* is the causative agent of Anthracnose, a fungal disease which produces black or brown blemishes on the peel of green as well as ripe fruit. Anthracnose infection develops on fruit which has been damaged by bruises or scratches. An elongated, slightly diamond-shaped blemish, coloured brown to black, forms on the peel of the green fruit. Severe infections generally promote the ripening process and so the size of these lesions may also increase during ripening. Measures taken to prevent scarring and bruising both during growth and after harvesting will reduce the risk of anthracnose. A fast "cooling-down time" limits the growth of the fungi, thus inhibiting the further development of anthracnose during transport. Thiabenzadole is also applied inside the packaging to slow down fungal growth and thus preserve the fruit's quality during transit.

Stem-end rot and spot rot

The foregoing descriptions of post-harvest diseases clearly demonstrate that fungi are the principal causative agents. In chapter 6 we discussed the fungal spoilage of fruit in detail. As we saw there, one group of fungi can only penetrate the fruit via existing open wounds, whilst the other group can also gain entry through a healthy skin.

Spraying the bananas

Packing the bananas

Bruises, insect punctures and cutting wounds in particular are the areas which are vulnerable to attack by post-harvest decay fungi.

Stem-end rot and finger rot are caused by the fungus *Thie/aviopsis paradoxa* which attacks and infects the cutting wound suffered during the harvesting process. Before the banana begins to ripen, it has a good resistance to fungal attack, but this resistance decreases as the fruit becomes more mature. Latent infections are created if a fungus tries to penetrate the fruit but is (for the moment! unable to develop further because of the fruit's resistance. The infection will then provisionally come to a standstill but remain latent and later resume its development as the banana becomes riper. Fungi reproduce asexually via spores. The spores of all post-harvest pathogens require a number of hours of high humidity or freely available water if spore germination is to be successful.
There are various fungi which produce fruit spots on the banana. The most common types of fruit rot are: "pitting disease", "brown spot" and "diamond spot". For these diseases, too, the rainy season is the most dangerous period as regards fungal growth. If the spots are already visible during packing, the bananas should be refused for shipment. In most cases, however, the problems are caused by latent infections which develop during transport
As we have already seen, the washed fruit is subsequently dipped in a thiabenzadole (TBZ) solution so as to prevent fungal growth (specifically crown rot). Spotting is also countered by using fungicide-dusted bags or by spraying the fruit prior to bagging.

Physiological disorders

In addition to the previously mentioned non-infectious disorders like *yellow pulp* and *maturity stain,* other physiological disorders include the breakdowns which occur as a result of undesirable temperatures.

A) Heat injury

This may occur if the fruit has been exposed for too long to direct sunlight or excessively high temperatures. Heat damage will ultimately lead to deterioration of the fruit. The usual symptoms are surface burning, uneven ripening or dehydration.
In the event of exceptionally high maximum daytime temperatures, a slight underpeel discoloration (UPD) may occur as a result of sunburn.

B) Freezing injury

This generally occurs if commodities are stored at below their freezing point. The freezing point for bananas is -0.8°C. As the transport temperature is above 12°C, freezing injury cannot play a role in the case of bananas.

C) Chilling injury

Injuries of this type may occur if fruit or vegetables are exposed to temperatures which are below a critical threshold - specific to each type of product - but are above the temperatures at which the relevant products freeze. The critical threshold for chill injuries to bananas is 12-14°C.

Chilling

Of all the post-harvest damage suffered by bananas, the most widespread damage is undoubtedly caused by chilling. Intensive research has been conducted into the causes and extent to which this type of damage occurs and the results of these investigations have been extensively published in specialised brochures.
Chilling occurs if pre-harvest or post-harvest temperatures fall to below a critical threshold temperature Clearly, in (sub-)tropical regions the pre-harvest temperature will seldom drop below the threshold temperature, especially as the polyethylene bags wrapped around the bunches of bananas also provide some extra protection against too-low temperatures. Generally speaking, therefore, chilling injury as a form of post-harvest damage is principally caused by the fact that the delivery air during transport is lower than the critical temperature.
Chilling in transit is related to the storage duration as well as to the temperature. Cavendish varieties suffer chilling damage sooner than Gros Michel varieties.
In a healthy green banana a milky viscous fluid, "latex", flows along the epidermal layer, i.e. between the skin and the pulp. This latex-like fluid serves as a form of protection. If this fluid is

no longer present, this absence may have been caused by the cumulative effect of prolonged exposure to low temperatures. The result is a breakdown of cells within the vascular tissue immediately below the outer peel surface. Chilling causes a reddish brown discoloration of the latex vessels in the peel.
The best indicators of chill in green bananas are the reddish brown specks, like Cayenne pepper spots, under the peel. Other, less reliable indicators of chill are slow latex flow and latex that is clear rather than cloudy in appearance. In order to detect the presence of this "underpeel discoloration" (UPD), a thin sliver of the skin tissue must be carefully sliced from the edge of the epidermal (peel) layer. This may reveal a rusty colour in cases where chilling has occurred.
When investigating UPD it must be remembered that, when a banana is cut open, latex will flow both from the peel and from the pulp. During its initial flow, latex is a milky white fluid, but it soon assumes a brown colour because of the oxidation of the tannins. As the fruit ripens, the latex becomes clearer and flows less readily. When the skin is peeled off, therefore, a rusty colour as a result of oxidation must not be confused with a rusty colour due to chilling.
After ripening of "chilled" bananas in the ripening rooms, they will be seen to have ripened "unevenly"; their peel will have a dull yellow/grey colour. In serious cases of chilling injury the peel will even have a dull grey colouring. This colour difference is the result of necrosis of vascular tissues in the peel.
Obviously, the length of exposure affects the severity of the symptoms, but it still remains difficult to predict the extent to which the peel colour will have been affected after ripening. Apart from the severity of the chilling injury, in fact, an important role is also played by the ripening procedure applied in the ripening rooms. Only in serious cases will the pulp and flavour of the banana be affected. The consumer will as a rule not notice any change in the flavour. But the dull yellow colour of the peel does make the banana look less appetising. To complete the picture, we would add that there is also a more severe stage of chilling in which the fruit is so seriously damaged that it fails to ripen at all.
Apart from the temperature, other factors also have an effect on the chilling of the fruit. These factors include:

1) The ripeness of the banana: ripening fruit is more susceptible to chilling than pre-climacteric fruit. Remember: ripening may already have started if the bananas have been stored in a non-cooled environment for longer than 20-24 hours after harvesting.
2) The exposure duration[1] as can be seen from the above, too-low a carrying temperature during a certain number of hours is much less harmful if it occurs at the beginning rather than at the end of the transport period.
3| The relative humidity: the higher the R.H. of the storage air, the longer the banana will be able to withstand a temperature which is too low.

Note: Bananas which were superficially wet when harvested during the rainy season will subsequently evaporate water during the cooling-down period. In the air flow this evaporated water will give rise to a strictly localised "super-cooling" effect in the surface layer of the peel. The resultant UPD injury is also referred to as "September chill". It goes without saying that this phenomenon is not restricted solely to shipments made during September!

4) The place in which the bananas have been stowed: if the carrying temperature during transport has been too low for too long a period, then specifically the bananas stored close to the air delivery side will be the most vulnerable to UPD.

The green life of the banana

In the pre-clirnacteric stage even a small quantity of ethylene will accelerate the ripening process. On the other hand it has been found that during a brief period (approx. 20 hours] immediately after harvesting, the fruit is unsensitive to the effects of ethylene. We already noted in chapter 3 that during maturation the fruit shows distinct changes in respiration pattern, ethylene production, colour of the peel and permeability of the peel. Since these factors play an important role as regards maintaining good transport and storage conditions, we will discuss them briefly below.

Cut bananas have three stages in their life cycle:

First period: the fruit remains green and its respiration rate at any given temperature stays roughly constant.

Second period: this is marked by a rapid increase in the respiration rate to a peak more than four times that during the first period. After peaking, the respiration rate falls rapidly again to about two to three times that experienced during the green stage. This second period is called the "climacteric". During this stage, however, there is no visible change in the fruit's outward appearance, i.e. it remains hard and green.

Third period: this is the ripening (maturation) stage when the colour changes to light green and then to yellow (ripe). Finally, black spots begin to appear on the peel surface; these spots spread until eventually the peel turns completely black. The bananas become progressively softer during this period and the starch in the fruit is converted into sugars.

Respiration

Respiration in fruit is similar to that in mammals: oxygen is absorbed from the atmosphere, whilst carbon dioxide and water vapour are released into the atmosphere.
A problem with the carriage of banana cargoes is that bananas release traces of ethylene gas as they breathe. Green fruit has a very low rate of ethylene release and can therefore be stored in a recirculating atmosphere for a long period. The rate of ethylene production increases more than thirty-fold during the climacteric stage and remains high in the third period of the banana's life cycle.
Ethylene promotes ripening and, even at concentrations of as low as 0.8 ppm, it will significantly shorten the green life of bananas. It follows that, once part of a cargo of bananas starts to ripen, the ethylene produced will trigger ripening of the other still-green fruit.

Quality standards

As described previously, checks are made prior to shipment to make sure that the fruit complies with the various quality standards for export products. The sales contract that has been drawn up between the buyer and the seller usually sets out the quality specifications which the fruit has to comply with before being shipped.
Quality specifications are important not only for the carrier but also, in the event of damage, for the quality controllers. Since we will be discussing some of these requirements and specifications below and in the next chapter, here is a list of the way in which these quality standards might be worded in a contract:

Checking the UPD

Checking the seedbed

(a) first class fruit with green coloured peel;
(b) fruits must be sound, fresh, clean, without any defects, pests and/or damage caused by pests, and without mechanical defects;
(c) finger length (e.g. 16-18 cm); grade (e.g. 32-34 mm);
(d) minimum mass of fruits (e.g. 100 g), fully green, physiologically mature;
(e) permitted tolerance for yellow bananas; a tolerance (e.g. of 2%) has been agreed for light or moderate defects, such as mechanical damage, scars, latex stain, and broken necks;
(f) bananas packed in standard cartons; approximate gross weight (e.g. 20 kg); weight of empty cartons (e.g. 1.70 kg);
(g) bananas will be cut in clusters and wrapped in strong polyethylene bags under vacuum; bags will be long enough to ensure proper sealing

Types of packs

Since about 1960 bananas have no longer been transported "on the stem" after being harvested, but have been shipped as clusters packed in cartons. The packaging consists of telescoping, double-faced corrugated cardboard boxes provided with ventilation holes and grip openings. A standard carton contains an approx. net weight of 18 kg of fruit packed inside a polyethylene liner bag. The material used to manufacture the cartons and, specifically, the material used for the plastic liners have an essential role to play as regards the keeping properties (shelf life) of the bananas. There are two types of plastic bags in common use[1]

(a) "Polypack", a perforated or non-perforated plastic bag.
(b) "Banavac", a modified atmosphere (MA) polyethylene bag invented by Badran (US patent No. 3450542, assigned to the United Fruit Company in 1969)
The modified atmosphere is created by packing the bananas in a polyethylene bag of a specified thickness and gas permeability, such that a suitable oxygen and carbon dioxide balance is obtained by the respiration process of the fruit itself.

"Banavac" bag

Banavac bags are intended to create a low oxygen atmosphere of around 2% and to increase the carbon dioxide content to about 5%. This serves to prevent ethylene, the ripening hormone (a volatile gas produced by the bananas themselves) from ripening the fruit in the package, whilst at the same time avoiding anaerobic respiration. Banavac bags are principally used during long transit times to extend the green life of the fruit.
As we have meanwhile learnt, the rate of respiration at a given temperature is related to the oxygen content in the atmosphere. If the oxygen content is lowered, the fruit's respiration rate will decrease. The respiration rate also decreases if the carbon dioxide concentration is increased These physical factors form the basis for the principle of how the Banavac bag works. The polyethylene film is relatively permeable to both oxygen and carbon dioxide. However, if gas transmission is to take place through the film, the concentration on one side of the film must be higher than on the other. In principle, the oxygen concentration inside the bag will decrease as oxygen is absorbed by the fruit. However, because the rate of oxygen permeation through the film is dependent on the difference between the concentration of oxygen inside and outside the package, the rate of permeation will increase until the oxygen will eventually pass through the film at about the same rate as it is being absorbed by the fruit. The same mechanism in reverse applies to the carbon dioxide, whose concentration inside a bag will increase to an elevated level and will then remain roughly constant.
Given the fact that the bags possess a certain permeability to gases, the composition of the surrounding air in the ship's hold is obviously also of crucial importance if a proper balance is to be maintained in the gas composition.
Despite the ideal MA conditioning offered by such a packaging form, it may none the less occur in practice that bananas shipped in Banavac bags sometimes ripen prematurely. Upon outturn, or usually at a later stage during storage,

it is then found that, although the banana looks healthy and green, its pulp reveals symptoms of premature ripening or has even turned soft.

The explanation for the above phenomenon is as follows Bananas will suffer physiological damage if the oxygen concentration in the atmosphere is too low or the carbon dioxide concentration too high. The packaging system is therefore designed to ensure that a steady state situation is created well before either of the two gases reaches its critical concentration. However, if the respiration rate is raised and specifically if the carbon dioxide concentration in the circulating air has been raised because of ripening fruit in the second or third stages of its life cycle, then the $C0_2$ content inside the bag of green fruit may increase to above the critical value If this high $C0_2$ concentration is maintained over a long period, the metabolism of the bananas inside the MA packaging will change in such a way that the pulp will soften but never ripen properly, whilst the skins will remain green.

Unsatisfactory outturns of bananas packed in Banavac bags

Although MA packaging may reduce the risk of unsatisfactory outturns of bananas at the port of destination, it still does not fully rule out the possibility of damage. Since damage claims may involve substantial amounts of money, it is important to emphasise several essential aspects which may give rise to damaged products.
As mentioned earlier, bananas will suffer physiological damage if the oxygen (0_2) concentration is too low or the carbon dioxide ($C0_2$) concentration is too high. The original Badran patent for MA packaging defined limits of 1 % to 5.5% for oxygen and 2.5% to 7.0% for carbon dioxide. We would remark here that, since a concentration of 1 % for oxygen is very close to the level at which anaerobic respiration is a realistic possibility, our suggestion for the ideal oxygen concentration would in all probability be between 2% and 3%.

As we saw earlier, the atmosphere inside an MA package is produced by the combined action of two factors: the respiration rate of the fruit, and the permeability of the package. If an MA package fails to perform satisfactorily, then this must be attributed to one, or a combination of more than one, of the following four possibilities:

(a) the volume of the atmosphere to be modified inside the bag;
(b) the holding temperature of the package;
(c) the inherent permeability of the plastic film;
(d) the thickness of the film.

With regard to (a): once a suitable volume of the bag has been tested and proven in practice, it should be rigidly adhered to. The free volume of the bag is always strictly controlled in experimental work, but it is always much more difficult to maintain that consistency of volume in cases involving a large number of growers who utilise numerous packing stations. It is important that the bags should be tied tightly before being placed in the cartons. If the bags have not been properly tied or have simply been folded, then this will have a negative influence on the bananas packed inside them.
As regards (b): the temperature of the fruit at the time of packing and for up to about 25 hours thereafter is of critical importance. In fact, the temperature effectively controls the fruit's respiration rate and therefore, if all other factors remain constant, it also governs the speed at which the required internal atmosphere is created.
Ethylene has virtually no effect on bananas for some 24 hours after the fruit has been cut from the parent plant. Consequently, that is the length of time which is available for the oxygen content of the package to be reduced to the required low level if the system is to work to the best attainable benefit.
Since both very high and very low temperatures will reduce the rate of respiration, the fruit should preferably not become overheated or be unduly cooled during, say, the first 20 hours after cutting.

Finally, referring to points (c) and (d), the permeability and thickness of the plastic film: there is a theoretical possibility (albeit most unlikely in practice) that the manufacturer may have modified the polymer's permeability characteristics. As regards the film's thickness, a gauge suitable for one specific combination of factors may prove unsuitable for use in other circumstances.

CHAPTER 14

TRANSPORT AND RIPENING OF BANANAS

Quality control prior to loading

The Master is responsible for the stowage and carriage of the cargo of fruit. He also has to sign the bills of lading (Bs/L). Bills of lading which contain no special remarks about the conditions of the cargo or the packaging are known as "clean bills of lading." If the conditions of the cargo as delivered to the ship gives rise to comments, then these comments must be recorded on the B/L In such cases we refer to "foul bills of lading". It is therefore essential that the ship's officers should supervise the loading and unloading operations and check the quality of the fruit and the packaging.

Under the "Hague Rules", however, the carrier is not liable for damage which results from the nature of the cargo or, specifically, from internal defects. In charter parties the liability for damage due to "internal vice" is likewise excluded.

The time between harvest and loading must be as short as possible. Bananas are normally loaded within 24-30 hours after harvest. If the harvested bananas have been stored for more than 24 hours in a non-cooled storage place, then ripening may already have commenced If the bananas are transported to the ship in non-refrigerated trucks, as is usually the case, then the fruit must have been protected against direct sunlight both during transport and during possible prior storage.

Before loading, measurements must be made at random of both the pulp temperature and the outside air temperature. The pulp temperature may exceed the ambient temperature by at most 2°C.

Pulp and ambient temperature must be recorded in the refrigeration log. If the pulp temperature is too high, the cargo must be refused or the Master must at least protest in writing to the shippers.

The bananas are checked as to maturity, shape, texture, skin and flesh colour, and freedom from decay, bruises, scars, latex stain, mechanical damage and other defects. Defects are understood to include all blemishes that affect the skin and pulp, such as bruising and scarring. This relates in particular to bruising, as bruising has a direct negative effect on the pulp. Scratches and punctures caused by insects or animals may also provide a means of ingress for pathogens. Any or all of these defects may cause the yellowing fruit to develop dark marks or blotches on the skin, collectively known as "scarring".

An assessment of the fruit depends very much on the quality category involved. In the sales contract, for example, the bananas may be described as "Category I" or "Category Extra", or as "first class" or "first class extra". However they are described, the requirement set for category 1 or "first class" is that the fruit should be of good quality, whilst some slight defects are allowed as long as these do not detract from the general appearance or uniformity. The "first class extra" category is expected to be of superior quality, free of defects, no malformation and without the slightest trace of defects on the fingers or the crowns. In the first case the agreed quality and grade tolerance will be much wider than in the second case.

If dehanding is done in the field, then the crown will have to be covered immediately after cutting with a "crown pad", a small strip of absorbent material impregnated with a fungicide. This pad serves to staunch the flow of latex and prevent further infection (e.g. *crown rot).* Usually, dehanding takes place in the packing station where the crowns are treated with a fungicide either by dipping or spraying. Immediately after the fungicide treatment the colour of the crown is light brown but, as time passes, the cut surface oxidises. The longer the period before the bananas are loaded, the darker the colour will become, eventually turning dark brown. The surface of the crown will ultimately assume a white colouring because of oxidation and

dehydration. The colour of the crown can therefore be used to check whether the fruit was in a fresh condition when loaded on board. If the bananas were fresh, the crown must still exhibit a light brown colour, like a milky cocoa drink, and the cut surface must still be moist.
Charter parties always contain the description "fresh green bananas". It is therefore up to the carrier to check that the fingers are indeed fresh and firm and that the skin is dark green without a trace of yellowing. If the fruit has been exposed to direct sunlight, a trace of mild yellowing may sometimes be seen on the heel of one or two fingers of a hand. If this is the cause of the discoloration, then there will in practice be no further adverse effect on the condition of the banana during storage

The pulp must be hard and crisp and, especially in fruit destined for distant markets, the edges of the skin must be sharp. Insect bites can be identified by rubbing over the peel which will feel like sandpaper. Insect bite damage should not, however, be confused with "rainspots" which cause small rounded spots on the peel.

As mentioned before, the latex fluid between the skin and the pulp serves as a protective barrier. The internal condition of the pulp can be examined by cutting through the banana diagonally. The latex should then flow out as a clear viscous sap. This is known as "bleeding" the banana. The ripeness can also be checked by cutting through the banana transversely or breaking it and then by pressing the two parts together again. Then the two parts should be slowly pulled apart slightly. Thin glutinous strings of a thick milk-like sap (latex) should then join the two halves together until they are a slight distance apart. If this is not the case, then the banana is dehydrated. Be careful while doing this, as the latex leaves indelible stains on clothing!

Shock damage: To avoid mashing and internal bruising, cartons of bananas must not be roughly handled or dropped from any height. The consequences of rough handling of banana cartons are: first, external damage to the fruit. Bananas at the top of the carton will mash those on the bottom, splitting fingers and breaking necks. Broken fingers occur above all when the fruit is still hard and green. Second, mishandling will result in internal damage to the fruit, possibly accompanied by external scarring. Internal damage is indicated by a dark streak running through the centre of the finger.

Box burn: In this case the quality of the pulp is not affected. There is only external damage caused by direct (friction! contact between the banana and the box. This may be due to the fact that the bananas have not been packed properly in the polyethylene film. Such damage manifests itself in the form of black peel and/or a black discoloration on the peel.
The packaging itself must also be carefully checked. The cartons must reveal no bulging and must be closed in such a way that the ventilation openings are not blocked off. The bananas inside the plastic packaging must be dry.

Shipboard checks prior to loading

Before the fruit is loaded on board the decks must of course be in a clean condition. The delivery air and return air ducts must be free of any obstructions. The gratings must be properly maintained and in good condition. The reefer certificates and all other appropriate certificates should be valid and in good order. Generally speaking, the shipper will also require that the holds have been pre-cooled, e.g. to S^0C, prior to commencement of loading.

The loading operation

The cartons should be stowed so that they align with each other in order to achieve maximum ventilation. As far as is possible, the cartons must be stowed with the carton ends in a lengthwise direction along the hold The top tier of boxes must have an air space of at least 10 cm between the top of the cartons and the deckhead. To prevent obstruction of the return air, the general rule on modern reefers is that the clear space above the topmost tier has to be 1 % to 2 times the height of the grating. We may assume that the staff officers of a reefer are sufficiently familiar with method in which the cargo has to be stowed. Solely for the sake of completeness, however, we will briefly mention a few of the important aspects again

Cartons should not be stowed in a position where they obstruct the return air openings in the cooler room bulkhead. This is achieved by omitting the final two cartons on the topmost tier in front of the return air screen. The last two cartons on the next-lower tier are also omitted, although it is sometimes possible to leave out only the final carton in this tier. The method of stowage close to the return air screen is of course also dependent on the height of the screen and the space that is left over between the topmost tier and the deck.
If there are not enough cartons to load the entire hold, then the "stepping down" method is applied in the case of break-bulk cargoes. This method means that the stacking height is gradually reduced in steps towards the return air screen. Obviously, the gratings must remain completely covered. In this method, therefore, the bottom two tiers cover the full length of the hold.
If a part of the hold has to be kept free, then the uncovered grating area must be covered with a plastic sheet or kraft paper so as to prevent "air bypass". Several laths are placed on top of the plastic sheeting to weigh it down and these can also be nailed to the gratings if the vessel is fitted with wooden gratings. Where palletised cargo is being carried, the edges of the plastic sheeting are folded upwards against the bottom cartons on the pallets and nailed with wooden laths against the pallets.

In some instances the shipper will also want cartons to be loaded in the hatch coamings. The drawbacks here are that the hatch coamings are less effectively insulated and also the fact that the stack height, which is normally 8 to 9 tiers high, may now reach a height of *as* many as 12 to 13 tiers. This, of course, brings a more-than-usual pressure to bear on the bottom tier. To compensate for this and also to ensure sufficient ventilation in the ha'tch coamings and to prevent the cartons from coming into direct contact with the coamings, the cartons along the edges of the coamings are stacked diagonally. The outermost cartons are then stacked in such a way that only a corner of the carton will touch the coaming Another solution is to place dunnage between the coamings and the cartons, which then enables the cartons to be stacked in the same pattern as in the hold

Bananas, as we know, belong to the category of climacteric fruit. In the preclimacteric phase they have a moderate ethylene production (1 to 10 microlitre/kg/h), but they are highly sensitive to ethylene action. At 25°C their carbon dioxide production amounts to approx. 45 mg/kg/h, whilst at 13.3°C it is approx. 16 mg/kg/h. The specific heat is approx. 3.40 kj/kg x °C and the heat production (green bananas) is approx 130 W/t at 25^{n}C and approx 45 W/t at 13.3°C. We would point out that the heat production and $C0_2$ production of bananas increases enormously during the climacteric phase, i.e. during the commencement of ripening In the climacteric phase the $C0_2$ production at 13.3°C is 50 mg/kg/h and the heat production is approx. 125 W/t. At 20°C these values are roughly 145 mg CO_2/kg/h and 400 W/t respectively. The stowage factor for palletised cartons amounts to approx. 2.9 cbrn/t (102 cft/t).

The pulp temperature of palletised fruit decreases much more slowly than that of bananas packed in "loose" cartons. Especially in the case of palletised cargo therefore, an effective air circulation THROUGH the cargo is required. This is obtained by stowing the pallets as close together as possible.

Before departure the following documents are made available to the ship's officers:
- Cargo Manifest
- Commercial Invoice
- Bill of Lading
- Phytosanitary Certificate
- Phytopathological Certificate
- Weight Certificate
- Quality Certificate
- Certificate of Origin.

Carrying instructions

The terms used in the carrying instructions may include the following:

Reduction period:

the time required to reduce the return air temperature to 2°C above the delivery temperature required for carriage.
This period is also known as the "cooling

down period". The duration of the cooling down period is between 10 and 30 hours.

Air cooling time:

the time it takes for the delivery air to reduce to the ambient temperature specified for the cargo.

Cargo cooling time:

the time required for the cargo to reach carrying temperature. The cargo cooling time is much longer than the cooling-down period and takes about 30 hours on an modern reefer. When cooling is complete, the difference between the delivery and the return air temperature will approach a constant value in the order of 0.5°C to 1 °C.

Chilled:

a condition in which bananas have been exposed to a temperature below the required carrying temperature. The "chilling" of products is governed by the temperature of the hold air and the duration of the exposure.

Carrying temperature:

the temperature of the delivery air.

Minimum pulp temperature:

this is the lowest pulp temperature at which the bananas do not run a risk of becoming chilled. In practice, this temperature is 0.3 - 0.5°C above the chilling temperature. The carrying temperature is mainly determined by the cultivar. The most common carrying temperature for Cavendish cultivars is 13.3°C.

The bananas may be packed in perforated or non-perforated Polypack bags or vacuum-packed in Banavac bags. Since the heat of conduction is lower in a vacuum pack than in a Polypack, the specified minimum pulp temperature for vacuum-packed bananas is 13°C, whilst that for Polypack bananas is 13.3°C.
Various carrying instructions exist for the transport of bananas. Though broadly similar, the instructions do reveal some differences, particularly as regards the loading method and carrying temperature. One major difference, for example, is whether or not a "shock-treatment" period is applied as part of the cooling-down procedure. If a load has to be taken on board in two ports and the hold was only part-loaded in the first port, after which shock treatment was applied, then once the second part of the cargo has been loaded in the next port, it is not possible to apply a shock treatment again in the same hold. The carrier must of course adhere strictly at all times to the instructions he has received from the shipper.

For bananas packed in perforated Polypack bags the carrying instructions read as follows:

> "Immediately after the completion of loading of a cooling compartment decks are to be closed and the delivery air temperature to that compartment is to be reduced to 13°C, utilising full refrigeration in order to produce the required air delivery temperature within the shortest period."
> "As soon as the return air temperature has reached 14°C, the delivery air temperature should be immediately raised to 13.3°C, and maintained at that level throughout the voyage. During the shock-treatment period, fresh air renewal flaps are to remain closed but not for longer than twenty-four hours".

As a further illustration we reprint below a part of the "Uniban" carrying instructions as issued by the Isabella Shipping Co. Ltd. (Bermuda). These cooling instructions apply to bananas vacuum-packed in Banavac bags for a sea voyage lasting 10 days or longer.

Schematic overview of the Cooling instructions:

During loading; fans at low speed and refrigeration in operation.
Whenever the refrigeration is not permitted to be operated during loading then vent the holds for 15 minutes at full speed before closing the hatches.

Close the hatches

Delivery air to be set at 11.2°C and air circulation fans at full speed.

When the delivery air temperature has been brought down to 13 3°C, the shock-treatment period starts.
When the delivery air temperature reaches 11,2°C, raise the delivery air temperature to 128°C.

Once the delivery temperature is brought back to 12.8°C then the shock-treatment is completed. To avoid chilling this period must not last for longer than a maximum of six (6) hours.

When the pulp temperature or the return temperature reaches 13 3°C, raise the delivery temperature immediately to 13.3°C.

Note: in all cases the delivery temperature of 12.8°C should never be maintained for a duration longer than 24 hours at the utmost

Maintain the delivery temperature of 13.3°C throughout the rest of the voyage.

Issued by Isabella Shipping Co. Ltd. (Bermuda) August 1993

Air refreshing and fan speed

The fresh air renewal flaps should remain closed during the cooling-down period but are not allowed to remain closed for longer than 24 hours after loading of each cooling compartment has been completed and after the hatch has been closed. Once fresh air ventilation has been started, the air renewal flaps should be regulated proportionally so as to maintain a $C0_2$ content of 0.2 - 0.3% in the cooling section.
During the winter season, when the ambient temperature shows signs of falling below 13.3°C, the refrigeration process should be discontinued in good time so as to prevent the carrying temperature from dropping below the instructed temperature. In this case the cargo must be vented twice daily for thirty minutes each time, whilst keeping a careful check on the delivery air temperature.

On ships with a secondary brine cooling system it may sometimes prove necessary during the winter season to raise the delivery air temperature prior to outturn. To achieve this rise in temperature the brine may need to be heated During the heating process the fans must be operated at all times in order to reduce the difference between the delivery and return air temperature and to produce a uniform temperature throughout the cargo. It is important that the fresh air intake is not closed during the heating process, except where unusual conditions exist

Another essential point to remember is that the cargo temperature should be reduced as soon as possible. The maximum amount of refrigerant or brine should therefore be circulated through the cooling batteries in order to achieve the required air delivery temperature within the shortest possible period
As soon as cooling of one section has been completed and the hatch has been closed, the air circulation fans should be operated at maximum speed for the entire voyage.

Temperature recording

All carrying instructions contain rules about recording the temperatures and the $C0_2$ content. Rules are also given about the frequency of recording these data in the refrigeration log and the times when information has to be transmitted to the shipper. Frequently, the instructions also contain the sentence "pulp temperatures are to be taken and recorded at least twice daily". Such a definition may give rise to misunderstandings, especially in the event of claims.

On some reefers the pulp temperature can be measured in the cooler rooms during the voyage. As these measurements can usually only be taken in one location, these pulp temperatures can at most provide an indication of the general situation. If the ship is fitted with a USDA refrigeration system, this will provide a better insight into the pulp temperatures throughout the entire ship.

However, this still leaves us with the question: what is meant by pulp temperatures? Obviously, the pulp temperature is the temperature measured inside the product. Though the carrying instruction may clearly state the words

Discharge of bananas

"pulp temperature", it is sometimes found in practice that the shipper does not want the sensor to be inserted through the bag to measure the pulp temperature. The usual practice, therefore, is to place one sensor between the first and second tiers and to place a second sensor between the two topmost tiers The reason for this is that the temperature in the two bottom tiers and in the top tier will decrease first. In our view this method gives a more reliable picture of the situation and is therefore preferable to measuring the pulp temperature. To rule out misunderstandings, therefore, the carrier must ask for clear instructions. We would point out here that the pulp temperatures are always higher than the ambient temperatures. It will also be clear that the reading taken for the delivery air temperature (carrying temperature) will give the most reliable picture of the proper functioning of the installation.

Most cases of cargo damage are attributable to a carrying temperature which has been too high or too low. The result of too high a temperature is a weak banana with soft, ripe pulp. The peel is a dull yellow or green/yellow with brown marks. In the banana shipping trade, this is referred to as "cooked fruit".

Quality control upon unloading of the ship

Depending on the circumstances the fruit and the packaging may be subjected to quality control as regards the following aspects.

1) the cartons: these must be clean and undamaged; the weight must correspond to the weight stated on the box; the codes and ink labels must have been correctly affixed to the cartons.

2) The plastic bags, where perforated Polybags have been used, these are checked as to the size and location of the perforations For Banavac bags in particular a check is made to ensure that the film thickness complies with the requirements. The bags must be properly sealed and not overfilled.

3) The bananas, these are examined for possible fruit defects, finger length, grade, brand labels and net box weight. Physical defects may include' bruises, latex stains, neck injury, neck rot and crown rot. The check on the physiological condition focuses on "ripes" and "turnings" and underpeel discoloration (UPD). Fruit defects include: scarring, maturity stain, thnps spots, damaged fingers, fingers with burnt/black tips ("cigar end"), fungus damage (pitting disease) and flower remnants adhering to finger tips

The most important check relates to underpeel discoloration (UPD). We have already described how this test is conducted. This physical test serves to ascertain whether there is perhaps a lack of latex flow. The absence of latex flow may be due to the commencement of climacteric ripening or, alternatively, to chill damage.
The principal change which occurs in the pulp during ripening is the conversion of the starch into sugar. The colour of the peel is therefore important, because the colour is closely correlated with the starch-sugar ratio. Bananas ripen from the top down and from the inside out. Thus, a slight colour break, yellowing of the peel at the shoulder or yellowing of the pulp will indicate the stage of maturity.
To investigate the condition of the pulp, the banana is cut open lengthwise down the middle to reveal the seedbed. The pulp must be hard and white with the exception of the core, which is generally slightly cream in colour due to conversion of starch as part of the normal metabolic processes. As climacteric ripening progresses further, the creamy area becomes broader. Normally speaking, the cream-coloured seedbed will be no broader than approx. 14 mm and the latex must flow freely from the pulp

Grade and finger length

The grade is measured on the middle outer finger of the cluster or hand. The grade is expressed using the metric system (mm) or in 32nds of an inch. In Central and South America, a separate numbering system is used for the grade.

The table below gives various calliper readings expressed in millimetres and inches and also the grading figures used in Central America.

The grade is a variable factor which is governed

Grades in mm	Grades in 32nds of an inch	Grades used in Central America
28.6	36	4
30.2	38	6
31.8	40	8
33.3	42	10
34.9	44	12
36.5	46	14
38.1	48	16
39.7	50	18
41.3	52	20
42.9	54	22
44.5	56	24
46.0	58	26

not only by the customer's requirements but also by the availability of fruit and the duration of the voyage. For European ports grade 10-11 (33.3 - 34.11 mm) is a common size. Japan requires a small banana and so the grade for the Japanese market is 5-7 (29.4 - 31.0 mm). In the event of lengthy transit times (e.g. 26 days and longer) the bananas are harvested earlier and the grade is therefore smaller. For Banavac shipments the minimum grade in these cases is 5.
Finger length is measured on the outside curve of the longest finger on the inner side of the cluster. The most common finger lengths are between 17 and 22 cm. The European Commission has also set quality requirements for the Euro-banana. These bananas must be at least 14 cm long and 27 mm thick. They should not be excessively curved in shape. The EU has drawn up standards for bananas in Class 1, Class 1-Extra and Class 2.
A Class 1-Extra banana, for example, may only have slight damage marks on a surface of no more than one square centimetre.

Banana ripening procedures

Bananas which have ripened on the plant do not turn yellow evenly and remain dull in colour; the peel splits and the pulp will be tasteless and have a "cottony" texture. Moreover, the fruit so ripened is prone to attack from insects and disease. Bananas which are harvested while still green but which have reached a certain stage of maturity will continue to ripen if exposed to tropical temperatures. But, here again, the fruit will ripen unevenly and the peel will reveal a dull yellow colour.
To obtain a uniformly ripened banana with a shiny yellow colour and a good flavour, the fruit needs to be ripened in special ripening facilities. Here, the bananas are placed in ripening rooms which use high humidity to control the fruit's temperature as well as the natural gases produced by the fruit during the ripening process. This process may take between 4 and 8 days, depending on the stage of ripeness that is desired by the retailers.

Immediately after the fruit has been unloaded it is transported in refrigerated trucks to the ripening facilities as quickly as possible
Depending on the number of ripening rooms available and/or on the market situation and the condition of the unloaded fruit, the bananas are sometimes stored for a time in a cooled warehouse before being ripened.
During the period between unloading, transport, cold storage and final ripening the fruit must not be exposed to excessive temperature fluctuations, as this has an adverse effect on the ripening process. The ripening rooms are in principle of the same design as refrigeration rooms. They must be well insulated, as air-tight as possible and equipped with a heating and cooling installation. Just as in the case of other types of refrigeration rooms, proper hygiene and cleaning of the ripening rooms is of the utmost importance. Regular cleaning and disinfection will help to reduce the possibility of infection and, ultimately, the risk of fruit spoilage.

A modern ripening room is a vented moislure chamber where humidity and temperatures can be precisely controlled and where the fruit's normal gaseous exchange can take place.
Bananas in the green stage and in early ripening require high humidity (85-95%). PreviouslyTiis high humidity was achieved by flooding the room floors with water twice a day. Nowadays, modern ripening rooms are equipped with automatic humidifiers. Under prolonged conditions of low relative humidity even minor blemishes tend to take on a darker, woody appearance. Dehydration caused by low humidity may also result in weight loss.

Ethylene

Ripening is initiated by injecting ethylene gas (C_2H_4) into the ripening room. Ethylene gas promotes uniform ripening at the lowest possible temperatures and in a minimum of time. The gas is injected into the room when the pulp temperature is at least 15°C. The doors are kept closed for 20-24 hours after gassing with ethylene. After 24 hours at most the rooms must be vented with fresh outside air twice a day for at least 30 minutes each time. Since the bananas are alive, the oxygen in the room needs to be replaced if they are to survive. The "gassing time" must therefore not exceed 24 hours. Ethylene gas is explosive at concentrations in excess of 3 to 34% V / V The recommended dosage for ripening bananas is 0.1 % or one cubic foot of pure ethylene for every 1.000 cubic feet (1 litre per 1 m^) of room or air space. It would take 27 times this quantity of gas to reach an explosive concentration.

It is virtually impossible for the cell to be made absolutely air-tight in practice. Leaking rooms are a frequent problem and often cause uneven ripening of the fruit. Uneven ripening is prevented by admitting more ethylene than the required dosage. To distribute the ethylene effectively and to remove the respiration heat, vigorous air circulation is necessary.

Ripening

A proper ripening process is of decisive importance for the quality of the ripe, ready-to-eat banana as regards its colour, flavour, aroma and, in particular, its shelf life. It is important that the desired colour is uniformly achieved throughout the entire cell and that the fruit is delivered to the customer at a temperature of 14.5°C. An attractive colour helps to promote sales to the consumer. The temperature determines the banana's keepabihty. For example, a banana supplied at colour No. 3 (more green than yellow) and with a pulp temperature of 14.5°C will keep for at least 4 days. Factors such as the outdoor temperature, the efficiency of the trailer refrigeration and the distance over which the fruit has to be transported will also determine the pulp temperature at which the fruit is supplied to the retailer. The common practice is to deliver the fruit at colour No. 3 and with a pulp temperature of 14.5°C in the summer and 17°C in the winter.

Inside the ripening room the pallets must be distributed in such a way that a uniform air flow is guaranteed throughout the room. The cartons on the pallets have to be spaced to ensure effective air circulation and uniform exposure to ethylene gas. In conventional ripening rooms the air circulation system is so arranged that the air expelled from the cooler unit is directed over the tops of the boxes and is then returned via air channels between the boxes. The ripening rooms must not be filled to more than their effective capacity, as this can result in serious ripening problems. The same may in fact also occur in the event of underloading. For this reason a room must in any event be at least 50% filled.

Ripening has to take place within a very limited temperature range whose extreme lower and upper limits are 13.5°C and 18.5°C. Immediately after the fruit has been brought into the ripening room and when the pulp is between 15°C and 17.5°C, "gassing" is started. During the gassing period all fans are off and all vents are kept closed The pulp temperature during ripening must definitely not be allowed to move above 18.5°C. High pulp temperatures will cause unduly soft ripe pulp with greenish-yellow skin colour ("cooked fruit"), weak necks, split peel, brown flecks on the peel, and abbreviated shelf life. Nor must the pulp temperatures become lower than 133°C.

Low pulp temperatures can cause chilling. Mildly chilled fruit has a greenish-yellow colour due to discoloration of the latex vessels in the peel Severely chilled fruit will not ripen.

Note: If bananas are supplied with a pulp temperature of less than 13 3°C the risk of chill damage can sometimes be reduced by raising the pulp temperature as quickly as possible. In such cases, however, do not use a heat setting above 19°C, as this may result in uneven ripening. Chilled fruit may be more difficult to process and should therefore be ripened at pulp temperatures 2 to 3 degrees higher than normal throughout the entire cycle.

Processing log

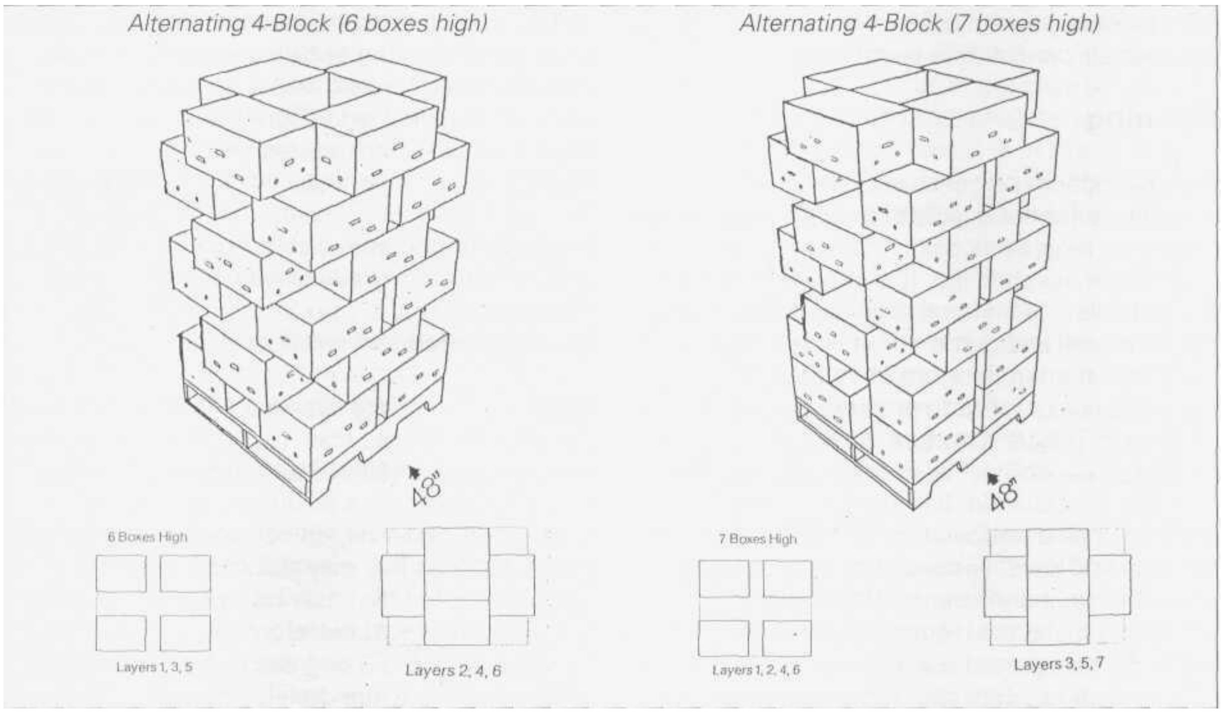
Each ripening room should have a processing log. After the room has been loaded, all relevant data relating to the ripening cycle are recorded in the processing log. This log, posted on the door of each room, should display the following information: date, time, number of boxes; shipped from; beginning and end of ripening cycle; room temperature; pulp temperature; and thermostat setting.

The stacking pattern

Adequate air ventilation is essential for the uniform ripening of bananas. From this it follows that in conventional ripening rooms the boxes must be stacked to ensure an effective flow of the circulating air. Since heat rises, the amount of box top area exposed is the most important factor in preventing heat build-up in the stack and controlling the pulp temperature during processing.

To ensure maximum control of heat build-up through the stack, the best stacking pattern for a palletised operation using a 1.00 m x 1.25 m (40" x 48") pallet is the alternating 4-block, stacked 6 boxes high.
If the boxes are stacked seven high, then the bottom two tiers should be stacked identically and the alternating pattern should start on the third tier. Other stacking patterns are also used, but all of them are aimed at achieving the same objective, viz. preventing heat build-up in the stack. The figures below show the different stacking patterns. Note the alternating pattern between odd and even numbered tiers.
In view of the increasing use of palletised boxes, a new system of banana ripening has been developed by Chiquita. This involves compactly stacked cartons, six in one layer: the tight-stack system. Ventilation is obtained by means of a transverse air flow and by creating a pressure difference to force the air through the grip openings and the ventilation holes. The ripening process is initiated by injecting ethylene gas. After gassing for 24 hours, oxygen is introduced to provide a regular air supply.

This gassing and aeration process is fully automated, as is the computer-controlled regulation of the temperature. The result is a temperature difference of as little as 0.25°C to



Stacking patterns

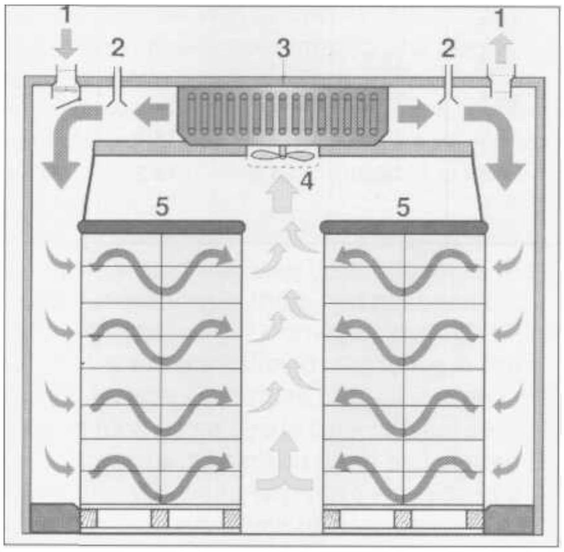
0.5°C between the individual cartons. These ripening rooms are equipped with electrically adjustable ceilings so that the room height can be adjusted to the height of the stack of pallets. The operating panel, installed outside the cell, also comprises an automatic display system with error printout.

The colour stages

The ripening process is subdivided into 7 stages based on the colour of the peel:

colour 1: green
colour 2: green with a trace of yellow
colour 3: more green than yellow
colour 4: more yellow then green
colour 5: only a green tip remaining
colour 6: all yellow
colour 7: yellow flecked with brown (sugar spots).

Ripening room with transverse air circulation



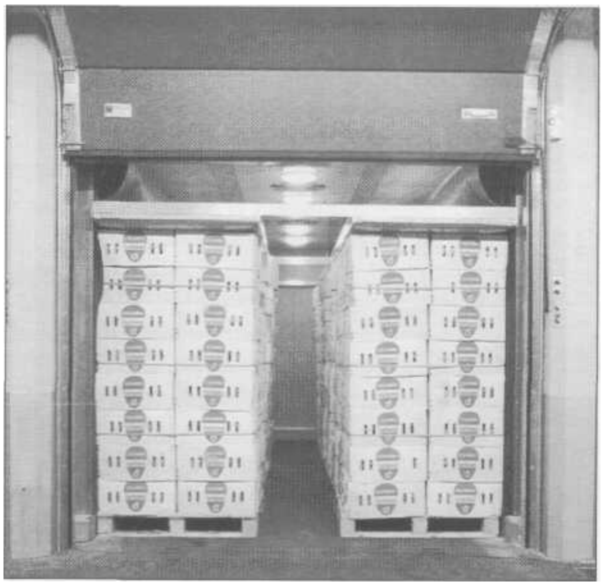
1 = Automatic computer-controlled air delivery and discharge
2 = Automatic computer-controlled ethylene gas injection
3 = Evaporator
4= Fan
5 = Electrically adjustable ceiling

In principle the fruit must be ripened to colour 3, as a lower colour brings the risk that ripening may not continue normally. At higher numbers than colour 4, the (riper) fruit is more likely to suffer handling injury. Customers prefer bananas which have been ripened to colour 3-4.
The table shows the pulp temperatures which are required to reach colour 3-4. Gassing takes place only on the first day of the ripening process and the pulp temperature upon outturn amounts to 14.5°C for all days.

A 5 to 7 day ripening cycle is best. Shorter cycles of 4 days or less can only be achieved by maintaining higher pulp temperatures, which accelerate the softening of the pulp and shorten the shelf life. Fruit will stay longer in the recommended 3-4 colour range if ripened at the lower temperature cycle of 5 to 7 days.

Uneven ripening

As we mentioned earlier, bananas can only ripen uniformly in ripening rooms. However, bananas treated in such rooms may not all have the same colour or may ripen unevenly. Even during a normal ripening process in a properly equipped ripening room it cannot be expected that the banana will ripen for 100% to exactly the desired colour. However the colour deviations are slight and they are of course less prominent in cases where a more modern ripening facility is used.



Suppose that the desired colour to be outturned is colour No. 4. In this case it is not exceptional if 80% of the bananas have colour 4, 10% a colour between 3 and 4, and 10% a colour between 4 and 5. A difference in colour may also be the result of the growing conditions or the maturity of the fruit. The main cause of a colour difference within one box or between various boxes is usually incorrect stacking patterns, resulting in improper air flow, or the wrong choice of ripening cycle.

Causes of uneven ripening may be.

1) Fruit with different origins or from different vessels, the bananas are generally at different stages of maturity and will not ripen at the same speed; wide variations in pulp temperatures on arrival at the ripening facilities; excessive holding periods prior to the start of the ripening cycle.

2) Improper gassing techniques e.g. gassing when pulp temperatures are below 15°C; inadequate ethylene gas-to-air ratio; gassing at uneven pulp temperatures; venting too soon after gassing; attempts to induce abnormally fast ripening.

3) Using rooms with insufficient heating and/or cooling capacities; leaking rooms, overloading or underloading the rooms; too frequent inspections of the ripening rooms; alternating air temperatures during ripening, which result in too wide a variation in pulp temperatures.

Temperatures for normal ripening schedules and days to reach colour 3-4

	Pulp temperature "C							
Days to colour 3-4	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
4	18	18	16.5	15.5				
5	16.5	16.5	16.5	16.5	15.5			
6	16.5	16.5	15.5	15.5	15.5	14.5		
7	15.5	15.5	15,5	15.5	15.5	14.5	14.5	
8	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5

CHAPTER 15

THE KIWIFRUIT

The commercial success of the kivvifruit is attributable to the fact that it can be kept in storage for a long time after harvesting To guarantee a lengthy storage time it must be possible for the fruit to be picked whilst still unripe and/or the fruit must soften only slowly after being harvested. Kiwifruit meets both these requirements.

The kiwifruit cultivar mainly shipped is "Hayward" which is harvested in New Zealand in late April to early June. Hayward is said to have a storage life of at least five months at 0°C. But we would sound one note of warning: kiwis are one of the "climacteric" fruits. Though the fruit itself produces little ethylene, it does have a high sensitivity to ethylene.

History

Originally the kiwi was known as the "Chinese Gooseberry". A very apt name for the plant, as it originates in the south of China, in the Yangtze Kiang valley, and the taste of kiwifruit is similar to that of the gooseberry. Its Latin name is *Actinidta chinensis Planchon.* In China the plant is known as "Yang Tao".

The "kiwi" would still have been known as the Chinese Gooseberry if there had not been a missionary who, whilst journeying through China, realised that the plant would also thrive in the pleasant, temperate climate of New Zealand. He therefore took some seeds back to New Zealand. The plant soon acclimatised there and started to grow in the wild. In its wild form *Actinidia* is a superb climbing vine, with handsome (usually white) flowers which produce small berries. The cultivated commercial varieties produce much bigger berries.

In its commercial form the fruit is oval-shaped or round and about 6 cm in diameter. The berry has a thin, hairy brown skin, not unlike the plumage of the KIWI bird. It is the only fruit in the world (apart from melons) which has a soft, green juicy flesh. When cut open, the kiwifruit reveals an attractive pattern of black edible seeds surrounding a white edible core. The fruit has a tangy, sweet-sour taste.

An important site in the fruit's history can be found at No. 3 Road in the village of Te Puke in the Bay of Plenty on New Zealand's North Island There lies the land on which horticulturalist Jim fvlcLoughlin started the world's first large-scale kiwi cultivation in 1934. Today, the area surrounding Te Puke is one immense kiwi orchard. New Zealand's mild maritime climate proved ideal for growing kiwifruit of unsurpassed quality.

But it took a long time for the kiwi to achieve international success. Half a century after its introduction, the total area under cultivation in New Zealand still did not exceed fifteen hectares. In 1952 a number of crates were shipped to London for the first time. Only late in the 1970s did exports start to show a rapid increase.

The idea of naming the fruit after the flightless kiwi bird, which occurs solely in New Zealand, came from the Turner brothers, leading fruit exporters. An American importer had asked whether a new name could be found based on the language of the Maoris, the original inhabitants of New Zealand. Eventually, the name "kiwi" was chosen.

The kiwi bird is New Zealand's national emblem. It is a remarkable (nocturnal) bird with no tail and very weakly developed wings. It is covered in hair-like brown feathers which enclose the bird's body almost like a fur coat

Exports of kiwifruit really took flight in the late 1970s Nowadays, kiwifruit is a major New Zealand export product with an annual value in excess of 160 million dollars. But the product only accounts for 3% of the country's total exports and is also meeting with growing competition from other kiwi exporting countries. In 1977 the area planted with kiwis amounted to a mere 200 hectares, as compared to 12,000 hectares today.

In the initial years the New Zealand government helped to promote cultivation by making investments in kiwi plantations tax-deductible. In 1982, however, the fear of over-production caused the government to rescind the tax facilities. Because of the overall decline in the prices of agricultural land which followed the abolition of farm subsidies in 1985, the value of the kiwi plantations has declined substantially.

The world kiwi trade

Until 1980 New Zealand enjoyed a virtual "kiwi monopoly". Since then, however, there has been a strong emergence of other producer countries, such as Japan, France, Italy, Israel, Spain, Chile and the USA (California) New Zealand's market share currently amounts to scarcely 50% and is likely to decline even further. Other subtropical regions will also be able to cultivate the plant successfully in future. The following table shows kiwi production volumes in various countries

In New Zealand harvest-time is between late-April and early-June. The harvest in most other producer countries in the Northern Hemisphere takes place in September/October. Because of the kiwi's "staggered" harvest-times and its lengthy keeping properties, the fruit is now available all the year round.

The kiwifruit has meanwhile become much cheaper and is seen less as an exquisite and special treat but more as simply a tasty fruit. Only at a late stage and then on a limited scale did the New Zealanders start looking for other processing possibilities for the kiwi, e g. in the making of wine, juice, liqueur, shampoo, etc. Because of this one-sided focus and since other countries have now also started marketing the kiwi, vast surpluses of rejected fruit have been created in New Zealand. Each year more than 80,000 tonnes of kiwis are rejected. A large

Production of kiwi (1,000 tons)

	1985	1990	1991	1992	1995 (F)	1998 (F)
Nothern hemisphere						
Italy	32	250	235	320	370	400
France	14	40	40	60	90	90
Greece	3	15	20	45	70	65
Japan	17	69	45	70	80	80
USA	13	35	27	48	40	45
Other	2	11	18	25	50	70
Total	84	420	385	568	700	750
Southern hemisphere						
New Zealand	110	312	278	280	300	320
Chile	1	25	38	58	100	140
Other	2	16	26	30	40	40
Total	113	353	342	368	440	500
TOTAL	197	773	727	936	1140	1250

(F) = Forecast *Source: Market Intelligence LTD*

proportion of this over-production is dumped on the local market where kiwifruit is sold for as little as 15 cents per kilo. During the season baskets can be seen everywhere along the country roads with the words "Free Kiwifruit".
Since New Zealand was unable to register the name "kiwi" as a trade mark, other countries are now able to profit from the promotional activities undertaken over the past years by the New Zealand Kiwifruit Authority for the fruit under what has now become its "generic name". Even the Chinese sell their canned Chinese Gooseberries under the name "kiwifruit"!

The New Zealand Kiwifruit Authority in Auckland supervises the quality and quantity of the fruit for export. Only about 8 recognised exporters ("competitive coordinated cooperation") hold a licence to export kiwifruit.
Now that the trade in kiwifruit has come under severe pressure, attempts are being made to emulate its initial success by growing new varieties of fruits. New Zealand currently has as many as three hundred growers of the "Kaki" (Persimmon), a fruit which sells well in Japan in particular.

The growth of kiwifruit

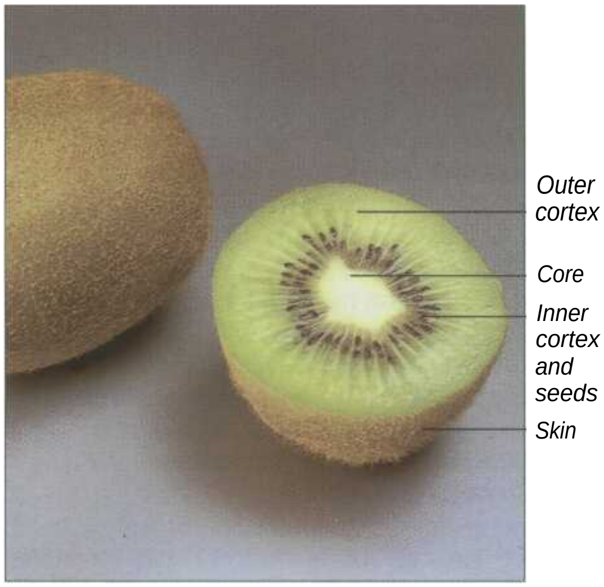
It takes 6-7 years before a new kiwi plantation starts to bear fruit. The plantations have to be surrounded by windbreaks in the form of metres-high hedges. Without this protection the bunches would lash against each other, damaging the fruits or causing them to fall off. The windbreak hedges consist of poplars or willows, with conifers as a secondary row, and they take two years to grow to the required height. After that they are trimmed every year with the aid of big mobile shears.

The kiwi plant is deciduous and has woolly-haired leaves and branches (similar to the blackberry) which climb by means of tendrils. Just like grape vines, the tendrils are trained along wires and have to be pruned at regular intervals. Every plant is either male or female and it takes a seedling five or six years to flower. For fertilisation purposes one male seedling has to be planted between every eight females.
Whilst the plant is still fully dormant and leafless, it will withstand low temperatures, even down to -15°C, but after this period it will no longer withstand even a mild frost. Frost damage causes mushy flesh. To ensure the further good development of the fruit, the plant requires a warm and moist summer. A short dry period during the growing season may have deleterious effects.
During the development of the fruit the main causes of damage are hailstorms, but also wind and salt spray.

Properties of the kiwifruit

The kiwi is in fact a berry. It is usually picked when unripe and can also be eaten at that stage, though it will still taste slightly sour. The kiwifruit is ripe when it gives slightly when pressed at the stem end. The fruit will then have a tangy, sweet-sour taste and will keep for several more days in the refrigerator.

From May to December kiwis are supplied from New Zealand, from December to March from France, Greece and Italy, after which they are shipped in from Chile through to May. From being an exclusive fruit which was sold only in delicatessen stores, the kiwi has grown to become a mass-market product which is now available in every supermarket.



Cross section through a kiwifruit

The vitamin C requirement of humans is approx. 70 mg per day. No other fruit is as rich in vitamin C as the kiwi. In 100 g of kiwifruit flesh there is as much as 70 milligrams of vitamin C. Citrus fruits contain an average of about 30 to 40 mg of vitamins per 100 g, whilst a banana has approx. 10 mg per 100 g. In addition, a kiwi contains the vitamins A, beta-carotene, D and E, and also potassium as well as many fibres.
Other favourable properties of the kiwi are its low contents of calories, fat, cholesterol, starch and sodium. Its nutritional value amounts to 40 Kcal/100 grams of fruit flesh (by comparison, a dessert banana has 96 Kcal/100 grams).
Just like the pineapple, the kiwi contains a proteolytic (protein-splitting) enzyme. This substance helps to make the fruit easily digestible. Meat cooked with a slice of kiwi is much more tender. The-enzyme does, however, have an adverse effect on proteins in dairy products and in gelatine.

The moment of harvesting

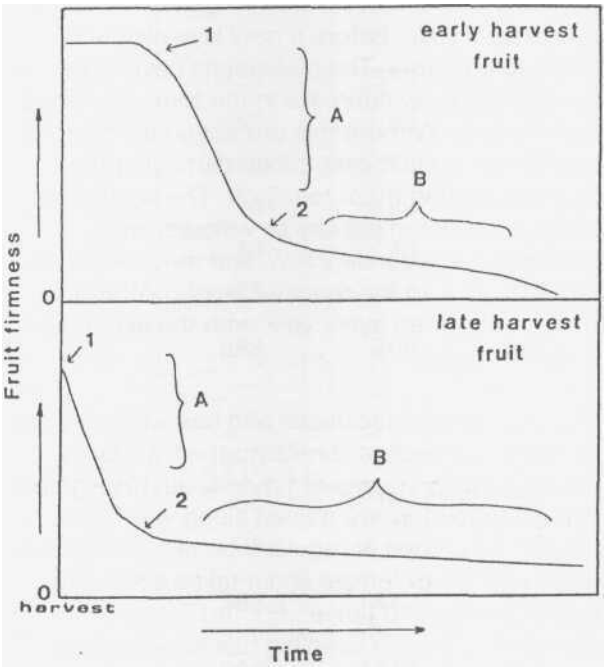
It takes a fairly long time before kiwis ripen naturally in the orchard. If the fruit is harvested before it is fully ripe and is then stored at ambient temperature (e.g. 18-20°C), then the ripening process will continue further. Once the fruit has eventually become ripe, the moment of "eating-ripeness" of apparently similar fruit may still vary widely.
It has been found, however, that if the fruit is stored at 0°C both during and after storage, it will ripen more evenly. But even in this case there may still be several days' variation in the time to eating-ripeness for individual fruit. During ripening two important changes take place in the fruit, i.e. the fruit flesh and core become softer and the soluble solids concentration (SSC) increases.

In New Zealand the fruit is harvested when the fruit juice has achieved a maturity index of approx. 6.2% SSC. The New Zealand Kiwi Board considers that kiwis which are harvested at this index or slightly higher and which are then immediately stored at a temperature of 0°C can be kept for up to 6 months.

Just like bananas, the kiwifruit is highly sensitive to ethylene and the onset of ripening and the respiratory climacteric are accelerated if ethylene is applied as a ripening agent. If the fruit is harvested at an SSC lower than 6%, then the kiwi must be subjected to a ripening treatment with ethylene immediately after harvesting, as otherwise the fruit will not have an acceptable flavour and/or texture.

Fruit softening

After 1985 a spectacular increase occurred in the production of kiwifruit, but at the same time there was an enormous surge in the economic losses due to soft fruit. Scientists therefore conducted much research work into the pre-harvest and post-harvest causes of the soft fruit problem.
When the fruit is harvested, it has a fruit firmness in the range between 7 kgf and 11 kgf (= kilogram force, a measure of firmness), but the fruit is not "eating ripe" until the firmness has decreased to below 1 kgf. The decrease in the firmness therefore mainly occurs during the post-harvest storage period. As regards the loss of firmness in the first two weeks after harvest, a distinction has to be made between fruit harvested early in the season and late harvest fruit.



Diagrammatic representation of softening in kiwifruit
Source: Research Centre, Auckland.

As we can see from the diagram, early harvest fruit will show little change in firmness in the period immediately after harvesting (about two weeks). In phase A (from the 2nd until about the 7th week) a sharp decrease occurs, with the firmness decreasing from, say, 8 kgf to approx. 2 kgf. From point 2 in phase B the firmness decreases only slightly Roughly speaking, it can be assumed that between the 7th and 18th week the firmness decreases from 2.5 kgf to 1 kgf. The fruit is considered to be eating ripe when the firmness drops below 1 kgf. As we can also see from the diagram, fruit harvested late in the season reveals a decrease in firmness immediately after harvesting. If the fruit is exported immediately or shortly after harvest, then the average period between harvest and marketing will amount to 4-6 weeks As the two diagrams clearly show, early harvest fruit which is marketed, say, after 6 weeks will be much firmer than fruit which was harvested late in the season and stored for the same length of time.

As we will see later on in this chapter, not only the moment of harvesting but also various other factors will influence the softening of the fruit. We should also bear in mind that the physiological maturity of the fruit is not identical every year. In other words: the diagrams and the values shown in them serve only to give a general indication of the development of the fruit. If we compare the two diagrams, then another striking point is the difference between the initial firmness at harvest and the end-firmness after storage. This is due to the fact that late harvest fruit softens faster than early harvest fruit. Strangely enough, however, the firmness after long term storage develops in exactly the opposite way. Not only is phase B longer, but late harvest fruit ultimately retains much more firmness.

Pre-harvest and post-harvest causes of fruits oftening

The possible pre-harvest contributory factors leading to fruit softening are;

(a) orchard management;
(b) unfavourable nitrogen and calcium levels;
(c) fertiliser imbalance;
(d) SSC levels and fruit size;
(e) vine health;
(f) waterlogging (excess rain or irrigation);
(g) canopy density.

The post-harvest causative factors include:

(a) the time of harvesting;
(b) transport time from orchard to coldstore;
(c) time spent in cooled storage;
(d) handling of the fruit (intake, turnover, checking and repacking);
(e) coldstore malpractices (temperature and hygiene);
(f) ethylene effects;
(g) transport for shipment;
(h) shipping.

Explanatory comments on the causes of softening

The main question that now arises is: what percentage of the causes of fruit damage is attributable to cultivation practice and what percentage is due to post-harvest treatment? Scientists engaged in pre-harvest production research and those involved in post-harvest work each have their own, differing opinions on this. The same applies to the question of whether a correlation exists between fruit softening and the calcium and nitrogen levels during production. Most scientists (e.g. Dr Nagan Lallu) believe strongly that there is such a correlation but other studies (e g. those by Dr Garth Smith) have shown that there is little or no relationship between fruit quality problems and the mineral composition of the fruit or fertiliser. We will not deal here in further detail with the scientists' views about the extent to which mineral nutrition influences the fruit quality, but will simply present some of the general conclusions from the various reports.

It is a well known fact that calcium deficiency causes disorders in some types of fruit, e.g. *bitter pit* in apples and *blossom end ml* in tomatoes. The kiwi, however, has high natural levels of calcium, higher than in other types of fruit, and so no calcium deficiency disorder has been found to occur in kiwifruit But this still does not answer the question of whether a relationship exists between natural calcium levels

and premature ripening of the fruit.
One proven fact is that post-harvest calcium dips do improve the firmness of the fruit. The drawback of this treatment, however, is that it causes damage to the fruit's skin *(skin pitting).* Against this, no certainty exists as to whether there is a relationship between the natural calcium concentration in the fruit and the firmness of fruit during storage.
It is quite possible that, despite a high calcium level, the calcium is not distributed sufficiently inside the fruit, with the result that only a small proportion of the calcium has a direct influence on the fruit firmness. This explanation seems logical when we realise that the highest proportion of fruit calcium is located in the inner cortex and will not contribute to the quality of the fruit because it is located inside seeds or as crystals of calcium oxalate.
These crystals do not dissolve readily. Therefore, any calcium that is present in kiwifruit flesh in the form of calcium oxalate is unlikely to become available to the fruit during the ripening process.

The cell wall of the fruit is what holds the fruit together. Part of the calcium is in fact located in structural components of fruit flesh, such as the cell wall. The strength of the walls, and hence the firmness of the fruit flesh, is partly determined by the quantity of calcium present in the cell wall. The integrity of the cell wall influences the ethylene production which is in turn the major cause of fruit softening.

Waterlogging is another cause of soft fruit. If there is insufficient run-off and the soil has to absorb too much water at critical moments during the growth period, this may give rise to waterlogging. Large quantities of water may remain on the soil surface because of exceptionally heavy rainfall but also because of man-made factors (irrigation practices).

Excessive quantities of water on the land give rise to too-low a concentration of oxygen and nitrogen in the soil. For the vine the consequences of a low nitrogen status are that the plants carry fewer leaves, the fruit yield is considerably reduced and the root system develops less favourably. Clearly, high-nitrogen vines will have better developed roots and will thus be better equipped to withstand the stresses of waterlogging.
During a dry period almost all growers are tempted to give fruit trees a lot of water to ensure a bigger fruit crop. In many cases, however, this leads to over-watering, the result being that soil aeration and soil composition are sometimes so adversely affected that the fruit quality will turn out to be inferior upon harvest. The same applies to kiwi cultivation where it has also been found that the fruit is most susceptible to the adverse effects of waterlogging particularly where it occurs late in the season.

We can summarise the effects of waterlogging as follows:

(a) Over-watering reduces the nitrogen level in the vine.
(b) Vines which have a nitrogen deficiency are extra-sensitive to the effects of waterlogging.
(c) The fruit is the most susceptible to over-watering when this occurs towards the end of the growing season.

Ethylene

The most important cause of premature fruit softening is ethylene. Ethylene gas is produced naturally by ripening fruit as part of the ripening process by the cells which make up kiwifruit tissue.
The question now is: where is the greatest concentration of the ethylene gas located? Is it in the fruit itself, or in the cooled cell?
It is true that ethylene in the cooling cell air causes premature fruit softening at volume levels as low as 0.03 ppm (parts per million). But, via proper ventilation, we can prevent too-high an ethylene concentration in the cold cell.

When we discussed the risks involved in carrying combined cargoes, we pointed to the fact that ethylene diffuses from regions with a high ethylene concentration to a cooling cell with a lower concentration. The expectation is that the ethylene produced by the fruit itself will diffuse via the skin into the cooling cell. But the skin of the kiwifruit represents a greater barrier to ethylene diffusion than do the skins of other types of fruit. To give one example: the skin resistance of kiwifruit is 12 times higher than that of bananas and 3 times higher than that of apples. This skin barrier restricts outward diffusion of ethylene. The fruit's internal ethylene concentration (IEC) therefore continues to build up. The outcome: the fruit ripens prematurely and turns soft. Nevertheless, this still does not obviate the need to prevent ethylene contamination in the cooling cell. This would in fact cause an additional increase in the ethylene level already present in the tray and would thus have an adverse effect on the IEC. It follows, therefore, that the polyethylene tray liners may also form a barrier to outward diffusion and thus have a cumulative effect on the IEC.
It will be clear that liner materials which have a higher permeability to ethylene, or liners which are partly perforated, will have a positive influence in this respect. Rigorous avoidance of ethylene is important not only as regards the prevention of fruit softening but also in inhibiting the development of fruit rot.

Storage rot

Kiwifruits may be rotted in storage by grey mould *(Botrytis cinerea)* and by *Phomopsis stem-end rot.*
A high nitrogen status in the fruit has been found to promote fruit softening and encourage botrytis storage rot. *Botrytis storage rot* only becomes visible when the fruit is eating ripe and when the firmness of the fruit has decreased to about 1.5 lbs or less.

In most cases nitrogen fertiliser is applied to the vine before the fruit sets. Research has shown that a high nitrogen treatment consistently causes more botrytis rot than low nitrogen treatment. Effective dosing of nitrogen can therefore help minimise botrytis rot. It has also been found that the incidence of botrytis rot varies between orchards and is dependent on the cultural and environmental conditions.

In addition to botrytis rots, other problems we are confronted with during storage are fungal pits and wound rots. Just like other fruits, kiwifruit is also prone to a number of latent or "dormant" infections. Many of these infections commence during the blossom period, others are mainly the result of a warm and damp summer. Latent infections may sometimes become manifest during the cooled storage period in the form of small depressed pits with a diameter of 2-5 mm directly under the skin. Generally speaking, however, the infections only become visible when the fruit begins to ripen, in which case they develop into destructive *ripe rots.* During cooled storage at 0"C the pathogens which incite these rots are unable to develop further. As we can see, therefore, any small rot lesions which occur as the fruit ripens have not been caused by fungal growth during cooled transport but result from the development of a latent infection which was already present before the start of cooied storage.

Wound rots, however, are one form of damage that can occur during cooled storage. In such cases wounds or damage marks on the fruit skin will have been infected by fungi during cooled storage. The rot remains restricted to the immediate environment of the wound and forms virtually no threat to the sound fruit in its vicinity.

Another possible problem during cooled storage is that of "superficial storage blotching". This is caused by organic contamination, e.g. fruit juice or pulp, on the skin. During storage this contamination forms a substrate for the growth of certain fungi. This merely results in an unsightly, superficial disorder but does not cause any rot, nor does it impair the quality of the fruit.

Methods of cooled storage

To enable New Zealand kiwifruit to be put on the market "ready to eat" early in the season, the research centre of the Division of Horticulture and Processing in Auckland has investigated some ripening and handling strategies based on ethylene treatment of the fruit. The Pomology Department of the University of California has also studied the problems of flesh softening in Californian grown kiwifruits. Similarly, the Sprenger Institute in Wageningen (Holland) has conducted an extensive study into this subject matter and published its findings in a report (1988). Since our aim is to provide some insight, albeit in a very concise form, into the problem of fruit softening during transport, our own observations have been supplemented by some data derived from the reports referred to above.

Kiwifruit is normally harvested when it has reached a maturity index of approx. 6.4% SSC. The firmness of the fruit is then between 8 and 10 kgf (18 Ibs), the size range is 30-40 count and the weight approximately 110 grams. The firmness can then be measured using an Effigi penetrometer with an 8 mm plunger. An optical refractometer is used to measure the SSC. The method used to measure the SSC percentage accurately involves cutting one slice from each end of the fruit If the fruit has just been harvested, then the difference in the SSC between the two ends will amount to 0.5 to 0.7%.

To summarise, five possible storage methods can be used for kiwifruit:

1) Ethylene treatment immediately after harvesting.
2) Ethylene treatment at any required moment during the storage period.
3) Ethylene treatment at the end of the storage period.
4) No ethylene treatment.
5) CA storage.

These treatment methods do have a certain influence on the softening of the fruit flesh but, apart from the duration and timing of exposure to ethylene, there are also other factors which significantly influence the ripening and softening of the fruit. These factors are:

1) The SSC percentage at the moment of harvesting.
2) The firmness of the fruit during harvesting.
3) The area and/or district of origin.
4) Seasonal influences.
5) The time that elapses between harvesting and cooled storage,
6| The temperature of the fruit at the moment when it is loaded on board for transport overseas

We will give a more detailed explanation of the effect of the various storage methods on the fruit and its storage life. However, this explanation gives only a general impression since we are limiting ourselves solely to cooled storage at 0°C and solely to the case where a specific quantity of ethylene is admitted during a specific period (18 hrs). Besides, as we have seen above, there are a great many other factors which may affect the overall picture.

A) Storage without ethylene treatment

If, shortly after being harvested, the fruit is stored in a cooled cell at a temperature of 0°C, then the fruit will have a storage iife of about 6 months. Changes in the flesh firmness during storage will vary, depending on the SSC at harvest-time. We will assume here that the average temperature during the harvest period amounted to approx. 19°C and that the fruit was stored at 0°C for a period of 18 hours after harvesting.

Research has shown that, if the fruit is harvested at an SSC of 6% and with a fruit firmness of 19 Ibf, then the firmness will amount to 18 Ibs after 2 weeks and 12 Ibs after 6 weeks If the fruit is harvested at an SSC of 7% and with a fruit firmness of 19 Ibf, then the firmness will also amount to 18 Ibs after 2 weeks but will then decrease to 7 Ibs after 6 weeks. If the fruit is harvested at an SSC of 8.5% and with a fruit firmness of 16 Ibf, then the firmness will amount to 14 Ibs after 2 weeks and will decrease to approx. 6 Ibs after 6 weeks.

As mentioned above, these are only approximate figures. But one fact is at any rate certain: without ethylene treatment in the first two weeks of storage, the firmness will show only very little change. After the first two weeks a sharp decrease will then occur. This decrease in firmness also continues after the 6th week until about the 12th week, when a firmness of 2.5 to 2 Ibs is reached. Once this stage has been reached, the firmness hardly changes further until the 24th week (after approx. 6 months).

We will now look at the storage performance in cases where the fruit is kept in a controlled atmosphere (CA}. We will again assume that the fruit is kept at 0°C and in CA air, i.e. 2% 0_2 + 5% $C0_2$.
Let us assume that the fruit firmness at the moment of harvesting amounted to 16 Ibf. We now find that the firmness of the fruit decreases during the first 2 weeks of storage to 10 Ibf. Between the 2nd and 16th weeks the firmness changes only little. From the 16th week until the 24th week the firmness decreases from 10 Ibf to 8 Ibf. Fruit which has been kept in CA storage will therefore keep for longer than 6 months!

If there is a wish to make the fruit flesh softer at a certain moment or even to make the fruit "eating ripe", then this can be achieved by applying ethylene (C_2H_4) either continuously or for specific periods. The problem here, however, is that under CA storage conditions ethylene has a deleterious effect on apples, potatoes, lettuce, and kiwifruit. The basic problem is that, though ethylene will accelerate fruit softening, ethylene combined with an elevated $C0_2$ level will induce some physiological disorders. These in turn cancel out the benefits of CA storage. In the case of kiwifruit the presence of ethylene during CA storage causes *white core inclusions* (WCI). WCI incidence and severity are dependent on interactions between temperature, $C0_2$ concentration and ethylene concentration and on the actual exposure time during storage.

In general, the longer the duration of the exposure to ethylene, the greater the incidence of WCI. The WCI disorder also increases in severity along with any increase in the CO_2 concentration. The conclusion therefore is that it is best to cool the fruit down to 0°C as quickly as possible and, immediately after that, to store it in CA storage (2% 0_2 + 5% $C0_2$), without any application of ethylene.

B) Ethylene treatment prior to storage

Here we will assume that, immediately after being harvested, the fruit is first stored for 18 hours at a temperature of approx. 2Q°C, during which period it is subjected to an ethylene treatment and is then cooled to 0°C.

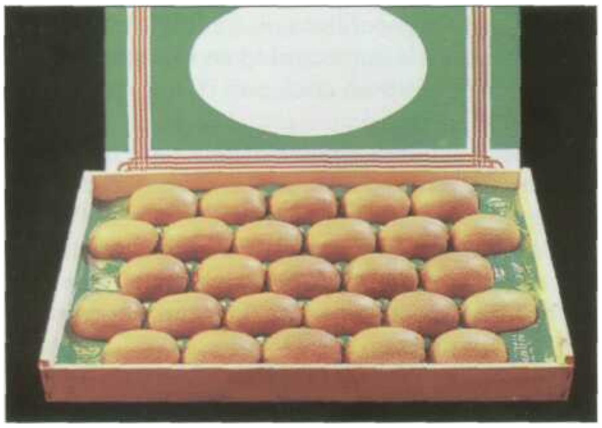
The SSC at harvest amounts to 6% and the flesh firmness is 19 Ibs. After 18 hours delay and exposure to ethylene, this fruit is stored at 0°C. In this case the firmness after 2 weeks will have decreased to approx. 12 Ibs, declining further to 11 Ibs after 5 weeks and $8^1/$ Ibs after 6 weeks.

If the SSC upon harvesting had been 7% and the firmness 19 Ibs, then the firmness under the

above conditions would have decreased to approx. 8.5 lbs after 2 weeks, to 7 lbs after 5 weeks, and to 3.5 lbs after 6 weeks.
If the SSC upon harvesting had been 8.5% and the flesh firmness 16.5 lbs, then the firmness under the above conditions would have decreased to 3 lbs after 2 weeks, to 2.5 lbs after 5 weeks, and to 2 lbs after 6 weeks.

C) Ethylene treatment after storage

Let us assume here that the fruit has been harvested at 6.4 SSC and with a fruit firmness amounting to 9 kgf (20 lbs). Immediately after harvesting, the fruit is stored for 6 weeks in a cooled cell at 0°C. Inside the cooled cell, which contains no ethylene, the firmness has decreased to 5 kgf after 6 weeks. To bring the fruit to eating ripeness as quickly as possible, the kiwis are then exposed to ethylene (24 hrs, 20°C). After this treatment the decrease in flesh firmness then follows approximately the following pattern:
In the first 4 days after treatment the flesh firmness decreases to approx. 2 kgf (SSC 12.5%). This is followed by a second phase which is substantially slower and in which the flesh firmness decreases further to approx. 1 to 1.5 kgf. Once it has reached this level it sometimes reveals practically no further decline for a while, after which the decrease will continue down to eating ripeness (0.7 kgf). Generally speaking, it can be said that, depending on the maturity at the moment of harvesting, kiwifruit will take 4 to 7 days to reach 1 kgf firmness after storage at 0°C for 6 weeks and subsequent treatment with ethylene. If untreated, it will take 8 to 10 days before 1 kgf is reached.



N.B.:If the fruit is again placed in the cooled cell at a temperature of 0°C after ethylene treatment, then the decrease in firmness will of course take place much more slowly.

Roughly speaking, we can distinguish between the following stages:

Harvest time:	firmness 7-11 kgf; SSC 6-7%;
Hard fruit:	firmness more than 2.5 kgf;
Sensitive fruit:	firmness between 1 kgf and 2.5 kgf;
Soft fruit:	firmness lower than 1 kgf;
Eating ripe:	firmness 0.4-0.8 kgf; SSC 13.0-to 14.5%.

The above figures are approximations, since the physiological maturity of the fruit is not identical in each harvest year. This is why variations may occur in the SSC and eating firmness even in cases where the time of harvest was determined on the basis of the same maturity index.

Packing and loading

Kiwis are harvested by hand, collected in picking bags and then tipped into bins for carriage to the packing station. In the packing station the fruit is mechanically graded for size and weight, checked as to possible blemishes and tested for firmness. Most of the fruit is packed into single layer trays in pocket packs. The other fruit is packed in bulk tri-packs, and sometimes also in bulk bins. To prevent dehydration, this fruit is wrapped in a polyethylene sheet.
Within 24 hours after packing, the fruit must have been placed in cool storage and its temperature reduced to approx. 0°C.

In most cases the trays are palletised before transport. The usual practice, for instance in New Zealand, is to attach a card to the pallets. This "pallet card" carries the relevant data about the fruit, e.g. grower, packing station, date packed, grade, and the code number of the pallet. When the pallets are being loaded on board, they should be carefully inspected to ensure that packaging and palletisation are satisfactory. It is also good policy to take random measurings of the pulp temperature and to check the firmness of the fruit with the aid of an Effigi penetrometer as described in Chapter 4. The measured values must be recorded in the reefer logbook and, if temperatures are found to deviate from normal, the shipper must be notified. The pulp temperature at the time the fruit is loaded into the vessel must not exceed 5°C. The firmness shortly after harvesting should be between 8 and 10 kgf (approx. 18 lbs).

It goes without saying that the fruit must be free of cracks, pressure marks or signs of mechanical damage and must not be infected by rot or mould.

Transport

As is customary in the case of cooled transport, the hold must have been pre-cooled (0.5°C) well before loading commences. The hold must also have been thoroughly cleaned, ventilated and made odour-free. The gratings must be in good condition and, if pallets are being loaded and if the ship is equipped with pallet side-support boards, then these must be securely erected on arrival. In the case of cooled cargoes it is advisable to conduct a pre-loading survey.

In most cases the shippers require a pulp temperature of between -0.5°C and 0°C during the entire voyage. The minimum freezing point for New Zealand kiwifruit is -1.5°C. Obviously, the temperature of the delivery air during the "cooling down" period must never be lower than -1.5°C. It is therefore advisable to set the alarm and safety cutouts at a temperature of -1.25°C.

Kiwis are classed in the climacteric fruit category. Kiwifruit is not chilling sensitive and has a low ethylene production (0.1 to 1 microlitre/kg/h). We would note that ripe kiwifruit does have a high ethylene production (10.0 to 100.0 microlitres/kg/h). Kiwis are, however, sensitive to ethylene action. Ethylene, as we know, will trigger the ripening process of the fruit. It is therefore definitely essential for the holds to be continuously ventilated to remove any risk of ethylene build-up. Unfortunately, the great majority of ships are still not fitted with a gas chromatograph, which means that the CO_2 percentage still needs to be measured in order to provide an indication of the air refreshment

requirement. If a gas chromatograph has been fitted, then the ventilation can be regulated in such a way that ethylene levels are kept below 0.03 ppm (parts per million).

If it is only possible to measure the $C0_2$ percentage, then the ventilation system must be set in such a way that the $C0_2$ levels do not exceed 0.2%. In practical terms this is equivalent to a continuous fresh air ventilation at a minimum rate of one-fifth (1/5) air change per hour (as measured on the basis of an empty hold). In practice it is customary to run the fans at full speed during the entire voyage.

As we have meanwhile learnt, we need to prevent dehydration of the fruit because this leads to weight loss, wrinkling of the skin and abbreviation of the storage time. Kiwifruit requires a high relative humidity (90-95%). It goes without saying that the fruit must be pre-cooled when loaded. Another important point to watch is that the pulp temperature during loading is close to the transport temperature. In any event the pulp temperature during loading should not exceed 8°C.

At 0°C the heat production amounts to 10 W/tonne. The specific heat amounts to 3.65 kJ/kg x °C. The stowage factor for boxed fruit on pallets amounts to approx. 2.8 cbm/t **ClOOcft/t).**

Damage claims

Both during loading and upon outturn it is obvious that the fruit must be clean and sound and with no signs of internal breakdown or decay. The fruit must also be checked as to firmness and should not be infected by rot nor damaged by frost; it should also be free of bruises or signs of mechanical damage, etc.

Apart from the above-mentioned cases of damage in kiwifruit, it often occurs that the consignee submits a damage claim because he takes the view that the fruit is sensitive or overly soft upon outturn. In cases where the fruit has - been properly cooled, one of the causes of premature softening may be that the ethylene percentage was too high during transport, or that the period spent in cooled storage was too long Too-high an ethylene percentage in the hold may have been caused by the kiwifruit having been shipped as a combined cargo, for example, together with apples.

Combined cargoes

In previous chapters we have repeatedly pointed to the fact that extreme caution should be observed when combining cargoes of high ethylene producers such as apples and pears with products which are highly sensitive to ethylene, in this case kiwifruit, Ethylene gas is in fact a very potent promoter of softening. Probably forced by economic considerations, there are cases in which, say, kiwis and apples are transported on the same ship.
In such cases, though, the products will be placed in completely separate cooled compartments. Despite all the precautions that are taken, this method of transport is still not without its risks.

In any event it is perfectly clear that the cooling air and/or the exhaust air from the holds loaded with another type of fruit must not be allowed to penetrate into the holds with kiwifruit. This is why alternative venting of holds loaded with different fruit types is essential.

Long term storage

As we explained earlier, the firmness of the kiwifruit at harvest-time is generally between 7 and 11 kgf. We also explained that the firmness of fruit harvested at the beginning of the season normally shows little decrease during the first two weeks. That is followed by a period during which the fruit firmness declines rapidly.

In the case of late harvest fruit, the flesh firmness decreases directly after picking, resulting in a firmness of 2-3 kgf after about 4 weeks. Subsequent to this period the firmness only decreases slowly and, after long term storage (e.g. 8 weeks) the kiwifruits are, relatively speaking, firmer than early harvest fruit.

To sum up:

a) At harvest-time the firmness of early harvest fruit is higher than that of late harvest fruit.
b) During the first 4 weeks of cooled storage the firmness of early harvest fruit remains higher than that of late harvest fruit.
c) Fruit which is harvested early in the season will tend during cooled storage to soften sooner than late harvest fruit.

We have placed extra emphasis on the facts set out above because they may play a significant role in assessing a damage claim.

To give one example of a typical instance of such a claim, let us assume that the fruit was harvested at the beginning of the season. At harvest-time the firmness amounted to 8 kgf. About 18 hours after harvesting, this fruit was placed in cooled storage at 0°C.
After a storage period of 4 weeks the fruit is loaded into a reefer. The sea voyage in our case amounts to 4-5 weeks, which means that the fruit outturn occurs about 3-9 weeks after harvest.

Let us now take a look at what the fruit firmness is expected to be upon outturn.
During loading (4 weeks after harvesting! the pre-shipment firmness will amount to approx. 6 kgf.
Upon outturn (8-9 weeks after harvesting) we can expect the penetrometer readings to show a firmness of between 1.5 and 2.5 kgf.
These figures are based on the assumptions that little time has elapsed between harvesting and cooled storage and that the loading period has been so short that the pulp temperature has risen only slightly during the loading operation. Despite these ideal conditions, however, it may still be found that upon outturn the fruit is sensitive and even that a certain proportion of it has turned soft.

GROUNDNUT KERNELS AS REFRIGERATED CARGO

The commodity

When Chinese exports of groundnut kernels reached a peak in the years 1989-1990 after disappointing harvests notably in the USA, the transport of kernels in 50-kg jute bags in large quantities on conventional freighters to the mainports of Rotterdam and Flushing frequently resulted in serious damage because of mould growth.

Important contributory factors were[1]

- duration of the voyage, often more than two months;
- moisture content of the kernels when loaded;
- dramatic fluctuations in temperature and humidity when crossing different climate zones in different shipping seasons;
- inadequate ventilation routines, often in combination with unadapted stowage arrangements and limited fan capacity.

Peanuts are a semi-perishable crop and there are many variables which affect their storage life. Some of the most important pre-storage variables are growing conditions and harvesting, drying and handling treatments.

Mould growth which could lead to the formation of aflatoxin is perhaps the greatest single cause for concern during peanut storage (Dickens and Hutchison, 1976).
The quality of peanuts in storage, like most agricultural food commodities, can best be maintained by controlling their moisture and temperature: groundnut kernels in storage are greatly affected by the temperature and moisture content of the ambient air.

Psychrometrics

Problems in storage are thus principally caused by the heat and moisture conditions and are related to the psychrometrics and the hygroscopic properties of groundnut kernels (Smith/Davidson: Psychrometrics and kernel moisture content as related to peanut storage).

This involves measurements of dry-bulb, wet-bulb and dewpoint temperature, absolute humidity, specific humidity, relative humidity, sensible heat, latent heat, total heat and specific heat.
Usually, when any two of these measurements are known, the others can be determined from a psychrometric chart. In this case the dry-bulb and wet-bulb temperatures are the two measurements usually taken to identify the prevailing conditions (see Chapter 8).
Groundnut pods consist of one or more seeds (kernels! enclosed by a shell. The kernel and the shell have different hygroscopic properties. Conventional overseas transport of groundnuts in shells does not normally result in damage - provided that the basic routine of the dewpoint-based ventilation method is adhered to - due to the fact that the shell not only protects the kernel against temperature fluctuations and moisture migration, but also seeks a higher hygroscopic equilibrium moisture content.

Peanut moisture

The moisture content of peanut samples taken prior to shipment is used to calculate an average moisture content for each specific batch. It should be borne in mind, however, that any given batch will consist of millions of individual pods, usually containing two kernels each. These individual kernels vary greatly in moisture content. This depends on such factors as: moisture content before drying, drying method, etc.
Safe storage at an average kerne! moisture content of, say, 10% (wet basis) will be highly dependent on how much the moisture content of individual pods deviates from the average

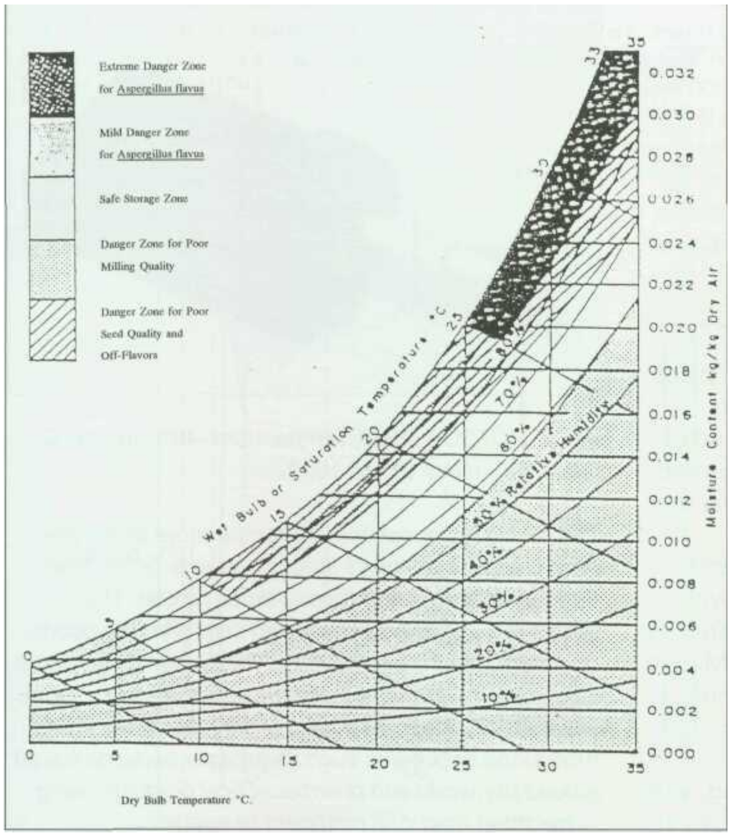


Fig. 1 Psychrometric chart indicating desirable and undesirable storage conditions for farmer's stock peanuts.

moisture content and on how quickly the kernels can be cooled.

Storage conditions

Growth of the *Aspergillus flavus* fungus and subsequent formation of aflatoxin in peanuts presents the major problem in storage and therefore also during a voyage lasting longer than five or six weeks.
The optimal conditions for the growth of *Aspergillus flavus* include temperatures of between 25°C and 35°C and relative humidities of 85% or higher, or kernel moisture contents higher than 10%.

The graph (Fig. 1) shows approximate boundaries for danger and safety zones for the storage of farmer's stock peanuts. It is compiled from research data by Diemer and Davis (1977). As we can see from the graph, the ideal conditions for normal storage periods of farmer's stock peanuts are about 10°C and 65% R.H.

However, during part of the peanut's storage life
- and certainly during (conventional) carriage overseas from China to the Netherlands via the Suez Canal - the air temperatures and relative humidities surrounding a kernel are much higher than ideal.

Especially where mould-susceptible groundnut kernels are involved, therefore, the best procedure is to cool down the produce as soon as possible by keeping the psychrometric properties of the interstitial air within the safety zone as defined in Fig. 1.

Refrigerated transport

Especially in the case of Chinese groundnut kernels which were loaded cold in wintertime and/or transferred from cold storage, there have been many instances in which conventional (ventilated) carriage by sea did not lead to a sound discharge condition, despite exhaustive inspection of the quality of the produce prior to shipment.
Following satisfactory experiences with refrigerated storage of groundnuts in warehouses in the Netherlands, therefore, Kroesen Marine Surveyors of Rotterdam - together with commodity experts ACE Survey and in consultation with the author of this book - suggested that transport of groundnut kernels on a reefer vessel under controlled and carefully monitored conditions might be successful.

The underlying idea was that refrigerated transport would offer both a constant carrying temperature and a homogeneous distribution of air in the cargo compartments. In addition, if the R.H. was too high, it would be possible to reduce it by extracting moisture from the circulating air via the evaporator. The theory was that, if these conditions were met, mould growth could be considerably retarded or even prevented.

The first experiment with the carriage of groundnut kernels under refrigeration took place in the summer of 1993. This trial cargo was transported in a "fish freezer" and consisted of 5,000 tonnes of groundnut kernels to be carried from China to Flushing (the Netherlands) via the Panama Canal.
Based on their reefer transport expertise and taking into account previous experiences with conventional (ventilated) carriage and the specific properties of groundnut kernels, Kroesen Marine Surveyors handed over the following carrying instructions to the master:

- Stowage of bags to be full bag on full bag, with a small vertical channel every 4 to 5 metres at right-angles to the bottom-up delivery air flow.
- Leave a headroom of approx. 20 cm in each single (cooled) compartment in order to facilitate the return air flow.
- A carrying temperature of +7 to +8°C based on the delivery air.
- Fans to be operated at full capacity for the entire voyage.
- Control of R.H. at 60% to 70% (max.).

Note: Controlling the R.H. on board the ship is not normally as easy as it looks. This fish freezer had a temperature range capacity of -20°C to + 10°C, was not equipped with humidifiers and had no provision for fresh air supply. Therefore, "air hoses" made from canvas around wooden hoops were rigged from the weatherdeck down to the coolers so that moisture could be added to the circulating air when necessary.

To monitor the cargo temperature inside the stow, a "hamster" was used. The "hamster" is a data-logging instrument which registers the temperature (and/or the humidity) continuously over a certain period.

Fig. 2: HOTDOG DH 1: Temperature -40°C to +70°C, relative humidity 0% to 100%

The humidity sensor and the temperature probe are protected by a stainless steel sinter or a Teflon filter fitted directly over the measurement probe. This allows the unit to be packed and sent with the goods or, where required, to be left in the holder for stationary monitoring of climatic conditions. For some years ELPFtO Loggers have been travelling the world monitoring shipments such as tobacco being delivered around the world and pharmaceutical products being airfreighted from one continent to another.

The "hamster" pictured in Fig. 2 is the "Hotdog" type DH 1 (Elpro-Buchs AG, Switzerland) which has a temperature range capacity from -40°C to +70°C; 0% to 100% for R.H.

During this first experimental voyage the "hamsters" indicated that the kernels had reached a homogeneous temperature of +7°C within 24 hours in all compartments. The R.H., measured continuously by Kroesen using a whirling psychrometer, stabilised at 58-60% after five days.

For subsequent shipments modern fruit carriers were used. A modern fruit carrier will probably face problems if carrying instructions are accepted which include control of the R.H. and if the cargo of kernels releases moisture during transport. This will also occur, for example, if the kernels are loaded cold - possibly below zero - and shortly after harvest and if the temperature drop in the coolers is not sufficient to extract moisture from the circulating air (see the Mollier diagram for humid air, Chapter 8).It is a well-

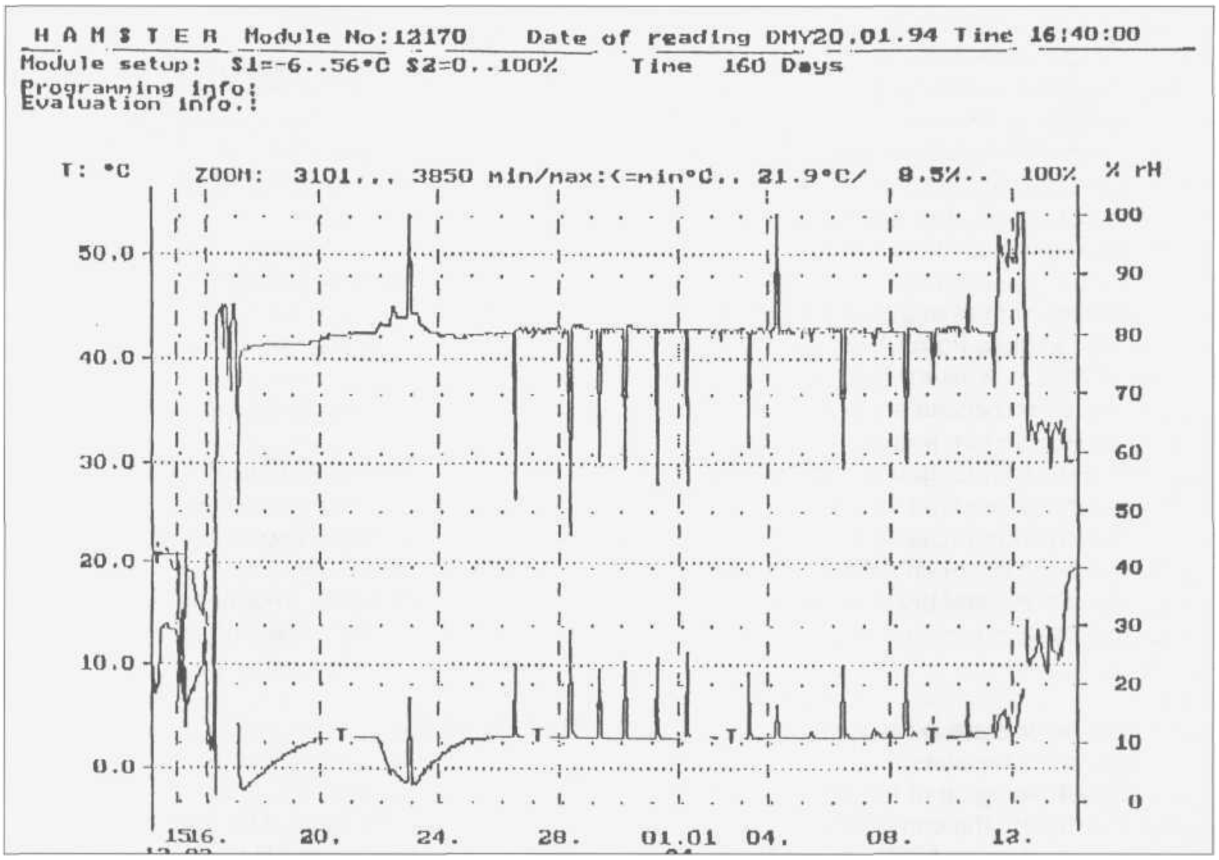


Fig. 3: Computer graph of "hamster" recordings

known fact that during the transport of onions (approx. 0°C) the required R.H. in the hold is also a source of concern. The required R.H. for onions (dry) is 65-70%. To achieve this low R.H., what are known as "onion doors" were fitted on "Winter" class vessels (Cool Carriers) in the holds on the suction side (in the cooler room bulkhead). This was done in order to accelerate the transport of hold air back to the evaporator so that absorbed moisture could be released again and fed to the cooler.

Fig. 3 shows a specimen computer graph of "hamster" recordings made during subsequent shipments with fruit carriers. The bottom line in the graph indicates the air temperature between the bags in a given compartment, whilst the top line shows the relative humidity as a %.

Evaluation

Following some twelve carefully monitored shipments of refrigerated Chinese groundnut kernels in jute bags to the Netherlands in various seasons, the main conclusions that can be drawn are:

- If the bags are always stored full bag on full bag and preferably athwartships, this stowage method will guarantee a sufficient air flow at all times, even after the cargo has settled, on board selected reefer ships which have a vertical bottom-up air flow. This eliminates the need for the small vertical air channels which proved costly and difficult to build in China.

- Careful monitoring of cargo temperatures upon loading (definitely below zero in wintertime in China) against the desired carrying temperature; it is also essential that the atmosphere in the reefer compartment should have the maximum permitted R.H.

- Since kernels offered for shipment some two months after harvest will most probably have a high moisture content (possibly up to 12%), a constant lower delivery air temperature of 3 to 4°C has proved effective in ensuring that the cargo is delivered in the same good order and condition as shipped, with no signs of mould growth whatsoever but also without significant moisture losses. Successful storage for a longer period after discharge will then normally require additional (mechanical) drying.

- It should be emphasised that refrigerated groundnut kernels from China, if discharged in summertime in Western Europe and if not destined for immediate storage in a refrigerated warehouse, must be protected against "cargo sweat" before prolonged storage in a warm-humid atmosphere.One very effective method involved a gradual increase in delivery air temperatures up to +15°C (depending on the capacity of the installation), starting a few days prior to arrival.

Note:
Groundnut kernels are in no way comparable to fruit cargoes like bananas.
The routine opening up of the fresh air supply in order to "refresh" the compartment atmosphere and remove foul air contaminated with $C0_2$ will merely humidify the circulating air to a level in excess of the permitted parameters.
Refrigerated groundnuts are in a dormant condition but are still alive.
In spite of the relatively low temperature, therefore, any increase in moisture will most probably activate the respiration of micro-organisms and consequently lead to increased microbiological action after the kernels have become hydrated.

Carriage instructions

The above experiences have resulted in the following standard carriage instructions being drawn up for groundnut kernels shipped from China to Europe under refrigeration:

- Stowage of bags preferably full bag on full bag.
- Leave a headroom of approx. 20 cm to facilitate return air flow.
- A carrying temperature of +3°C to +4°C based on delivery air.
- Recirculation fans to be operated at full capacity.
- Control of R.H. at 60% to (max.) 70%. This will most probably mean that fresh air ventilators have to be kept fully closed throughout the voyage.
- Temperature and R.H. of both delivery and return air should be measured and recorded twice a day.

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THE TRANSPORT OF VARIOUS TYPES OF FRUIT

International trade in fresh fruit

In line with the higher per capita income in recent decades there has been a significant increase in fruit consumption as part of the trend towards a more varied and healthy diet. Demand for fruit is partly influenced by its price and by consumer income and also by changes in the size and composition of the population.
The fruit consumption patterns of young people differ from those of older people. The increase in global population numbers (now 5 6 billion people! has had a positive effect on the quantity of fruit demanded.
In 1992 world production of the most important types of fruit amounted to 348 million tonnes.

Citrus fruit, grapes, bananas and apples account for 20%, 17%, 13% and 11 % of total world production respectively. Although the fruit trade has grown considerably over the past two decades, only about 7% of world fruit production is transported internationally in the form of fresh produce The total value of world imports of fresh fruit (including those by the former COMECON countries) amounted to $23 billion in 1991.
The European Union's imports of $12.3 billion represented 53% of world imports. The developing countries imported only $1.8 billion worth of fruit

The table below shows the exports of the 4 most important types of fruits.

Table 1:Fruit exports from the major exporting countries, 1991
(volume in '000 tonnes and as % of domestic production)

	table grapes		citrus		bananas		apples	
	vol.	prod.%	vol.	prod.%	vol.	prod.%	vol.	prod.%
World	1.659	3	7,531	10	10,333	22	3,934	10
USA	246	5	845	8	356		432	10
Argentina	12	1	241	15			270	25
Brazil	2		131	1	38	1	4	1
Chile	419	37	6	3			392	52
Ecuador					2.714	92		
Colombia					1,473	90		
Costa Rica					1,541	99		
Honduras					699	64		
Panama					707	60		
Italy	460	5	223	7			342	19
Spain	114	2	2,302	53			17	2
France	12				25		639	32
Hungary	10	1					350	37
Greece	109	8	385	41			9	3
South Africa	62	4	432	52			198	37
Morocco			678	53				
Israel	8	8	325	53	49			
Philippines					951	27		

Source: FAO, Trade yearbook and Production yearbook.

Bananas, apples, citrus fruit and grapes are by far the most important fruit types in terms of international trade. Kiwifruit, though less important in this respect, has built up a significant position in the northern hemisphere, whilst the avocado is also making good progress both in the USA and in Western Europe.

The preference for certain types of fruit is not the same in each region. Western consumers mainly prefer "easy peelers" like bananas and mandarins In Western Europe, the USA and Canada consumption of citrus fruit and apples is particularly high. In recent years there has been an enormous increase in banana consumption, notably in the USA and Germany.
Within the European Union, even in neighbouring countries, the preference for a specific type of fruit is not identical. In 1991, for example, 14.6 kg of bananas per head were consumed in Germany, whereas per capita banana consumption in the UK was 7 kg and in France 4.2 kg. In that same year per capita consumption of citrus fruit in Germany was 16 kg, as compared to 11 kg in the UK, 28 kg in the Netherlands and as much as 42 kg in Spain.

In a great many tropical regions per capita income is usually very low, which is why people there mainly eat the cheaper, local fruit. Besides the banana, one of the main fruits consumed in the tropics is the mango. The papaya and avocado are also very popular.
In regions where per capita income is increasing, such as in South East Asia, consumers are demanding greater diversity in the choice of fruit and vegetables.

APPLES

The origins of apples should most probably be sought in Europe or the West Indies. There is a three-year interval between the planting of an apple tree and commercial production. The economic lifetime of a tree is between 10 and 15 years. Harvest time in the northern hemisphere is between August and November; in the southern hemisphere between March and July. Nowadays, the keeping time of apples can be extended by means of climate-controlled storage, but the result is that fruit from the northern hemisphere then has to compete with the fresh fruit crop from the southern hemisphere.
Since apples have been cultivated for several thousand years, there are now a great many varieties in existence. Apples can be cultivated in all temperate regions of the world. Mainly because of climate differences but also as a result of taste preferences, a wide diversity of familiar apple varieties are grown in Europe alone, examples being Golden Delicious and Granny Smith. In recent decades interest has been growing for new varieties, such as Jonagold and Elstar. Apples are in fact cultivated in virtually all parts of the world and the total annual production amounts to some 39.5 million tonnes.

Production and export of apples

If we assume that commercial production of apples is equal to 100%, then only 10% (3.9 million tonnes! of that quantity is destined for export and 32% is destined for processing. Even if we assume that 2% of total production is lost, then that still leaves 56% for domestic consumption.
Table 2 shows the eight biggest apple producing countries and their production volumes of apples in millions of tonnes. Apple exports by the eight major exporting countries are shown in thousands of tonnes and as a percentage of each country's domestic production.

Table 2: Production and export of apples (1992 figures)

Production of apples (millions of tonnes)		Export of apples		
			(volume x 1,000 1)	prod.
CIS	6.0	France	547	24
USA	4.8	USA	524	11
China	4.8	Chile	418	52
Germany	3.2	Italy	409	17
South America	2.6	New Zealand	206	54
Italy	2.4	South Africa	198	37
France	2.3	Argentina	195	18
Turkey	2.0	Hungary	125	14

Source: FAO.

We should add here, however, that annual production volumes may be strongly affected by weather conditions, e.g. night frost and hail during blossom time. One striking example of this is the poor crop in the EU in 1991. Apple production in Germany in that year amounted to only 1,0 million tonnes. By contrast, in the good production season of 1992/93 the German apple harvest was 3.2 million tonnes. In Italy the apple production in the same years amounted to 1.8 and 2.4 million tonnes respectively. There are also structural factors which can lead to changes in production volumes. The most significant trend in recent years is the sharp fall in production in what was formerly the USSR. However, though the importance of the CIS may have decreased, the CIS is still the world's largest apple producer with a 14.5% share of production. Most of this comes from the regions to the north of the Black Sea in the republics of Moldavia, the Ukraine and Russia. China, however, is one country which has revealed the opposite trend and has raised its production substantially in recent years.

Export prices

The prices fetched by apples vary according to season, cycle and trend. High production levels in the 1992/93 season in the EU, for instance, resulted in a sharp fall in prices not only within the EU itself but also in other sales markets. Since EU production is likely to remain high for some years, the downward pressure on prices will continue.

The export prices of apples are mainly determined by their country of origin.
In 1991 the price for apples from France and Italy amounted to about US$900/tonne, whilst apples from the USA fetched US$600/tonne. Exports of apples from Argentina (US$300/tonne| have fallen sharply because of growing apple exports from Chile. As a result Argentina has been forced to sell its apples at considerably lower prices on the local market. By contrast, Chile offers high quality products and is gaining increasingly more ground on the international apple market. The 1991 price for apples from Chile amounted to US$490/tonne.
For many years the lowest price has been paid for apples from Hungary (US$160/tonne). The quality of these apples is mostly low, as Hungarian growers still mainly cultivate the traditional apple varieties which are little in demand.

To summarise, it can be said that the saturated demand for apples in certain European markets has directly affected the price level. Modern techniques have boosted the fruit yield per hectare and have also made it possible to reduce the costs of packaging, transport, etc. Ultimately, these savings will be passed on in consumer prices. It is therefore a fair assumption that the price of most varieties of fruit will continue to reveal a downward long-term trend.

Imports of apples

The most important market for the international trade in apples is the European Union. The EU imports a total of 2.0 million tonnes, equivalent to 56% of all world apple imports. Most of these apples are supplied by the EU member countries themselves.
The main importing countries are: Germany (735,000 t), the United Kingdom (458,000 t), the Netherlands (288,000 t), Belgium (229,000 t) and Spain (212,000 tl.

In the 1980s the former USSR was always a big importer of apples. Between 1980 and 1990 its average annual imports amounted to 450,000 tonnes. These apples were mainly imported from Hungary and Poland. In 1991 imports fell to 120,000 tonnes and in 1992 they plummeted to a mere 31 tonnes.

In Western Europe the harvest time for most apple varieties is in September and October. The apples which are imported into Western Europe arrive from the United States in January, February and March. Particularly in the spring and summer apples are imported from South America, South Africa, Australia and New Zealand. A large proportion of the fruit imported into the EU is sold on to other countries. In Western Europe Belgium and the Netherlands are two of the most important "re-exporters". Antwerp and Rotterdam are two of the world's largest ports, both with a hinterland comprising large sales areas for re-export. Most of the apples re-exported by Belgium and the Netherlands come from Chile and to a lesser extent from Argentina and the USA. The largest importers of re-exported fruit are Germany, the United Kingdom and France.

Harvesting and storage of apples

The keeping time of apples is influenced not only by the conditions under which they are stored but also by the conditions under which they were grown and handled prior to storage.

Apart from the growing conditions and the right moment of harvesting, the way in which the apples are handled in the period between harvest and storage also plays a very important role in the fruit's storage life. This is specifically of influence on the physiological or storage diseases which we will be discussing later on. It is important that the fruit should be transported to the coldstore as quickly as possible after harvesting. Rough and careless handling should be avoided, as this can result in bruises, skin damage, etc. which may subsequently give rise to premature breakdown or mould infections

The correct moment of harvesting plays an essential role: if the apples are immature when picked, the fruit will be susceptible to excessive moisture loss and shrivelling. In addition, susceptible varieties will run the risk of developing scald and bitter pit. On the other hand, if the apples are picked too late, the fruit will be more prone to water core, decay and premature ageing.

The principal late (autumn) apple varieties which are exported are Golden Delicious, Golden Rennet, Cox's and Jonagold. Especially the Jonagold is an excellent storage apple. The apple varieties Granny Smith, Sturmer Pippins, Breaburns, Jonagold and FUJI'S are mainly exported by New Zealand.

Apples may be shipped at varying stages of maturity, depending on the time of year, the cultivar and the market. Obviously, however, the shipper must ensure, firstly, that they are not so immature that they will never become palatable and, secondly, that they are not so mature that they will fail to arrive in good condition and with an adequate shelf life. Both during and after cool storage or refrigerated carriage earlier maturing varieties will ripen faster and have a shorter life than later varieties. Earlier varieties therefore play less of a role in world trade. This is the reason why only very few of the familiar West European summer apples such as the Benoni, Summer Red, Discovery and (Vlantet are exported.
Non-chilling sensitive apples can be kept in storage for 3 to 9 months, whilst chilling sensitive apples have a storage life of approx. 45 days.

CA storage

The storage life of apples can be substantially extended via CA storage (see also Chapter 11). CA storage slows down the fruit's respiration rate. The speed at which the air is circulated through the storage space can therefore be reduced so that the product dehydrates less quickly.
The recommended atmosphere during CA storage contains 2 to 3% oxygen (O_2), whilst the carbon dioxide ($C0_2$) content amounts to 1-2% for non-chilling sensitive apples and 2-5% for chilling sensitive apples.

Apples and pears in particular are the fruit types which are most stored under CA conditions. By reducing the $0_;$ and the $C0_2$ content the ripening process is delayed and fungal growth inhibited. The $0_?$ content must not become too low as fermentation reactions will then occur, causing spoilage of the fruit. The $C0_2$ content must not become too high, as this results in spoilage, e.g. brown discoloration
The fruit must be brought under CA conditions as soon as possible after picking. As an example we would mention here the Golden Delicious variety of apple If this apple is kept in ambient air at a temperature of 2"C, its storage time will amount to 4 to 5 months. If the apple is stored at a temperature of 2°C in air with an 0_2 content of 3% and a $C0_2$ content of 4% (the remaining volume being filled by N2), then its storage time will be 7 to 8 months. For Granny Smith apples (storage temperature 0°C) the storage time is extended by about 4 months to about 7 months and for .Jonathan (storage temperature 4°C) it is extended from about 3 to about 5 months.

Deterioration of apples during cold storage

Pome fruits (apples and pears) are classed in the climacteric fruits category This means that during storage apples and pears produce a lot of heat, ethylene and $C0_2$- The fruit should therefore best be stored whilst it is still in the preclimacteric phase and should preferably be pre-cooled before shipment to a fruit temperature as close as possible to the designated carrying temperature. One of the methods of determining the maturity is to use colour charts (for some varieties this can give a misleading picture) or to use an iodine test. A reliable method of determining the ripeness is to measure the soluble solids content (SSC) or to test for firmness. Generally speaking, the SSC should be 11-12% and the firmness 18-21 Ibs The hard stage for Golden Delicious is between approx. 18 and 16 Ibs (see Chapter 4). Another, possibly not so scientific but certainly practical method is to determine the ripeness on the basis of the colour of the pips

During cold storage the fruit may suffer damage as a result of:

a) excessive ripening,
b) shrivelling,
c) discoloration,
d) development of physiological disorders,
e) bruising,
f) mechanical damage or
g) freezing.

Most recipients want the apples to have a long market life after outturn. In most cases, therefore, the apples must be in a hard and relatively green condition when unloaded. In any event they must be intact, sound and clean, i.e. free from decay, internal browning, internal breakdown, scald, bruises, insect damage, freezing injury, and other defects. For trade within the EU apples have to comply with EEC Standard No. 1. Other recommendations, e.g. those given in the quality factors for apples in the US Grade Standards, are not mandatory in international trade.

If apples are unloaded in a "forward" condition, then this is usually due to slow cooling or too high a temperature during transport or is the result of over-long voyages. If the apples have been properly pre-cooled before shipment they are less likely to arrive in a damaged or over-ripe condition.

Shrivelling

Shrivelling is the visual evidence of excessive moisture loss from the fruit and is due primarily to the storage atmosphere having too low a humidity. In general terms an apple harvested in an immature condition will lose moisture more readily than one that has been allowed to become fully mature. On the other hand, however, some varieties tend to shrivel or wilt more than others. This mainly depends on the nature of the skin. One example is Golden Delicious which suffers a high moisture loss even immediately after harvest.
Here again, quick cooling and the maintenance of a uniform transport temperature will help to prevent shrivelling. An especially crucial factor is to maintain a high relative humidity (about 90%). The most effective solution to prevent shrivelling, however, is to line the package with plastic film sheet.

"Scald"

"Scald", whose symptoms are a diffuse browning of the skin, is perhaps the most widespread physiological disease in apples. Scald is not, however, a skin injury but an ageing disease of the skin caused by certain toxic gases given off by the apples themselves. Scald is characterised by irregular, brown patches, sometimes slightly sunken. These patches are caused by necrosis of the cells in the outer layer of the skin.

Scald usually affects only the apple's skin and therefore only its external appearance, but in advanced stages it may extend into the flesh. Sometimes the disorder only develops after the fruit has been warmed following storage
The older the apple the more susceptible it is to scald. As a rule, apples picked early and very early or those with poor colour development are more likely .to reveal scald than those picked at a later stage. Delayed storage and too-high storage temperatures also favour the development of scald

The sooner the apples are treated against scald, the better. To prevent scald, some apple varieties are sprayed with scald-inhibiting chemicals even before picking This is of course only done if the chemical agent used for spraying is also permitted by the importing country. The problem is that during the voyage it is mostly impossible to see whether scald will occur. However, if the fruit is taken into warmer surroundings, scald will develop quickly.

"Brown heart"

Brown heart (low temperature breakdown) is also known as brown core or core flush. Brown heart is a brown discoloration of the fruit flesh around the core. It does not affect the surface of the fruit, but the flesh inside turns brown from the core through to just under the skin. The factors which cause brown heart are: a long storage time at a low (in fact, a too-low! temperature, a very high air humidity in the storage space and the $C0_2$:0_2 ratio prevailing in the storage atmosphere. It is therefore obvious that CA storage will enable the suppression of brown heart for a lengthy period.
Brown heart does not occur in all apple varieties. Susceptible varieties include: Cox's, Mclntosh and Newton.
Nowadays, brown heart caused by an excessive $C0_2$ content hardly occurs any more.

We would point out here that the "low temperature breakdown" we have just described displays more or less the same symptoms as "senescent breakdown". Senescent breakdown occurs specifically in shorter keeping, eatlier varieties. It is a softer, more mealy internal breakdown and in severe cases the affected flesh turns brown. Senescent breakdown is encouraged by late picking, (over-maturity), delayed cooling, high storage temperatures and longer voyages.

"Bitter pit"

Another possibility is that the fruit may have been damaged during growth because the composition of the plant feed was not properly balanced. Calcium deficiency, for example, can cause bitter pit (see also Chapter 4). Bitter pit is characterised by sunken spots on the surface of the apple. Mostly, these small brown spots are concentrated in the outer portions of the flesh just under the skin and towards the blossom end and in the early stages they have a water-soaked appearance. Many pits show through the skin as small brown or greenish-brown depressions, later turning grey or black. The disorder is most severe on apples picked when immature; and more severe on larger apples than on smaller ones
The problem may be visible at harvest but often only develops during storage. The disease will increase in severity during storage and will develop more rapidly at a higher storage temperature. Bitter pit does not spread from apple to apple. Fast cooling and high relative humidity can reduce symptom development during storage. In some areas calcium sprays are applied before harvest or calcium dips after harvest.

Fungal spoilage

Damage may also arise because of rotting due to mould attack. Here, too, the damage may become visible both during and after the cold storage period. Rots may be the result of skin injuries caused by rough handling. Other causes are: over-maturity or high temperatures and wet weather around harvest time. In the case of skin injury the flesh around the spot where the tissue has been damaged turns soft and watery and takes on a brown colour. Later, fungal growth develops on the surface. In Chapter 6 we have already described how wounds, bruises, insect punctures, etc. are the usual points of ingress for decay fungi. The most common fungus that develops in ripe fruit is *Penicillium expansum.* the causative agent of blue mould. At first the fungal growth on the surface is white or pale green, later turning a blue-green colour.
Blue mould and other mould diseases such as grey rot, anthracnose rot, etc. have already been discussed in Chapter 6. Mould attack can be prevented by handling the fruit carefully and by using effective and approved fungicidal chemicals. Obviously, prompt cooling-down is of the utmost importance here, too.

Carriage instructions

Although - as we have seen above - various types of damage can occur during cold storage and transport, apples usually present few problems as a cooled cargo Any damage claims that are made usually relate to low temperature spoilage (l.t s), brown heart, scald and bitter pit. In many cases the cause of the damage will have occurred prior to the time of loading on board.

Temperature

Apples can withstand small temperature fluctuations better than pears and other soft fruit. Yet care is essential to ensure that they do not become "frost-bitten". The extent to which apples become "chilled" depends on how low a temperature they have been exposed to and on the length of time they have been frozen. Severely frozen apples will be water-soaked when they thaw out and will eventually reveal a brown discoloration, after which they will quickly rot. Slightly frozen apples will recover if thawed slowly by raising their temperature by about 2°C. In that case the boxes must not be moved, as frozen apples will bruise easily and severely.

As regards the transport temperature we have to make a distinction between "non-chilling sensitive" and "chilling sensitive" apples. In addition, a role is played by the highest freezing point. As will be known, this temperature is determined by the type of fruit and by the concentration of sugars and acid in the cell sap. For apples the freezing point is approx. -1.5°C. The carrying temperatures may differ to some extent, depending on country of origin and variety. The most commonly prescribed delivery air temperature for non-chilling sensitive apples is between -1 °C and +1 °C. Other apple varieties, including Golden Delicious and Jonathan, are subject to scald and soggy breakdown at temperatures below 2°C. For chilling-sensitive apples the delivery air temperature should be between *2"C* and 5"C.

In general, apples will keep for approximately 25% longer at -1 °C than at CTC. Scald and decay are likewise less prevalent at a lower temperature.

Normally speaking, apples are pre-cooled before shipment. Especially in the beginning of the season the fruit temperature during loading must not exceed 5°C. Obviously, the cargo compartments must also have been pre-cooled to approx. 2°C.

The storage air

At a carrying temperature of 0°C the heat production of apples ranges from 5 to 15 W/tonne. At this same temperature the $C0_2$ production amounts to 2-6 mg/kg/h. The specific heat amounts to approx. 3.64 kJ/kg x *°C.* Apples have a very high ethylene production (more than 100 microlitres/kg/h).

Both before and after harvest apples lose a great deal of moisture, largely through the lenticels or pores in the skin. Since their source of moisture supply has been cut off by harvesting, apples will wilt unless they are kept in a moist atmosphere. This is why the shipper will generally require a relative humidity of between 90% and 95% in the cool compartment. If apples were to be transported at an R.H. of, say, 80% some varieties would lose 3-5% in weight, with the result that the skin starts to wrinkle and the fruit flesh loses its normal freshness. The carriage instructions will also prescribe a $C0_?$ concentration of lower than about 0.8%.

To disperse the heat that has been produced, the cooler fans must be operated at full speed, especially at the beginning of the voyage. Periodic ventilation with outside air is required to keep the $C0_2$ content within the prescribed limits.
We would add here that apples not only emit a strong fragrance but will themselves readily absorb other odours.

PEARS: COLD STORAGE AND SHIPMENT

Production and export of pears

World production of pears amounts to 9,360,000 tonnes. Of this quantity, 62% is for domestic consumption and 22% for processing, while 16% is destined for export as fresh fruit.

The main producer countries are: China (2,728,000't), Italy (864,000 t}, the USA (824,000 t), the CIS (500,000 t), Japan (420,0001), Turkey (420,000 t) and France (280,000 t)

For the ED the total production works out at 2,174,000 tonnes. In addition, the EU imports 640,000 tonnes and exports 360,000 tonnes of pears.

The most important export countries are:

Argentina (151,000 t), the USA (121,000 t), Chile (114,000 t), South Africa (82,000 t), China (35,000 t) and Australia (26,000 t).

Cultivation and storage

It is impossible to say for certain where pears originate from. Wild pears still occur in Asia and Europe. The general assumption is that pears originate from North West Asia. There are many pear varieties which differ from each other in size, flavour and colour. The principal storage varieties include: Bartlett, Bosc, Anjou, Conference, Comise and Williams.

Many of the conditions which influence the storage and transport temperature and keeping time of apples also apply to pears. In the case of pears, however, an additional factor is that they are much more sensitive to the temperature conditions In most varieties, particularly the Bartlett, ripening changes take place more rapidly than in apples. Speed during handling operations and rapid cooling-down are therefore even more essential than for apples. Just like apples, pears may also reveal considerable variation in fruit storage behaviour from one production area to another and from year to year within the same area.

Export pears are harvested when the mature fruit has a pulp pressure reading of between 18 and 21 Ibs as measured by a penetrometer (plunger diameter 8 mm). If the pears are destined for immediate sale they are only harvested when the pressure reading is approx. 15 Ibs. The pears are "eating ripe" when their firmness amounts to approx 3 Ibs. A rough idea of how the firmness develops can be seen from the following example Pears picked with a firmness of 21 Ibs are placed in a ripening chamber with a temperature of 21 °C immediately after harvest (no ethylene treatment). During the first two days we then see only a minor decline in firmness. During the following 24 hours we will see the firmness falling rapidly to approx. 13 Ibs, after which it declines further to approx. 5 Ibs on day 5.

Like apples, pears are a classical climacteric fruit. In other words, if the (mature) pears are kept in storage at a temperature of approx. 20°C immediately after harvest, their respiratory rate will decline shortly after harvest and then rise rapidly to a peak, followed by a second decline as the tissues become senescent As explained earlier (see Chapter 3} the rise in the respiratory rate is accompanied by a rapid rise in the production and release of ethylene gas, a softening of the flesh, a decline in acidity, a loss of green colour and an increase in yellow colour. During this respiratory climacteric phase the fruit has an increased susceptibility to mechanical injury and thus to decay, as a result of water-logging of the intercellular spaces Ultimately this leads to a brownish deterioration of the tissues adjacent to the core in the final stages of senescence.

The temperature of the fruit is the most critical variable involved in handling, storing, shipping and ripening. As we have seen, the fruit must be cooled as quickly as possible after picking but in any event within two days. Delay between harvesting and the commencement of pre-cooling results in the faster onset of ripening.

In cold storage the firmness during the first 4 weeks remains practically the same as it was when the fruit was originally placed in storage. Fruits whose cooling has been delayed for 3-4 days will exhibit a high percentage of senescent breakdown upon outturn.

As far as ripening is concerned, we need to consider not only the influence of the temperature but also one other critical factor. The rate of ripening is largely influenced by the percentage of ethylene gas in the internal atmosphere of the pears. It is quite possible that a small proportion of the pears will have more ethylene gas in their internal atmosphere than the remainder of the pears. Such fruit is able to start ripening immediately after being picked. Once initiated, ripening is irreversible. It can be slowed down, but not stopped, by reducing the fruit temperature or by modifying the composition of the storage air.

In the remaining fruit the ethylene gas percentage in the intercellular spaces is sufficiently far below the threshold level that is needed to trigger ripening (approx. 0.1 ppm). This fruit will therefore not start to ripen during cold storage, except in the unfortunate case where these pears are mixed with ripening fruits. In that case they, too, will be encouraged to ripen by the ethylene gas produced by the other pears.

Damage and fungal diseases

Generally speaking, we can say that the storage life of pears is limited by:

1) time and place of harvesting,
2) weather conditions,
3} methods of handling,
4) time required for the initial cooling,
5) core breakdown,
6) loss of ripening capacity.

Pears harvested whilst still immature are subject to excessive water loss and subsequent shrivelling. Pears which have been picked too late lover-mature) are more likely to show internal brown discoloration (brown heart! Over-maturity quickly results in over-ripeness.

Storage conditions

If cooling is delayed after harvest and/or if the storage temperature cannot be achieved through to the core within a few days, the fruit will start to ripen. Though perhaps not directly noticeable at first, the basic green colour will disappear and make way for yellow; the pear will turn soft. This is easy to see when the fruit flesh around the stalk "gives" when pressed.

If held in storage "for too long and especially at a higher temperature (e.g. 2°C), the well-known pear varieties such as Anjou, Bosc, Bartlett and Comise will lose their ripening capacity and will fail to ripen even when later exposed to suitable ripening temperatures. With the exception of Bartlett, no external symptoms of over-storage are visible upon outturn but, when ripening is attempted, the pears will turn yellow but will remain hard. Bartlett, however, may start to show a light yellow colour during storage, but that is specifically an indication that it has been stored for too long. Bartlett in particular must therefore still have a slight green colour upon outturn. Scald and breakdown may be the result of over-lengthy cold storage. As a general rule, therefore, pears should never be kept in cold storage for longer than the maximum time specified for each particular cultivar.

As in the case of apples, the storage time of pears can be substantially prolonged by CA storage (0_2: 2% to 2.5%; $C0_2$:0.8% to 1 %). Just as with apples, however, it is also possible to extend the normal storage life of pears by placing polyethylene liners in the cartons. The liners are usually perforated or provided with ventilating holes to prevent excessive moisture build-up inside the package.
The rapidity with which the fruit is cooled to storage temperature after harvest is crucial for its subsequent storage life. To ensure a favourable storage time it is essential that pears are cooled immediately after picking and that the storage temperature is achieved right through to the core of the fruit within a few days. Provided they have been correctly cooled, Bartlett, Comise and Bosc can be kept up to 3 months and Anjou for 5 to 6 months.

Unlike the customary practice for apples, pears are generally packed for shipping before storage. The reason for this handling difference is that pears become very sensitive to skin injuries from handling after only a few weeks in storage. Any pressure marks will always result in brown discolorations.
We would emphasise yet again that pears which are to be held in storage for a long time or are to be shipped over long distances must be pre-cooled!

Weather conditions

Weather conditions may have an adverse effect on the quality and condition of pears. Low temperatures during fruit setting may give rise to physiological imbalances. Pears harvested after abundant rainfall may also be adversely affected in their further development. Pears which originate from a comparatively cold region or which have been picked after abnormally low night temperatures during the final 3-4 weeks before harvest (e g. 8°C at night as compared to 18°C in the daytime) will have a shorter keeping time.

Causes of damage during cold storage

Brown *heart*

Brown heart (brown core! is a common disorder but can sometimes be more serious in pears from some cultivation regions than from others. Not all varieties are equally susceptible to this disorder. The main susceptible varieties are Bartlett, Cornice and Bosc Brown core and senescent breakdown are characterised by a breaking down of the tissues in the core area and this may later spread to just under the skin. In the initial phase the fruit flesh is soft and watery and in a later stage it turns brown. Ultimately, the skin will also start to display colour abnormalities. Affected fruit can also be recognised by its unpleasant smell and taste. The causes of brown core (core breakdown) are: late harvest (over-mature), slow cooling, high storage temperature and extended storage periods.

Shrivelling

To an even more serious extent than in apples, shrivelling due to moisture loss frequently occurs in pears.

The R.H. in the cooled compartment must therefore be kept as high as possible. To prevent shrivelling, pears were formerly packed in unsealed polyethylene film bags or bag liners. This method was not suitable for all varieties and is hardly used any more nowadays. However, one method which is used today, particularly for Bartlett, involves applying a wax or plastic coating on a corrugated container so as to provide a moisture barrier.

Fungal spoilage

If the fruit is handled carefully and there is effective control of sanitation, fungal spoilage will not be able to attack pears to any great extent. Fungal rot can also be combated through a careful use of an effective and approved fungicidal chemical.
In some varieties, e.g Anjou, the pears may suffer serious loss from grey mould rot as a result of a lengthy storage period. This type of spoilage is also known as "nest rot" or "cluster rot", the reason being that a large number of affected pears are often found in a "nest" or "cluster" in one position in the carton surrounding the original infected pear.

Blue mould rot *(Penicillium expansum Thorn)* is yet another problem that may affect pears. Whereas grey mould rot is caused by the *Botrytis* genus, the causative agent of blue mould rot is the *Penici/iium genus.* This is the familiar blueish-green growth that occurs on mouldy foods. It is a parasite of wounds and can also penetrate a fruit through the undamaged skin (via lenticels). Usually, these lenticels are found in the vicinity of damaged areas (bruises caused by knocks and falls)
It is therefore important that damage due to rough handling during or after harvesting is avoided so that the fruit is in a clean and intact condition before being placed in storage.
As we know, moisture encourages mould growth. Though plastic liners do indeed prevent shrivelling, their drawback is that the air inside the liners has a very high relative humidity, which in turn is conducive to mould growth.

Freezing injury

In some instances pears will freeze at temperatures as high as -1.6°C. Frozen pears exhibit the same symptoms as frozen apples: they have a glassy, water-soaked appearance and often have a wrinkled skin. When such frozen fruit is thawed out, a brown, dry and pithy area develops around the core. Frozen pears will fail to ripen and after a while this will lead to a general breakdown.

Just as in the case of other fruit, the extent of the damage will also depend here on the exposure period and the temperature during that period.
If the freezing is not too severe, no subsequent damage seems to occur. In such cases it is quite possible that the fruit will recover provided that it is thawed slowly and undisturbed at a temperature of + 1°Cto +2°C.

The shipment of pears

Unlike apples, pears must be harvested, handled, stored and shipped in a hard, green condition and then ripened after discharge. Pears will not generally ripen satisfactorily at low temperatures. Their optimum ripening temperature is approx. 20°C.

Before loading, the hatch must be pre-cooled to between 0°C and 3°C. In view of the odour-sensitivity of pears, the hold must be properly ventilated before cooling-down starts. The hold must also be completely free of cleansing odours.
Usually pears are loaded pre-cooled. In the coldstore the temperature is brought as close as possible to the desired transport temperature (-0.5°Q. An increase in the temperature during transport from coldstore to the ship is in most cases unavoidable However, this must be prevented as much as possible and the temperature increase must in no event exceed 4-5°C. Upon loading, the pressure - measured on the skinless pulp - must amount to at least 16lbs.

Depending on the variety and the picking time, the freezing point of pears will be approximately -1.6°C.
Roughly speaking, the hold temperature for pears is between -0.5°C and 0°C. During cooling-down the cooler fans should be operated at full speed. The delivery air temperature is usually set at 0.5°C above the pear's freezing point.
The storage time of pears varies from 2 to 6 months and is largely governed by the period of time between picking and cooled storage Under CA storage conditions Conference will keep for up to 6 months and Comise for up to 4 months.

The ethylene production of pears (10-100 microlitres/kg/h) is slightly lower than that of apples, though the ethylene-sensitivity of pears is in fact somewhat higher. The P.M. during transport must be between 90 and 95% and the CO_2 content must remain below 1 %. If necessary, fresh outside air must be admitted.

Things become more difficult if the pears have not been (properly) pre-cooled before loading and if the voyage is also likely to be a very long one Since in this case every tenth of a degree is crucial, the delivery temperature can best be set at -1.5°C, assuming that the freezing temperature of pears is -1.6°C. However, the hold temperature must not be allowed to fall below -0.5°C. Effective and accurate temperature control is essential here, but this is not difficult with today's modern measuring and control equipment.

The heat production for pears amounts roughly to 10-18 W/tat 0°C and 20-45 W/t at 5°C. The specific heat amounts to 3.70 Kj/kg x °C.
At 0°C the CO_2 development is approx. 3-4 mg/kg/h (75-100 g/tonne/24 h) and at 5°C it is 120-250 g/tonne/24h.

The keeping time of early varieties such as Williams and Bartlett is 2.5 to 3 months. The safe maximum voyage length for these varieties is approx. 50 days. Especially towards the end of the season pears may be discharged "in a forward condition". In this case ripening has already commenced, the fruit is starting to soften and consequently will have a short market life.
If the pears are more or less yellow in colour upon outturn and if their pulp temperature is above 0°C, people soon tend to assume that the temperature during the voyage was too high. From what we said previously about the cooling of pears it should be clear that another highly probable cause is that the pears were not properly cooled after picking.
Naturally, every degree of temperature increase or decrease during the sea voyage has an influence on the ripening process. But, as the voyage (approx. 4 weeks) accounts for only a small proportion of the total keeping period, slight temperature fluctuations will have no visible effects - provided that the pears were immature when loaded. If stevedores are constantly eating pears during unloading operations, then it is more likely that the ripening process had already progressed quite some way by the time the pears were originally loaded on board. The advanced state of ripeness should therefore be attributed to the fruit's condition prior to shipment. As we have pointed out several times earlier, once the ripening process has been initiated, it is unstoppable.

The standard requirements for trade within the EU are identical for apples and pears Within the

EU pears must comply with EEC Standard No 1. Other standards, such as US Grade Standards, are not mandatory in international trade. It goes without saying that at the time of loading and unloading, pears should be free from foreign taste or smell, their skin and flesh should be free from blemishes or spots and there should be no signs of mould or rot.

CITRUS FRUIT

World production

Citrus fruit is the collective name for oranges, tangerines, lemons, limes, grapefruit and other edible fruits derived from *Citrus* and related genera. The value of the world trade in citrus fruit is higher than that for any other fruit. Most kinds of citrus fruit originated in South East Asia.
Citrus fruit is widely cultivated in what is known as the "citrus belt", a zone which extends across the tropical and subtropical parts of the world between latitudes 35°N and 35°S. In the Mediterranean region cultivation is possible up to a latitude of 44°N thanks to the favourable climate. If citrus fruits are cultivated in such regions there must be no frosts lower than -4°C, as otherwise the citrus crops cannot be protected, whatever methods are used.
The harvest and sales season runs from October to May in the northern hemisphere and from May to November in the southern hemisphere. Due to cultivation of early and late varieties and improved methods of conservation, these seasons increasingly overlap each other.

In 1992, world-wide production of fruit stood at 348 million tonnes, including citrus fruit with a 20% share of the world market. Citrus production grew by an average of 5% per year over the 1980-1992 period, making it the fastest growing fruit product group.

Western Europe has an import share of 60%, of which Spanish exports to other EU member states alone account for 30% of world trade. There is also a substantial volume of exports from other Mediterranean countries to the EU and the USA and from the USA to Japan and Hong Kong.

Citrus production

World production of citrus fruit in 1992 amounted to about 77 million tonnes. The six largest pro-ducers are Brazil (20 million t), the USA (10 million t), China (6 million t), Spain (4.4 million t), Italy (3.3 million t) and Mexico 132 million t).
Production is increasing fastest in Brazil and China, while production in the other four countries has remained fairly constant.

Citrus imports

World citrus imports in 1992 totalled 7.4 million tonnes. The seven main citrus importing countries are[1] Germany (1,258,000 t), France (1,135,000 t), the UK [681,000 t), the Netherlands (681,000 t), Japan (511,000 t), Canada (381,000 t) and Saudi Arabia (283,000 t).
In 1991 France re-exported 44,000 tonnes of citrus fruit Germany re-exported 29,000 tons of fresh fruit.

Production of oranges

Oranges hold a predominant position amongst citrus fruit, having a 71 % share of total production. In 1992 the world production of oranges amounted to 56.5 million tonnes.

The six main producers of oranges are Brazil (19.6 million t), the USA (8 million t), China (5 million t), Mexico (2.8 million t) Spain (2.7 million t) and Italy (2.0 million t).
Mandarins are the second most important citrus fruit, having a 12% share of total production. Mandarins are mainly produced in Italy, Spain and Japan

Main citrus producer countries

China

Chinese fruit cultivation has booked substantial growth over the past 15 years The 1990 fruit-growing area of 5.5 million hectares represented a threefold increase on the 1979 level. Around 60% of the fruit area under cultivation is accounted for by apples, pears and citrus fruit.

The quality of the fruit is low, diseases are present in the plants and transport and preservation leave a lot to be desired.
China is currently the world's third largest citrus producer. Production is expected to increase to some 10 million tonnes by the year 2000.
The oranges produced in the People's Republic are destined solely for domestic consumption.

Brazil

Brazil is the world's largest producer of oranges. Brazilian oranges are mainly produced for the juice industry. The greater part of the country's total citrus production (84%) is processed into citrus concentrate, some of which is shipped in modern bulk juice tankers (see Chapter 5).

USA

The production of oranges in the USA fell during the 1980-1991 period because of frost damage. In 1980 oranges production amounted to 10.7 million tonnes, but in each of the following years up to 1992 the production level was always 2-3 million tonnes below that level. The 1992/93 harvest was significantly higher than those of the previous years

TheEU

Spain and Italy are by far the biggest citrus producers in the European Union. Within the EU there is a surplus of citrus fruit and part of the production is taken off the market. This is especially true of Italian products for which there is insufficient international demand. The reasons are. the older varieties that are cultivated there, the average quality and the small-scale structure of production with little cooperation between growers.

Spanish production is also characterised by its small-scale structure. Eighty per cent of all Spanish citrus is sold on the fresh fruit market, 65% of this fresh fruit is exported.

History

Most of the citrus varieties originate from Asia, which is also where they were first cultivated. The first mentions of citrus fruit in literature date from about 4,000 years ago. Around 300 B.C. a citrus fruit was described for the first time in European literature That fruit was the cedrate (Italian: *cedrato)* or citron, a precursor of today's lemon. The cedrate is still grown in Italy today.

In the Middle Ages the bitter orange, the lime and the lemon reached the rest of Europe. People appreciated the orange most of all, particularly because they saw the fruit as exotic and ornamental. Via Genoa the sweet orange arrived in Europe in about the 15th century.

On his second voyage to Haiti, Christopher Columbus took the seeds of the orange, the lemon and the cedrate with him. Only later were seeds also taken to North and South America. It was the Portuguese who, through their imports (by sea) of a superior sweet orange from China, laid the foundations for the cultivation of citrus fruits in Europe. In a similar way, the introduction into the USA in 1870 of the "Bahia navel orange" from Brazil formed the stimulus for its cultivation in California. The California-grown variety, the "Washington navel orange" is named after the place where the first tree was planted.

Via cross-breeding, improving and then further hybridisation, many different subspecies and cultivars now exist. These subspecies can be subdivided into 11 groups. Take the orange, for example; there are some 2,000 known varieties of oranges, of which about 100 are grown on a commercial basis. Because of the many varieties and cultivars (and growing areas) citrus fruit can be supplied the whole year round-

Citrus fruit as a cargo

The original tropical Asian plants of the rue family *(Rutaceae)* formed the basis for countless varieties and hybrids. Citrus fruit lends itself excellently to the creation of new varieties. The grapefruit, for example, is derived from the shaddock (known in the East Indies as the "pompelmous"), whilst a cross-breed of these two is marketed as the pomelo.
Taste and colour variations exist between the citrus fruits which are cultivated in the citrus belt. But the one thing that they all have in common is the leathery peel which contains a volatile, aromatic oil.

Usually citrus fruit has been pre-cooled when it arrives on board. Consequently, the hold must be pre-cooled as well. On the whole, citrus fruit - especially oranges - is a simple cargo, one of the reasons being that a minor fluctuation in the carrying temperature will not have any disastrous consequences.
Grapefruits and oranges, whose transport temperatures differ by only a few degrees, can therefore easily be shipped in one and the same hold at an average of these two temperatures.

We would, however, add a note of warning: if oranges have been fumigated with biphenyl, they are not compatible with other products.

If the fruit has not been pre-cooled when it arrives on board, then the warm fruit will emit a great deal of $C0_?$. This means that very powerful ventilation will be needed whilst the fruit's temperature is being brought down. If the fruit is in a pre-cooled condition when loaded, moderate ventilation will suffice. The intake of fresh air must in any event be sufficient to keep the CO_2 percentage at below 0.3%.

The carrying temperatures for citrus fruit are very much dependent on country of origin, variety, season and duration of the voyage. Carrying temperatures range from 0°C for some oranges to 15°C for some grapefruit.
As in the case of other types of fruit, it is again important that the hold temperature should be kept as stable as possible during transport and that the fruit should be handled carefully during loading and unloading.
All citrus fruit is susceptible to chilling injury, but at widely differing temperatures and to widely differing degrees. Fruit harvested early in the season is more sensitive to chilling injuries than the more mature fruit that is harvested later in the season.
Citrus fruit produces very little ethylene, but appreciable amounts of this gas are produced by green mould growing on the fruit.
Citrus fruit will dry out if there is a wide difference between the moisture in the fruit and the drier hold air. Even under the most favourable storage conditions the juice content will decrease by 1 % each week. The required relative humidity is therefore between 85 and 95%.

Fungal diseases

n Chapter 6 we have already discussed the fungal diseases which can affect citrus fruit. The most commonly occurring post-harvest diseases in citrus fruit are blue and green mould rots. Normally, the post-harvest pathogens invade the fruits via wounds.
Other fungal diseases of citrus fruit include alternana rot, stem-end rots, sour rot and brown rot.

Brown rot causes cankers on the trunk and roots of the tree. A heavy downpour of rain will splash back up from the ground, transferring spores from the soil to the fruit growing at a lower level on the tree. Prolonged rainfall in particular will cause these spores to germinate and this may result in the onset of brown rot infection on the harvested fruit. This infection may then contaminate the water in which the fruit is washed or may be transmitted through direct contact with other fruit.

Sour rot is a soft, slimy, watery decay of citrus fruits caused by the fungus *Oospora citri-aurantii.* The infection is transmitted by fruit flies. These insects are attracted by the penetrating sour odour given off by wet and soft rotting fruit and then reproduce in the rotting fruit. Because of contact infection and "nesting" the rot can be transferred to healthy fruit. It is clear that rot will gain entry into other fruits particularly via injuries or by entering the stem of devitalised fruits.

To prevent the spread of diseases the harvested fruit is usually washed in a water tank containing a solution of chloride or some other fungicide. To prevent deterioration of the fruit during cold storage and to suppress fungal development, the paper sheets in the fibreboard citrus cartons are impregnated with biphenyl. Since resistance to biphenyl and TBZ is increasing all the time, these products are being replaced by newly developed fungicides, e.g Imazalil.

ORANGES

The orange is the nearly globose fruit of certain shrubs or trees of the genus *Citrus.* There are various sorts of oranges, such as the navel

orange, blood orange, etc. The most-grown sort is the sweet, or common, orange *(Citrus sinensis).*
Oranges from the tropics often do not have the familiar deep-orange colour we normally associate with this particular fruit. The reason'is that tropic-grown oranges have not been exposed to cold nights during the ripening process. Cold nights break down the chlorophyll in the peel.

Seville

The bitter orange *(Citrus aurantium),* which is also sold under the name Seville or sour orange, looks very much like a normal orange. It is slightly smaller than a regular orange and, as its name indicates, it has a bitter and sour taste. The fruit has a very thick orange-yellow rind with large pores. The fruit flesh is not very juicy. Seville oranges grow on a tall tree which can reach as much as 15 metres in height.
The Seville is processed, skin and all, to make marmalade, the peel is also used in the production of liqueurs.

Most probably the orange originally came from Southern China. It is generally assumed that *Citrus aurantium* is the forefather of the citrus varieties we know today. The Arabs brought the fruit to Seville.
From the fifteenth century it has been cultivated in Southern Europe. However, it was not until the end of the eighteenth century that oranges were grown on big plantations. Nowadays, the main producers of Seville oranges are Latin America, India, Spain and Italy.

Carriage instructions

As far as the transport temperature is concerned, we need to make a distinction between both the variety and the country of provenance A role is also played by the time of harvesting of the oranges. The highest freezing point for the varieties referred to above is -0.8^{Q}C. The required relative humidity amounts to 85-90%. The ethylene production is very low (less than 0.1 microlitre). Oranges have a moderate ethylene-sensitivity.

For navel oranges from Spain the transport temperature is 3°C. The transport duration at this temperature is 8-10 weeks. The recommended storage temperature for Castellanas is 1-2°C (storage time 10 to 12 weeks). Moroccan oranges should be transported at approx. 5 5°C (i.e. as much as 2°C higher than Spanish oranges) unless the shipper recommends or instructs otherwise.

The transport temperature for navel oranges from California and Arizona amounts to 7.2°C. The maximum transport duration is 4 to 8 weeks. Mid-season and later fruit is usually carried at a lower temperature.
Note: the term "transport duration" comprises the distribution period plus the period of storage, transport and display at the product's final destination.

The transport temperature for Valencia oranges grown in Florida and Texas is 1 °C to *2.2°C.* At this temperature the oranges have a keeping time of 8-12 weeks.
For Valencia oranges from California, Texas and South Africa the transport temperature is approx. 5°C. Valencias from Spain and Israel can be kept for 12 weeks at a storage temperature of 8°C and for as long as 16-20 weeks at a storage temperature of 2°C. The transport temperature for shamouti oranges from Israel is 4-5°C and their storage time is about 8 weeks.
The transport temperature for Valencias from South Africa is 4.5^{3}C and their storage time is between 4 and 16 weeks

The transport temperature for Seville oranges (bitter oranges! is 10°C and the recommended R.H. is 90%. At this temperature and relative humidity their shelf life is approx. 3 months.

General

As we will have noted, the above transport temperatures reveal quite considerable variation. They should be seen as examples of trends but must not be regarded as hard-and-fast rules. Let us repeat, the optimum transport temperature will vary, depending on the variety, time of harvest and country of origin. The important aspect here is that the fruit has been pre-cooled to the right temperature before loading.

Too high a storage temperature will cause an accelerated respiration rate, resulting in ageing and increased weight loss. Even apart from the resultant loss of aroma and nutritional value (vitamin C), a higher temperature will quickly increase the risk of blue mould and grey mould rot. Oranges in particular can suffer damage if the $C0_2$ percentage rises to more than 0,5%. Oranges are a prime example of a product which should be put on the market as quickly as possible after leaving cold storage.

When loading oranges, always make sure that - as generally applies to all other fruits - they are whole, sound, free from (discoloration) defects and decay or foreign smell and show no signs of freezing injury. Oranges should contain at least 35% juice in relation to the fruit's total weight and should also be free from scars, pitting, rind staining or insect damage.
For trade within the EU oranges (with the exception of bitter oranges) must comply with EEC Standard No. 18.

As a rough approximation the heat production of oranges amounts to 14 W/t (400-900 U/t) at 2°C and to 18 W/t (900-1,600 kJ/t} at 5°C. The specific heat amounts to 3.80 U/kg x *°C*
The average stowage factor for palletised cartons is 2.5 cbm/tonne (88 eft/tonne), whilst for bulk cargo it amounts to 2 cbm/tonne (71 eft/tonne).

TANGERINES AND MANDARINS

The group of smaller sized citrus fruits also comprises the fruits that resemble the orange. These include variants of the mandarin or hybrids between the mandarin and other citrus species. The mandarin *(Citrus nobilis)* originates from Mauritius (East Africa). The two most familiar variants of the mandarin are the tangerine and the satsuma. The satsuma comes from Japan. The tangerine originates from North Africa and takes its name from the Moroccan port of Tangier The tangerine has a orange-red, loose, wrinkled skin and the fruit flesh has a pronounced citrus taste.

Other, less familiar hybrids are[1]

Minneola,	a cross between a tangerine and a grapefruit.
Topaz,	a cross between a tangerine and an orange.
Ugli,	a cross between the grapefruit, the orange and the tangerine.
Clementine,	a cross between the bitter orange and the mandarin.

The minneola is an orange-coloured fruit with a pronounced "nose", a protrusion on the skin at the place where the stalk was attached. The thin peel is orange-coloured and the aromatic fruit flesh with its slightly sour flavour is reminiscent of the grapefruit. Israel is the principal producer of the minneola.

The ugli is mainly cultivated on Jamaica. It is a big, ugly-looking fruit, hence its name. The skin is bumpy and patchy (just like that of the Seville orange). The colour of the thick rind is green, sometimes with brown stains, and the fruit is easy to peel. The ugli has juicy, sweet and tasty flesh.

The fruit types referred to above have a sweeter flavour than oranges and a stronger aroma. Because of their thin skin they are easy to peel by hand. The most important production countries are: the USA, Brazil, Japan, Italy and Spain.

The highest freezing point is -1.1°C. The carrying temperature for Clementines and mandarins is 4.4°C and their shelf life is 14-28 days. For satsumas the carrying temperature is 4°C and the shelf life between 56 and 84 days. The carrying temperature for rninneola and ugli is 4-5°C. At this temperature and at an R.H. of 90% these fruits have a shelf life of 20 to 35 days. The carrying temperature for tangerines is 4.5°C to 7.2°C and their shelf life amounts to 21 to 28 days.

As said before, carrying temperatures for citrus fruit are highly dependent on the variety and the country of origin. For example, the recommended carrying temperature for mandarin varieties from California is 7°C, whilst for mandarins from

Florida it is between 0 and *3°C.* In general terms, the limits can be said to lie between 0°C and 7°C. The ethylene production of these types of fruit is very low and they have either no or only a slight ethylene-sensitivity.
Even more so than oranges, mandarins are easily damaged, which leads to a rapid deterioration in quality
Clementines and the other varieties of citrus fruit described above must comply with EEC Standard No. 18 when traded within the European Union. This is the same Standard as applies to oranges At the time of loading, the fruits must have a sound skin and must feel firm. The size and colour of the fruits must be uniform and typical of the variety. The fruit must be free from bruises, defects and decay and should not emit any foreign smell or taste.

LEMONS

The lemon is the fruit of the lemon tree *(Citrus medica)* which has a trunk 10-12 metres high. The lemon is an elongated round fruit with a thin leathery rind which contains a great many cells. Underneath the outer skin is a white layer of pith which encloses a fleshy tissue containing a very sour juice. The origin of the lemon is Northern India from where it spread to East Asia and China. The lemon is cultivated today in many sub-tropical regions, particularly for its lemon oil. Lemon oil is a pale yellow, essential oil which is obtained by pressing the outer peel of the lime *(Citrus Union)* and the lemon *(Citrus medica!.* The main countries in which these fruits are grown for export are the USA, Turkey, Italy and Spain

The trees grow throughout the year and, in principle, three harvests per year should be possible. In most cases, however, lemons are picked during the winter because the fruit is then easier to keep in storage and has a better resistance to shipping and marketing operations

Tree-ripened fruit does not keep well in storage and the fruits are therefore usually harvested before they are ripe whilst they still have a dark green colour. This is why most lemons are still not suitable for consumption immediately after harvesting, but need conditioning to develop further in colour, flavour and juiciness

Just like oranges, lemons must also be handled carefully during harvesting and transport so as to prevent cuts, scratches and bruises. As we have meanwhile learnt, such injuries will later lead to decay by green and blue mould rot The fungus that causes blue mould rot is able to penetrate the uninjured skin of lemons, but obviously this fungus can enter much more simply if wounds are present. For lemons, just like other citrus fruit, fungicides are added to the washing water to prevent decay. Another common method of achieving the same objective is to place a biphenyl sheet in the top and bottom of the carton. Another form of rot which occurs quite frequently in lemons is alternaria rot. This decay invades the fruit through the buttons (see Chapter 6). For some reason, however, the decay seldom invades lemons showing green buttons. The colour of the buttons is therefore a criterion for a lemon's susceptibility to alternaria rot.

Carriage instructions

As lemons are more sensitive to chilling than oranges, they must be transported at higher temperatures The highest freezing point is -1.5°C. The ethylene production is very low (< 0.1 microiitre/kg/h) and the fruit has a moderate sensitivity to ethylene. The holds must be ventilated to ensure that the $C0_2$ content remains below 0 5%.
The carrying temperature is dependent on the region of origin, the moment of harvest and the colour (green or yellow) and varies from 4°C (ex USA] to 15°C. The recommended temperature for green lemons is 12 to 14°Cat an R.H. of 85 to 90%. At this temperature and humidity, green lemons have a shelf life of 1 to 5 months. The recommended carrying temperature for yellow lemons is 10-11°C, in which case their storage time amounts to 1-1 *4* months. Lemons harvested when yellow in Israel and Turkey will keep at 15°Cfor5 months.

In the European Union lemons - like other citrus fruit - must comply with EEC Standard No. 18. When the fruit is loaded it must be inspected in the same way as described earlier for oranges, etc.
For the heat production and stowage factors, see the section on Oranges.

KUMQUAT

The kumquat is an elongated dwarf orange which originates from China and Vietnam. Its name originates from the Chinese word for 'golden orange'. From China it spread to Japan, the Mediterranean and Brazil. By contrast with orange trees, which grow to a height of between 5 and 12 metres, the kumquat tree is a mere 1.5 metres high. This small orange, 2-4 cm in length, is eaten together with its skin. The kumquat has a bright orange, fairly thin skin. The fruit flesh segments are light orange in colour. The kumquat has a strong and spicy orange taste. Its nutritional value amounts to 68 Kcal/100 g. The fruit also has a high vitamin C content.
The round version is of the same small size and is called *"Fortunella japonica".* Kumquats are chiefly used for making preserves and confectionery.

This fruit is better able to withstand the cold than other citrus fruits and so it has a more widespread production area. Kumquats are grown in Japan, Brazil, Africa, Central America, France, Italy, Spam and Israel.

Carriage instructions

Pre-shipment checks are mostly based on the same rules as previously indicated for other citrus fruits. The kumquat has a low ethylene production and is not sensitive to ethylene. This cargo does, however, require a high relative humidity (90%). By comparison with other citrus types, the kumquat is more sensitive to temperature fluctuations and chilling injuries. The skin must look fresh and shiny, must have an even yellowish orange colour and must be free of blemishes.The highest freezing point is -1.6°C and the optimum transport temperature is 10°C. At this temperature and with an R.H. of 90% the shelf life of kumquats is approx. 4 weeks. Specific heat: 3.60 kJ/kg; heat production amounts to approx. 30 W/t at 10°C. Storage factor (boxes) on pallets is approx. 3.1 cbm/tonne (= 109 eft/tonne) and for bulk cargoes it amounts to approx. 2 cbm/tonne (71 eft/tonne).

LIMES

The lime *(Citrus aurantifolia)* grows on a small and very thorny tree. The fruit originates from Malaysia and it spread from there to India and later, via Europe, to Central America. Today this fruit is cultivated in almost all countries in the tropics and around the Mediterranean. The principal producer countries are the USA, Mexico and Jamaica. The fruit is slightly smaller and more rounded than a lemon and has a diameter of approx. 4-5 cm. The thin skin has a bright green or greenish-yellow colour. The light-green,

Kumquat

Limes

seedless fruit flesh contains twice as much juice by comparison with a lemon. The juice is sourer and more aromatic than lemon juice. The lime contains a lot of vitamin C and has a nutritional value of 37 Kcal/100g.

We have to make a distinction between the Persian (Tahiti) lime and the Key (Mexican or West Indian) lime.

Persian limes are picked whilst green but after about 4 weeks in cold storage they lose their green colour to some extent. After about 8 weeks the skin may turn a yellowish-green colour. The carrying temperature is 11-12°C. If they are transported at a lower temperature, the skin will reveal less of a colour change.
At temperatures lower than 7°C, however, limes are subject to pitting. The usual colour for Key limes on the selling markets is yellow.

The ethylene production of limes is very low and they have a moderate sensitivity to ethylene. The highest freezing point is -1.5°C.
The carrying temperature for both Persian and Key limes is 11 to 12°C. At this temperature and at 90% R.H. the maximum transit and shelf life of Persian limes is 3-5 weeks and that of Key limes 6-8 weeks. The specific heat and the heat production correspond to those of oranges.

Note: Limes and oranges cannot be stowed together in the same cooling compartment.

Short-term storage is possible at 4°C, in which case the storage time will be 2-3 weeks. Watch out for low temperature injuries which take the form of brown to black blemishes on the skin and may result in discoloured flesh. The fruit is liable to dehydration, resulting in a hard, wrinkled skin.

Limquat

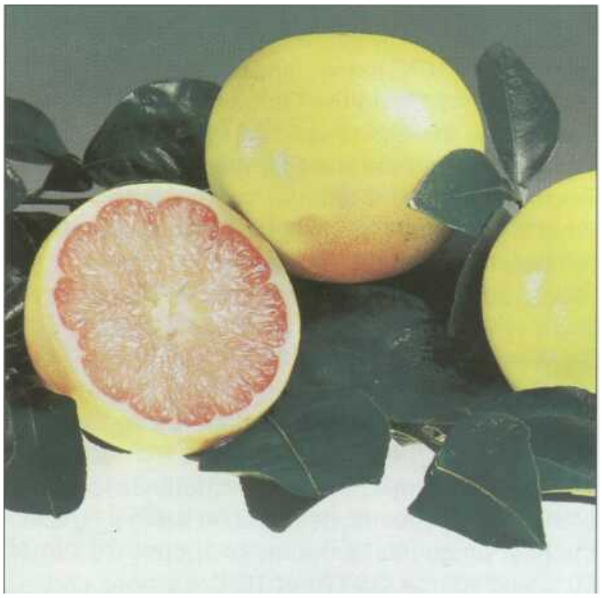
Even smaller than the lime is the hybrid fruit called the limquat. It is a dwarf lime obtained by crossing the kumquat with the lime. Limquat juice is sourer and more aromatic than lemon juice.
The ethylene production of limquats is low and they are not sensitive to ethylene. At a carrying temperature of 10°C and 90-95% R.H. these fruits will keep for 3-4 weeks.

GRAPEFRUIT

The grapefruit grows in clusters (like grapes) on a tree *(Citrus paradisi)* about 5 metres tall. The grapefruit is a cross between an orange and a pomelo. In the 17th century the tree was taken to the West Indies. Nowadays grapefruit grows in almost all tropical and sub-tropical regions.

The fruit is a large, roundish, yellow-skinned edible citrus fruit with a juicy, acid pulp. Modern-day grapefruits are virtually seedless and the varieties with pink and reddish flesh are highly popular. These varieties have a sweet taste and a slightly bitter aroma. The grapefruit with yellow pulp has a really bitter flavour. The bitterness stems from the small amount of quinine contained in the fruit flesh. Grapefruits are exported by Israel, Cyprus, Argentina, Cuba, Mexico and the USA.

Blue mould and green mould are common disorders in grapefruit. These rots may develop during cold storage or during transport but - just as in the case of other citrus fruit - they can be suppressed through the timely application of effective fungicides and/or by placing biphenyl-treated pads in the cartons (see Chapter 6).
Particularly if grapefruit are stored for too long, they may suffer from decay and rind breakdown. Grapefruit from Florida may also be affected by stem-end rot.



Grapefruit

We would point out once more that fungicidal treatments are used on citrus fruit to reduce spoilage caused by the above-mentioned fungal diseases. It is self-evident that only carefully regulated dosages of a suitable formulation should be applied, without exceeding the prescribed legal tolerances set by the importing countries.

Carriage instructions

Grapefruits, like other citrus fruit, are usually discharged without any damage problems
More so than other citrus fruits, grapefruit is sensitive to chilling injury. The freezing point of grapefruit is -1 °C, the fruit has a very low ethylene production and a moderate ethylene-sensitivity The introduction of fresh air must be sufficient to keep the CO_2 percentage lower than approx. 0.3% The recommended R.H. is 85-90%.

In the case of grapefruit, too, the country of origin, the variety and the harvest time govern the required air delivery temperature. The carrying temperature limits therefore range between 4 5°C and 16°C. The carrying temperature (= delivery atr temperature} for grapefruit from California and Arizona and from Honduras is 13.3°C. The storage temperature limits are between 14.0°C and 15.5°C. The transit and shelf life then amounts to 4-6 weeks

The carrying temperature for Florida-grown grapefruit is 10°C in the January-September period and 15.5°C in the October-December period. The storage time is 4-6 weeks.
The carrying temperature for grapefruit from Texas is about 10°C and the storage time 4-6 weeks. For South African grapefruit the carrying temperature is 11 °C. The recommended carrying temperature for grapefruit from Israel is between 5°C and 9°C. The storage time will then be 3-4 weeks.

No international standards are applicable to grapefruit and the inspection of the fruit during loading is subject to the same criteria as for oranges. The specific heat is 3.80 kj/kg x °C and the heat production amounts to approx. 25 W/t at 10 °C and approx. 35 W/t at 15°C. Lemons and grapefruit can be loaded in the same hold.

AVOCADO

Description of product

Avocados are one-seeded berries. The fruit, which has a smooth-textured pulp, grows on a shrub-like tree *(Persea amencana!* which has its origins in South America.
The Spanish *conquistadors were* the first Europeans to discover the avocado. They learnt about the fruit from the Aztecs whose name for the avocado was "Alvuacate" ("butter from the forest"). Later the avocado was transplanted to California, Florida, Latin America, Brazil and South Africa. The major producers today are: Mexico, the USA, the Dominican Republic, Brazil and Indonesia. To an increasing extent this fruit is now also being cultivated in Israel and Spam.
From May until December the fruits are exported from Africa and Central America. From September to May they are supplied from Israel.

Nowadays there are as many as 400 different varieties of avocado. Cultivars vary in size from variety to variety and can be between 5 and 20 cm long.
The fruit has a smooth, rough or wrinkled skin. The colour of the skin may be green to purple to almost black, whilst the fruit flesh can vary in colour from greenish to white or pale yellow.
An avocado has more energy value than meat of equal weight (140 Kcal/100 g) and is a good source of vitamins A and C and vitamins of the B complex. Of all tree fruits, avocados and olives are the highest in protein and fat content. Avocados contain 30% oil with the same composition as olive oil.

Export varieties

The best-known export varieties are Fuerte, Ettinger, Mass and Nabal.
Fuerte is a pear-shaped avocado with a slender neck and a smooth, light-green skin.
Ettinger is also pear-shaped, but with a fatter neck. It also has a smooth, light-green skin.
Nabal is a fat, almost round avocado with a smooth, dark-green skin.
Mass is a small pear-shaped avocado whose fruit flesh is characterised by its particularly creamy texture. This cultivar has a thick neck and a rough, thick and wrinkled skin which changes

colour from green to black during the ripening process. The green-skinned varieties do not reveal the same colour-phase change as the Mass variety.

Maturation and ripening

The avocado is a climacteric fruit. It has a relatively high respiration rate and ethylene production. Avocados do not ripen on the tree but only after they have been harvested. Unlike many other fruits, the avocado matures on the tree without showing any external signs of ripening, such as a change in colour. The exact nature of the ripening inhibitor is not known. The factors that prevent avocados from ripening on the tree continue to exert their effects for about 24 hours after harvest. The time-lapse between harvesting and the onset of softening will be shorter if the fruit has been allowed to mature fully on the tree. After the fruit has been severed from the tree, the natural ripening process may take 1-2 weeks during the beginning of the season and four to six days during the later part of the season.

The flavour of the fruit harvested during the season increases, but decreases again towards the end of the season. As with so many other types of fruit, therefore, the exact time of harvesting plays a crucial role for the avocado. The optimum picking time for each cultivar is determined on the basis of the percentage of dry matter (usually 17-20%, depending on the cultivar) which correlates to a preset oil content. As the harvest season advances, the avocado's oil content increases and its ripening time decreases.

Ripening is the period between the end of the maturation phase and the start of senescence This process involves softening, colour changes and taste improvement and is induced by ethylene. Once the fruit is mature, ripening will be achieved simply by picking. Depending on the variety, it will then take a further 4 to 16 days after harvest before the fruit is soft and edible. Cold storage and removal or exclusion of ethylene from the storage environment helps to extend the storage life of avocados by delaying ripening and the incidence of decay. Obviously, it is important for the keepability of the fruit that a continuous "cold chain" is maintained from the time of harvest until the fruit is put on display at the point of sale.

The preconditioning process

Besides delaying ripening by cold storage it is also possible to accelerate ripening by treating avocados with a low concentration of ethylene. The preconditioning process can take place either after discharge of the fruit at the wholesale market or in distribution centres or before the fruit is exported, if pre-ripened fruit is required, then ripening can be speeded up in ripening chambers provided that the softening process has not already begun.

Ethylene gas should only be used if the avocados arrive in the hard stage (32-29 lbs firmness). For proper ripening it is necessary first to raise the fruit pulp temperature to 20^{D}C in about 12-24 hours. Once the fruit temperature has stabilised at 20°C, ethylene is admitted and its final concentration in the room should be approx. 100 ppm. The ripening response depends on the stage of maturity that the fruit has reached. Early season avocado varieties usually require 24-36 hours of ethylene exposure. Later season fruit will normally require a shorter exposure, e.g. 12-24 hours. As a rule, the fruit is exposed to ethylene until a pulp pressure of 24-18 lbs is reached. This is then referred to *as "triggered"* fruit. *"Triggered"* means that the fruit has reached a ripeness at which it will quickly ripen further in a uniform way, unless it is placed in cold storage again.
After checks have been made to ensure that the ethylene exposure has been effective, the pulp temperature is reduced again as quickly as possible to approx. 5°C. After this phase the avocado will still possess cold storage stability for 5 to 10 days. As the fruit becomes riper it can be stored at a lower temperature without any risk of chilling injury. In most cases the preconditioned fruit is transported to the customers by trailer. The fruit is then delivered at a temperature of approx. 5"C and with a pulp pressure of 19-15 lbs firmness. At a firmness of between 18 and 10 lbs the avocado has reached "breaking point", i.e. the fruit is then just starting to ripen. Within this firmness range the fruit will become eating ripe lapprox. 3 lbs) within 2 to 4 days at room temperature.

An avocado is ripe if the fruit feels soft when pressed lightly near the stem end. In that case the avocado will keep for a further 2 days at room temperature.

Low temperature spoilage

Avocados are particularly susceptible to low temperature spoilage (l.t.s.) and in this respect they can be subdivided into two groups.The first group comprises those varieties from tropical regions (e.g. Latin America) which may become chilled at below 12°C. The storage time of this group is about a fortnight. The Waldin, Pollock and other varieties from the West Indies are highly sensitive to l.t.s. and must therefore be stored at 12.5°C.
The varieties which are mainly suitable for cooled shipment belong to the other group. For these varieties the most suitable carrying temperature is between 4.5°C and 7°C, depending on the variety and on the fruit's maturity at the time of picking. Avocados in this group will keep for 4-5 weeks.

The carrying temperature for Fuerte and Hass from the USA is 7°C. In cases of doubt it is better to set the delivery air at 7°C for varieties in the latter group.

Transport conditions

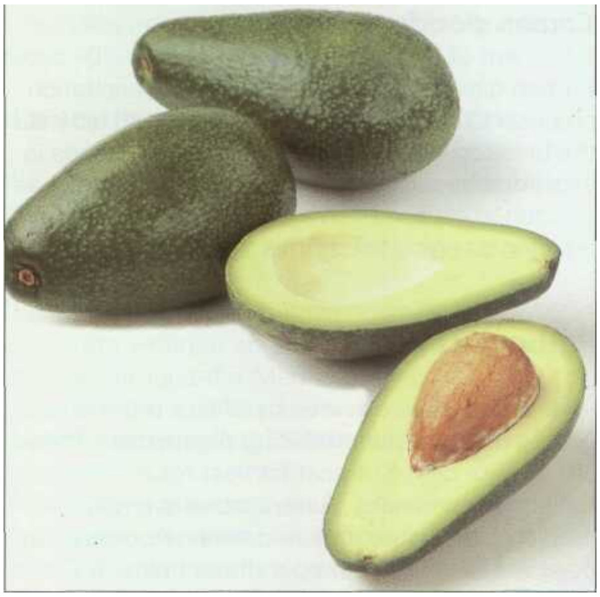
The avocado is a climacteric fruit and is extremely susceptible to chilling and low temperature injury. Since avocados also generate a lot of heat (approx. 90 W/t at 5°C), they are regarded as one of the most difficult types of cargo. Needless to say, the fruit should be cooled to near carrying temperature as soon as possible after harvest. The more the fruit is exposed to high temperatures the more days it will take for the fruit to soften. To ensure removal of the heat that is produced, the cargo must be packed in well ventilated packages and stowed with a lot of space between it so that there is a vigorous flow of air around the cartons. The cargo space should be well ventilated so as to prevent accumulations of carbon dioxide and ethylene. We would add that avocados can also be carried using a CA-controlled transport system. In such case the preferred O_2 level is 2-5% and the CO_2 concentration should be 3-10%.

The most suitable storage temperature is one which will inhibit the ripening process but will not cause chilling injury. For the varieties from sub-tropical regions the carrying temperature is between 4.5°C and 8°C. Specifically in the case of the avocado, however, the exact transport temperature depends on the variety, the maturity of the fruit at the time of picking and the country of origin. The maximum transit and shelf life for firm fruit of these sub-tropical varieties is between 3 and 5 weeks. It will be clear that it is particularly important in this case that, prior to loading, the shipper should give clear written instructions on the required delivery air temperature. As we mentioned previously, other (tropical) varieties such as Fuchs, Pollock and Waldin, whose storage temperature amounts to 10-13°C, have a much shorter keeping time and are not generally carried by sea.

Just like most fruit transport, successful carriage is here again dependent on the three main variables: temperature, ethylene and carbon dioxide.

Temperature:

Exposure to temperatures in excess of 25°C causes uneven softening, skin discoloration, flesh darkening and development of off-flavours in the avocado.



Avocado

Uniform ripening depends on maintaining a uniform temperature. Precise temperature control is therefore very important. The temperature governs the enzymatic reactions involved in fruit respiration and other metabolic activities which take place during the ripening process. Low temperature injury (chilling injury) will develop if pulp temperatures drop to below a critical level for each variety. Chilling injury is a time and temperature related injury. The longer the fruit remains at low temperature, the greater the severity of the chilling injury. The symptoms are as follows[1] first, the vascular bundles turn greyish-brown and then the flesh. The fruit flesh then has a bitter taste not unlike that of rancid fat. Other common symptoms of chilling injury are scalding and pitting of the skin, and failure of the fruit to ripen fully and effectively when removed from cool storage.
Ripe avocados will withstand lower temperatures than unripe fruits without danger of chilling injury.

Ethylene:

During cooled transport high levels of volatiles, such as ethylene, will increase the fruit's proneness to damage. Ethylene breaks down insoluble pectic substances into soluble pectics, which cause the fruit pulp to soften. During seagoing transport, therefore, such volatiles must be removed by ventilation

Carbon dioxide:

Carbon dioxide is a by-product of the respiration process. $C0_2$ levels in excess of 1 % can inhibit the breakdown of insoluble pectic substances in avocados, resulting in irregular ripening (or failure to ripen at all). Excessive $C0_2$ levels may also result in discoloration of the pulp.

Pathogens

Avocados can be affected by one or more pathogens (disease-producing organisms). These are a major cause of post-harvest rot in Californian avocados. Anthracnose is another problem, especially in humid areas. Anthracnose does not develop at temperatures below 6°C. Diplodia stem-end rot resulting from latent or quiescent infections can also pose a serious problem in humid growing areas (e.g. Florida and Israel). After harvest, the fungus first colonises the stem and then the flesh near the stem.
A post-harvest dip in TBZ will largely eliminate Diplodia rot. Diplodia rot does not develop at temperatures below 10°C. We should add here, however, that in most orchards, e.g. in Israel, avocado cultivation is totally under biological control. One of the biological control methods involves employing the natural enemy, or enemies, of a given pest. One example of this is the introduction of the Australian parasitic wasp to control the long-tailed mealy bug, a pest which causes considerable damage to avocados.

Mixed loads

Fresh avocados may be carried together with citrus fruit, lemons, papayas and tomatoes provided that temperatures are compatible. Avocados are ethylene-sensitive and should not therefore be carried in the same cargo space with products which generate a lot of ethylene, such as apples, bananas and pears.

Quality control

Prior to loading, random checks must be made of the pulp temperature and the outside air temperature must be measured at regular intervals.

If possible, the pulp pressure should also be determined by random measurings. In Chapter 4 we explained that the firmness pressure tester (penetrometer) is equipped with two plunger tips. The plunger with a diameter of 8 mm (5/16") is used for testing pears, kiwifruit and sometimes also for avocados. In addition, a special 6.4 mm (1/4") tip is available and is mainly used in the USA for testing avocados.
The following pulp pressure values can be taken as a basic indication: Harvest (hard) 32-29 Ibs; Triggered 24-18 Ibs; Breaking 18-10 Ibs; and Ripe 9-6 Ibs.

No international grade standards have been issued for avocados. However, it goes without saying that when the fruit is loaded, it should be clean, firm, intact, free from mechanical damage scars, sunburn and insect injury and without deformations or disease infections. The flesh should have a uniform colour and the skin colour should be typical of the variety.

Carriage instructions

The carrying temperature will range between 4.5°C and 13°C depending on the variety involved. As regards avocados from sub-tropical regions (Israel, South Africa) a delivery air temperature of 7°C is prescribed, as against a temperature of 13°C for fruit from tropical regions. Again, these temperatures are dependent on the variety. The highest freezing point for avocados is -0 5°C.
Since avocados are highly sensitive to the detrimental effects of ethylene, the holds must be properly ventilated to prevent accumulations of CO_2 and ethylene.
The ethylene production rate of avocados is high (10 to 100 microlitres/kg/h). The CO_2 content of the air must be lower than 1%. The recommended relative humidity is 85-90%.
The heat production at 7°C is roughly between 70 and 150 W/tonne. The specific heat amounts to 3.02 kJ/kgx°C.

Cargo stowage factor: palletised boxes 2.9 - 3.3 cbm/tonne (100 -115 eft/tonne); bulk cargo 1.8-2.0 cbm/tonne (60-70 eft/tonne).

GRAPES

World trade

World production of grapes totals some 55 million tonnes. The major grape producing countries are: Italy (9.2 million t), France (6.0 million ti, Spain (5.1 million t), the CIS (5.0 million ti, the USA (4.9 million t) and Turkey (3.6 million ti
Of this total world production, 3% (1.7 million tonnes) is destined for fresh export, 50% for processing and 47% for domestic consumption.

The main exporting countries are[1] Italy [0.50 million t), Chile (0.42 million t), the USA (0.25 million t), Spain (0.11 million t) and Greece (0 11 million t).
The major importing countries are: Germany (401,000 t), the USA (317,000 t), France (159,000 t), Canada (151,000 t), the UK (135,000 t) and the Netherlands (99,000 t).
(The figures are taken from FAO publications).

Exports

In recent decades the price for export grapes has increased steadily and currently amounts to an average of $1,000 per tonne, almost double its 1985 level.
In the main producer countries the harvest volume has remained constant or declined in recent years.
The major trade flows in grapes are restricted to only a few countries. Italy and Chile together account for 53% of world trade, with the USA coming in a respectable third place with a 19% share.
With the strong fall in demand for cheap wines, the production of grapes in France and Italy in particular has declined in recent years. In the autumn Italy mainly ships its export grapes to Germany and France, as well as to other EU member states and to the USA.
The CIS (Commonwealth of Independent States) accounts for around 9.5% of world production, though grape production in that region fell by more than 20% in the 1980-1994 period. The only increase in grape production has taken place in countries like Chile and South Africa which are able to export grapes in the first half of the year.
At the moment Chile exports 37% of its grape production, with most of the remainder being processed into wine. Of Chilean export grapes, about 70% are exported in the spring to the USA.

Harvesting and storage conditions

The grape is a berry fruit of the grape-vine *(Vitis vinifera), a* plant genus with a large number of varieties which forms part of the grape family *(Vitaceae).*
The grape is thought to have originated in S.W. Asia, from where it spread to Asia Minor and the countries around the Mediterranean.
Generally, the fruit has a few seeds but several seedless varieties (e.g. Sultanina) have been cultivated.
Unlike, say, apples and pears, grapes do all of their ripening on the vines before harvesting. Grapes should therefore be properly matured when harvested.

%&zs

To ensure their good condition during storage, grapes must have been plucked when they are fully mature and before they have been wet by rain. If the grape is wet, it will not be possible to make a proper evaluation of its colour - and hence its ripeness. The grape's natural wax layer will also be damaged if harvesting is done during wet weather.
The quality, i.e. the sum-total of flavour, colour and firmness and sometimes also aroma (Muscat), will be at its best if the grape is harvested at the right time. A firm skin is a primary precondition for good keepability.

Cooling-down

Any delay in cooling the grapes after harvest will cause unwanted drying of the sterns. After that, the grapes will start to wrinkle and become vulnerable to attack by micro-organisms.
In most cases the symptoms of drying-out are not immediately visible. The only obvious signs occur after some time in storage when the stems start to reveal premature browning and withering. This can be seen first of all at the end of the bunch stem near the point of cutting. Only later will symptoms of drying-out become visible on the heavier lateral branches running from the main stem. At a later stage the grapes themselves will start to wrinkle.
The Frankenthaler variety is particularly susceptible to this. Consequently, if we want to prevent stems and fruit from drying out, the fruit must be cooled down as quickly as possible after harvest. Even a few hours delay at field temperature can cause severe drying and browning of the cluster stem.

As we explained, the symptoms of drying-out can be noticed first on the stem and on the grape stalks and only at a later stage on the grapes themselves. The reasons why dehydration follows this pattern are as follows:

First, let us note that the moisture loss from a product is dependent on:

1. the protective layer (skin) of the product;
2. the degree of air movement around that product;
3. the difference between the water vapour pressure of the product and that of the air.

The skin of the grape has a thick natural coating of wax (bloom). This helps minimise the evaporation of moisture from the grape itself. In other words, most of the moisture loss must take place via the stalks. The natural bloom on the skin is particularly beneficial in preventing moisture loss and also provides resistance against infection by mould diseases.

The principal cause of moisture loss in grapes, however, is the difference in vapour pressure. Whilst the grapes are being cooled down, big differences in vapour pressure will occur, since the cold air - despite its high R.H. - will have a considerably lower vapour pressure than the warm grapes. As an illustration: air at 0°C and 94% R.H. has a vapour pressure of 4.3 mm mercury column, whilst grapes at 20°C have a vapour pressure of about 17 mm. As these figures show, the faster the temperature of the grapes is lowered to that in the cooled storage space, the lower the moisture losses will be.

Unlike, say, apples or pears, the flavour and ripeness of grapes does not improve after harvesting. Grapes contain no starch, i.e. their sugar content will not increase after they have been picked. During cold storage and transport their quality will gradually deteriorate, even where conditions are optimal. This ageing process may be accompanied by a discoloration of the skin and/or by flaking-off of the skin's surface.

Ripeness

The ripeness of grapes is assessed by reference to their colour, the discoloration of stalks and shoots, flavour and sugar content (SSC or % Brix).

Where the ripeness is evaluated visually, the colour of the grapes will provide a reasonably useful indicator. The colour will, however, vary according to variety or cultivation area. Black grape varieties must have a deep black/blue colour (the darker the colour, the better the keepability). As regards the white Muscat or Alexandria varieties, the yellow-coloured (ripe) grapes will keep best.

Sometimes, unripe grapes with a pale or reddish colour will be found at the ends of a cluster.

Grapes

Grapes of this colour will soon wilt during storage. These signs of ageing are related to the weakening of the skin and imply that the grape will have a very poor flavour. Its flavour was in fact already inadequate at the time of harvest. The skin turns a reddish colour and looks to have become thinner. The surface skin reveals fine wrinkles, works loose from the underlying tissue and will easily rub off. The stalks of a bunch affected in this way will often remain green.

An effective way to measure the state of ripeness is to use a refractometer. The refractive value indicates the percentage of dissolved dry matter. Grapes also contain a small proportion of undissolved dry matter. A close relationship exists between the dry matter content and the sugar content, i.e. the refractive value will give us a good approximation of the grape's sugar content.
Grapes must have a refractometer value of at least 14. Grapes with a refractometer value of 16 or higher will usually keep better than those with a low refractometer value. According to the mandatory minimum California standards an SSC of between 14 and 17.5 is required for grapes, depending on cultivar and production area. The same also applies for Arizona. The voluntary US grade standards specify a refractometer value of 17.5 for Muscat and a value of 15.5 for Cardinal, Emperor and Red Malaga. For most other cultivars the specified value is 16.5.

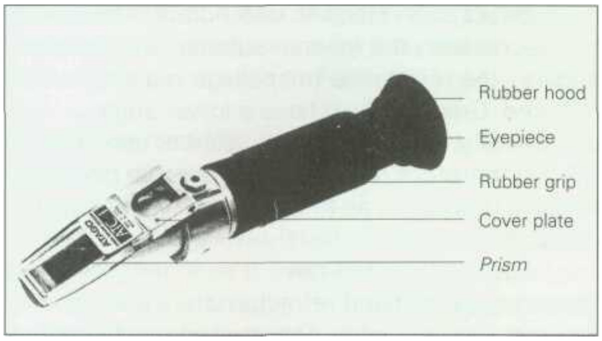
We still have to explain the reason why grapes have to be cooled down so quickly and why grapes with a refractometer value lower than 14 have a shorter keeping time.

The respiratory process after harvesting involves slow combustion, during which reserve substances (sugars) from the product are consumed in combination with oxygen. The rate of respiration is greatly dependent on various factors, the main one being the temperature. With each 5°C increase in temperature the heat production of grapes almost doubles. Fast breathing (at higher temperatures) means that the store of reserves is quickly consumed and the product soon starts to deteriorate. Along with the decrease in the reserve substances - mainly sugars - the resistance to spoilage is also reduced. Grapes which have a lower sugar content (e.g. a refractometer value of less than 14) will therefore not possess the same good keeping properties as those with a higher sugar content.

Various types of hand refractometers are commercially available. The illustration shows the ATC-1 hand refractometer by "Atago".

Using the refractometer

Refractometers are measuring instruments in which the phenomenon of light refraction is put to practical use. Their operation is based on the principle that, as the density of a substance increases (e.g. when sugar is dissolved in water), its refractive index rises proportionately.
The Brix % scale shows the concentration percentage of the soluble solids content (SSC). The soluble solids content is the sum-total of all the solids dissolved in water, primarily sugar, but also salts, protein, acids, etc.
Basically, the Brix % scale is calibrated to the number of grams of cane sugar contained in 100 g of cane sugar solution. In other words, when a sugar solution is measured, the Brix % reading should match the actual concentration perfectly.
The ATC-1 has a measuring range of 0 to 32%. The smallest scale division is Brix 0.2% and the measuring accuracy is Brix + 0.2%. The ATC-1 has a built-in mechanism for automatic scale correction. This means that, according as the temperature at which a measurement is made deviates from the standard temperature of 20°C, the borderline of the refractometer deviates from its correct position. The scale plate of the instrument moves along with the borderline to compensate for this temperature change. This eliminates errors and means that the correct value can always be read off directly.
The refractometer is designed with a rubber hood and a rubber grip. The rubber grip insulates the instrument from the user's body heat, while the rubber hood prevents light from entering through the eyepiece during measuring. The ATC-1 is simple to use. After opening the cover plate, place 1 or 2 drops of sample (kiwi or grape juice) on the prism surface, then close the cover plate, look through the eyepiece and read the scale.



"Atago" ATC-1 hand refractometer

The grape trade sometimes sets requirements as regards the sugar/acid ratio. As we have explained, grapes do not contain any starch, and so they cannot form sugars after being harvested. During storage, therefore, they should not in principle become any sweeter. It is true that the sugar content decreases during storage, but so does the acid content. Since the percentage decrease in the acid content during storage is bigger than that of the sugar content, the grapes may taste sweeter after all. Grapes with a high sugar content but a low acid content will taste insipidly sweet, while grapes in which both contents are high have a good, well-balancedflavour.

Causes of damage

Grapes are a non-climacteric fruit with a low rate of physiological activity. Especially immediately after harvest but also during cooled storage, grapes can lose a lot of moisture. This water loss can result in stem drying and browning. The grapes may lose so much moisture that their skin, as it were, becomes too big for them. Grapes with a thin skin will start to wrinkle and go limp. Grapes with a thicker skin will not reveal drying-out symptoms quite so quickly, but their skin will display slight depressions.
Unripe grapes will dehydrate more than grapes which are sufficiently ripe.
It will be clear that a primary precondition for good keepability is a firm, tough skin with a thick natural coating of wax (bloom). This will minimise the evaporation of the grape. Rough handling and rubbing destroy the bloom and should therefore be avoided.

Botrytis rot

The most common cause of grape losses during storage is grey mould rot *(Botrytis cinera Pers.).* This fungus can also affect the fruit whilst it is still on the vine. The most dangerous situation is if it has been misty just before or during harvest time or if there has been prolonged rainfall. As we know, however, it is mainly wounds which form the usual entry point for the fungus. In its initial stages the disease is difficult to detect.

Later on, a mouldy patch becomes visible on the skin. This then leads to some shrivelling of the skin, which becomes weaker but may still remain intact. By this time the contents of the grape have turned a darker colour and have become watery. Pre-harvest infections can be effectively reduced by applying fungicides in the vineyard whilst the grapes are still ripening on the vines.

In a moist environment mould filaments *(mycelia),* with the grey colour that is characteristic of Botrytis cinera, will then grow OLit through the skin, *Botrytis rot* cannot be prevented simply by using the rapid cooling-down method. That is why the grapes are fumigated with sulphur dioxide in some countries to combat the rot problem. Sulphur dioxide is also effective against other moulds such as cladosporium and alternaria rot

Sulphur dioxide fumigation

This method was first used in about 1925 for the shipment of grapes in America. Grapes treated with sulphur dioxide (SOj) have a reduced rate of respiration compared with untreated grapes. To some extent this reduction continues during further storage, so that the shelf life can be prolonged through the use of this treatment. Vinifera table grapes are virtually the only product that will withstand fumigation with SO_2. At the concentrations in which it is used for grapes, $S0_2$ would cause serious injury to almost all other types of fresh fruit and vegetables but also to the eastern, or American varieties of grapes. For this reason fumigated grapes must not be loaded together with other products.

In the event of excess fumigation with $S0_2$ the grapes and the stems may be damaged. After fumigation the colour of the mould growth may turn lighter and sometimes almost white owing to the bleaching action of this gas. This is later followed by the occurrence of depressions in those areas where accelerated water loss has occurred. Other unavoidable drawbacks of the bleaching of the damaged berries are a sulphurous off-taste. However, this disadvantage should be offset against the inevitable decay that would have occurred in the affected berries if there had been no bleaching. It is a different matter if bleaching is observed on healthy berries, as that means that the $S0_2$ concentration has been too high or the exposure too long.

During storage the mould may spread as a result of affected grapes coming into contact with healthygrapes.
Fumigation with $S0_7$ inhibits the growth of moulds present on the surface of the grapes but has little effect on fungal lesions that have become established in the vineyard before harvest. None the less, this method will effectively prevent the further spread of the mould.

Aiternaria rot

Grapes may be attacked during cold storage by *Alternaria and Stemphy/ium moulds.* Contamination with these moulds takes place during cultivation. The moulds grow inwards through the grape sterns. The first signs of rotting therefore occur at the base of the grape stalk and the grapes can then be easily shaken out of the bunch.

Splitting of the skin

Since the turgidity of grapes increases as the temperature is lowered, they sometimes split in storage. If the grapes are picked much too late in the season, the skin will be less firm. Particularly during days when the grapes do not dry off (e.g. misty weather with no wind) the skin will weaken and the pressure inside the grapes will increase. This situation can also occur if, after harvesting, grapes are placed in a moist environment with insufficient movement of air, for example in a section of the hold which the air flow cannot reach and where high relative humidity prevails.

"Shattering"

During prolonged storage the stem-end attachment becomes weakened, probably because of changes in pectic substances. As a result, the grapes loosen from the stem and fall out of the bunch of their own accord or when the bunch is picked up and shaken. Although "shattering" (loss of berries from the stem) can occur in all varieties, it is an ailment specifically found in the Sultanina variety (Thompson Seedless)

Chilling injury

Chilled grapes have a dull appearance and are soft and limp when thawed out. After excessive freezing they become dark-coloured and watery. As a rule grapes will still not freeze at -2°C because of their high sugar concentration. The stalks of the bunches and the grape stems often suffer injury even before the grapes themselves are affected. Frozen stems become limp and yielding and turn a watery, dark green. They soon dry out, take on a dullish, dark colouring and are highly vulnerable to attack by mould diseases.

Carriage instructions

The best-known varieties which are suitable for commercial shipment include: Thompson Seedless, Emperor, Black Alicante, Frankenthaler, and Muscat of Alexandria.
Of the black varieties, Black Alicante will keep longest (1 to 3 months). The storage time is largely governed by the characteristics of each variety. In general, the varieties with poorer keeping properties have a higher rate of respiration than those which will keep well.

Depending on such factors as sugar content and variety, the freezing temperature amounts to -1.5°C to -2°C. The carrying temperature (= air delivery temperature) is between -1°C and +0.5°C.

During transport there is not much need for ventilation and so only a very low air exchange is required. Unlike some other fruits, grapes do not give off any appreciable quantities of ethylene or other substances that accelerate ripening.
The grape is the only type of fruit which does not emit harmful odours (provided it has not been fumigated). Conversely, however, grapes are liable to be tainted by odours from other products. Careful attention should therefore be paid to this aspect.

Before grapes are loaded, they are sometimes fumigated once more with sulphur dioxide. Particularly for grapes which are to be shipped by sea, SO_2-generating pads are used. These pads are impregnated with sodium metabisulphate in an encapsulated form so that SO_2 gas is released slowly within the fruit packages during the voyage. If the grapes have been fumigated and/or if such pads have been placed inside the boxes, then we would emphatically point out once more that, because of the injurious effects of the gas on other products, the grapes cannot be loaded in the same compartment as other fruit. However, if circumstances rule out their separate carriage, it is possible for the grapes to be loaded together with apples and pears in one compartment. We should bear in mind that many importing countries do not permit fumigation of grapes with SO_2 or the spraying of a dilute SO_2 solution over the grapes when they are being packed into the boxes.

A low R.H. is undesirable for grapes since it causes shrivelling, especially of the stems. A high relative humidity (90-95%) will prevent drying-out; the stems will stay green for longer and the grapes will not wrinkle quite so fast. In this way the deterioration in the quality of the grapes is slowed down.Some shippers require the highest possible relative humidity, but we should always remember that an extremely high relative humidity will encourage decay and "shattering". We could inhibit decay by means of a high air velocity, but that will result in a higher moisture loss which will in turn lead to more shrivelling, a greater weight loss and a poorer appearance of the fruit, especially of the stems.

Kaki

Air distribution

Temperature fluctuations bring about a change in the relative humidity. This is why a constant temperature and an even distribution of air through the hold must be guaranteed for cargoes of grapes. Once the grapes have been loaded and the transport temperature has been achieved, a fast movement of air is undesirable. All that then needs to be removed is the heat generated by the product itself. An air velocity of approx. 0.25 m/sec. in the hold will then suffice.
At a transport temperature of 0°C the heat production of grapes amounts to approx. 8 W/tonne and the $C0_2$ production is about 0.03 cbm per tonne per day. Generally speaking, the required $C0_2$ percentage is lower than 0.5%. The ventilation with outside air (air refreshing) must be sufficient to keep the $C0_2$ percentage below the prescribed limit.

General quality requirements

Grapes can be packed in wooden or in fibreboard boxes. In the case of high-quality grapes the bunches are often individually wrapped in tissues ("wrap packed") before being placed in the boxes. Nowadays, grapes are predominantly packed in corrugated cartons (10 kg) and shipped as palletised cargo. The stowage factor for palletised cartons amounts on average to 2.8 cbm/tonne (100 eft/tonne).

Grapes are mostly loaded in a pre-cooled condition and their temperature must in any event be lower than 5°C. The delivery air temperature amounts to -1°C to 0°C and the required relative humidity is 90-95%.
The stow has to be as tight as possible, thus restricting air flow around the cartons.

In the European Union grapes must comply with EEC Standard No. 14. Outside the EU many recommendations have been issued but they are not mandatory. Apart from the desired minimum SSC, the following quality factors are important: freedom from damaged or mouldy berries, decay and other defects, freedom from shrivelling, "shattering" and any signs of attack by disease or insects.
The stems should not be dry or brittle and must in any event still have a fresh, green colour.

KAKI (PERSIMMON)

Description of the fruit

The kaki *(Diospyros kaki)* originates from China and Japan. In Southern Europe the kaki still often grows in the wild.
The main producer countries are China, Japan, the USA, Brazil and Israel. In the autumn kakis are shipped in from the Mediterranean region (Israel, Italy, Spain and the South of France) and in the winter and spring from various regions such as Brazil and California.
The fruit, which grows on a shrubby tree about 4 to 8 metres high, resembles a big tomato, the difference being however that the kaki fruit has four big sepals. The skin of unripe fruits is yellowish-orange in colour and that of ripe fruits is a glossy red.
The fruit has a high vitamin content (A, C and beta-carotene) and its nutritional value is 50 Kcal/100g.
When unripe, the fruit has a sour, bitter taste. A ripe kaki has a very sweet taste reminiscent of apricots. The bitter after-taste is caused by tannic acid (tannin), but this disappears in an over-ripe fruit, which means that the kaki only tastes really appetising when it is over-ripe.

In Israel growers in the River Shari'ah valley have succeeded in breeding a cultivar called "Sharon"

Mangoes

which does not have a bitter after-taste. The "Sharon" is a hybrid kaki variety which not only lacks the bitter compounds but is also seedless. The advantage of this fruit is that it can be eaten, skin and all, before it is over-ripe, whilst the fruit flesh also has a fairly firm structure.

Another method used for some varieties to remove the bitter taste involves storing the fruit for 24 hours in an atmosphere with a high $C0_2$ content. The drawback of this method, however, is that it may create black stains in the fruit flesh. Though this discoloration has no effect on the flavour, it does make the fruit look less appetising. From the foregoing it will be clear that the maturity and the right time for harvesting can be determined by measuring the tannin content by means of chemical tests or gas chromatography. Another indication of the stage of maturity is provided by the surface colour.

Carriage instructions

Kaki (persimmon! is a climacteric fruit. Its ethylene production is low (0.1 to 1 0 microlitre/kg/h). Kakis are sensitive to ethylene, and some varieties may even be highly sensitive to the detrimental effects of ethylene The air renewal rate must be sufficient to keep the $C0_2$ content below 0.5%.
The freezing point of the fruit is -2°C. Generally, the carrying temperature will be 0°C and the R.H. approx. 90% (e.g. for Mediterranean fruit and for Chinese persimmons). The storage duration for the different cultivars can range from 1 to 3 months.
Some varieties are chilling sensitive and must be carried at a higher delivery temperature, e.g. Fuyu (9°C) and Hachiya (5°C).Persimmons will also store well under CA conditions (0_2: 3 to 5%; CO?: 5 to 8%).
The average heat production amounts to 13 W/t at 0°C to 5°C and to about 18 W/t at 9°C. The stowage factor for kaki in cartons on pallets is approx. 3.1 cbm/t (110 cft/t).

All kaki cultivars are liable to wrinkle, so they should preferably be stored or displayed in perforated polyethylene bags or in small packs covered with plastic sheeting. Kakis also tend to suffer crush damage and over-ripe fruits will burst open.

There are no international standards for kaki. Inspection during loading mainly involves the familiar aspects already mentioned for other fruits, i.e. freedom from fungal growth, cracks, mechanical damage, bruises, decay or other defects.

MANGOES

Production and export

The mango *(Mangifera indica)* is one of the oldest known fruits and originates from India. The fruit is cultivated today in almost all tropical regions of the world
The production of mangoes has increased by almost 20% over the past 10 years. At the moment annual world production amounts to approx. 16 million tonnes. India is the largest producer (6.8 million t), with a share of around 60% of total world production.
Other major producing countries are Mexico (0 85 million t), Pakistan (0.8 million t), Thailand (0.6 million t), Indonesia (0.5 million t) and Brazil (0.4 million t)
The principal mango exporting countries include India, Mali, Upper Volta, Mexico, Brazil, Venezuela and the USA.
Mangoes destined for seagoing transport, especially those from the USA, are mostly carried in marine containers.
The mango, known as "the king of the fruits", is still little known in the Western import markets but its imports into these markets have also been increasing steadily in recent years.

Description of the fruit

After bananas, mangoes are the second most important cultivated tropical type of fruit.
Mangoes grow on long stems on the branches of the mango tree. These leafy trees reach a height of between 10 and 35 metres. Many different varieties of mangoes exist. The thick, leather-like skin of a ripe mango can be greenish-yellow, orange, red or even purple in colour. The fruit may be round, ovoid or pear-shaped.
The orange-yellow fruit flesh is attached fairly firmly to the big, oval seed. The fruit flesh is juicy, sweet and highly aromatic in flavour. The taste is not unlike that of the apricot or peach but may sometimes also smell slightly of turpentine.

When the fruit smells spicy and the fruit flesh "gives" slightly when pressed, the mango is ripe. In a cooled condition, a ripe mango will only keep for a further two days at most.
A mango contains vitamins A, C and beta-carotene and is rich in iron. Its nutritional value amounts to 60 Kcal/100 g.

Harvesting and post-harvest diseases

Mangoes destined for overseas markets are picked whilst their skin is still dark-green The problem here is that, if the colour change has still not commenced, it will be difficult to assess whether they are mature enough to continue ripening subsequently. The ripeness of dark-green mangoes cannot be determined by using the methods we have previously discussed for other fruit, e.g. flesh texture, SSC, etc. In some varieties the fact that the fruit has developed to its full size may be an indication of the stage of ripeness. Sometimes the starch content and the specific gravity can also provide a pointer to the ripeness.

After the mature green mangoes have been harvested, latex will start to flow from the broken or cut pedicels. Once the fruits have been collected, therefore, they are washed in a water-filled tank in the packing house
To prevent stem-end rot and particularly anthracnose, a fungicide (e.g. thiobenzadole - TBZ) may have been added to the water. An even more effective disease control method is to immerse the mangoes in a tank of warm water (52°C) in which a fungicide has sometimes been dissolved. In this method, e.g. as used in Mexico, the fruit is then left in the warm water tank for 1 to 3 minutes.

Mangoes are often picked whilst still too under-ripe and they then arrive at their destination unripe. In such cases they must be subjected to post-ripening treatment at their destination to promote faster and more uniform ripening and bring them to an edible condition. This treatment involves exposing the mangoes to ethylene (80-100 ppm) for 24-48 hours at an R.H. of 95% and a temperature of 21 °C. Lower temperatures are not advisable for post-ripening, as these usually give rise to an acid taste.

Anthracnose

Anthracnose is a typical mould rot of ripening fruit. In mangoes anthracnose *{Colietotnchum gloeosporiodes)* is usually the main post-harvest disease. In most cases the fungus will have attacked the young leaves and blossoms or the young fruit during the growth period. As we described earlier (see sections on bananas and avocados) the fungus spores are spread further through the orchard during heavy rainfall because of dripping and rain water splashing up from the soil. Whilst the fruit is growing, the infections mostly remain latent. The infections only develop after harvesting
In fruit which is ripe or nearly ripe anthracnose infections take the form of spreading black spots on the fruit.

Stem-end rot

Stem-end rot *(Diplodia)* chiefly occurs in wet regions. The fruit may be infected by spores which have developed on previously damaged parts of the tree or on fruit which has already fallen to the ground. The organism mostly infects the fruit close to the stem-end. The infections only become apparent as a brown (later dark-brown) discoloration on the peel once the fruit starts to ripen.
Attempts are made to combat the disease by spraying the orchard with fungicides during the flowering period.
As mentioned above, a hot water bath with a TBZ solution or a hot water bath followed by a fungicide (benomyl) spray has proved to be the most effective method of controlling latent infections.

Chilling

Green to green-ripe fruits in particular are highly susceptible to chilling injuries.
Low temperature spoilage (l.t.s.) is identifiable by a greyish, scald-like discoloration of the skin, accompanied by slightly sunken marks. Its other symptoms are uneven ripening and/or a standstill in the development of colour and aroma
Sometimes the skin remains bright coloured but the taste is neutral to nondescript. Chilled fruit has a fibrous flesh and smells of turpentine.

Dehydration

The mango is also sensitive to dehydration (wrinkling). It is therefore recommended that the fruits in cooling rooms should be covered with plastic film. Perforated polyethylene bags should be used to display them at the point of sale.

Carriage instructions

The freezing point of mangoes is -0.9°C. The most common carrying temperature (= delivery air temperature) is 12°C to 13°C. The P.M. should be 85-90%. At this temperature and relative humidity the fruit has a transit and shelf life of 14 to 25 days. Though the fruit itself has only a moderate ethylene production, it is highly sensitive to ethylene action. During the transit period, therefore, the fresh air renewal rate must be at least sufficient to keep the CO_2 content below the prescribed percentage. If no $C0_2$ percentage has been specified, 3 air changes per hour will be sufficient.
Mangoes are also suitable for cooled storage under CA conditions. In this case the recommended atmosphere is 5% 0_2 and 5% CO_2

Some mango varieties, especially mangoes from India (e.g. Alphonso, Badami and Bangalor) require a lower transport temperature which may range between 6°C and 11 °C. Generally speaking, these mangoes will also keep longer. By contrast, there are also varieties, e.g. Haden, which are particularly prone to chilling injury and must not therefore be carried at a temperature lower than 12°C.
Mangoes are chiefly packed in one or more layers in fibreboard boxes which are sometimes fitted with individual compartments to keep the fruits separate. The stowage factor for mangoes in palletised cartons is approx 3 cbm/t (106 cft/t). The heat production at 12°C amounts to approx. 140W/t.

Quality control

There are no mandatory international standards for mangoes. Obviously, just as we have described for other fruit, an inspection must be made to ensure that the fruit has a sound and fresh appearance and that there are no signs of diseases. The mangoes must, of course, also be free from spots, bruises or mechanical damage. Another important point to note is that they should be free of any foreign taste or smell. Mangoes in fact easily pick up odour taints from the surrounding air. A check on the absence of foreign taste or smell must be made when the fruit is being loaded. It goes without saying that mangoes must be kept separate from other produce. Frequently, therefore, mangoes are stored under plastic film. This eliminates odour taint and gives ethylene less of a chance of stimulating any unwanted ripening.

MELONS AND PUMPKINS

Description of the product

Melons, the oval or flattish-oval fruits of the tropical genus *Cucumis me/o,* belong to the *Cucurbilaceae* family. This family also comprises the water melon as well as such vegetables as cucumbers, pumpkins and gherkins. From the viewpoint of their cultivation, melons more closely resemble vegetables than fruits and some may argue that, if cucumbers and tomatoes are classed as vegetables, then melons should be as well. Nevertheless, it is customary for the melon to be classified with the fruits rather than with the vegetables.

The fruit's probable origins are in Central Asia. Melons are cultivated outdoors in many tropical and subtropical regions and under glass in other regions. The major producers are: China, the USA, Spain, Israel, Egypt and Iran.

Melons are available throughout the year. Since cross-breeding of melons is very easy, an especially large number of varieties exist. The flavour of each melon variety can vary as it depends on sugar content, soil condition and climate. Many of these varieties have differing ripening processes and different levels of ethylene production, etc. Consequently, the carnage instructions are not the same for each variety We will therefore give a brief description of the most important types and varieties together with the related transport temperatures.

Net melons

The net melon is a fairly big, round melon with a cork-like light brown or white network of lines on a pale, yellowish, smooth or segmented skin. One familiar variety is the "Galia" melon which is exported from Israel.

The carrying temperature (air delivery temperature) for net melons is 6^{3}C to 9°C at an RH of 85-90%. At this temperature the maximum transit and shelf life amounts to 10-14 days.

Honeydew melons

These melons are also known as "sugar melons". This variety is a late ripener and is therefore classed as one of the "winter melons". In the EU the honeydew exported from Spain is the most familiar. The honeydew is smaller than the net melon and has a smooth dark skin with longitudinal grooves. This category also comprises the "Casaba", "Grenshaw" and "Persian" melons.
The above melons are all subject to chilling injury. They are best stored at 10-1*2°C.* At a delivery temperature of 10°Cand an RH of 85-90% Persians will keep for 2 to 3 weeks, honeydews for 3 to 4 weeks and Casabas for 6 weeks. Honeydews are less perishable than most other melons. By contrast, however, the Grenshaw is very tender and requires special care.
Melons must be picked when fully mature as otherwise they will not ripen further after harvest. To obtain a faster and more uniform ripening, honeydew, Casaba and Grenshaw melons are sometimes subjected to ethylene treatment before being shipped. Ethylene-treated honeydew melons are best shipped at 5°C to *TC.*
At this transport temperature these melons have a low to moderate ethylene production and are also only moderately ethylene sensitive. However, untreated melons are much more sensitive to ethylene action than ethyiene-treated melons.

As far as the transport temperature is concerned, honeydew melons will carry well at temperatures from 10^{D}C to 22"C. For this reason honeydew melons can also be shipped quite successfully as ventilated cargo, in which case they will keep for a maximum of 14 days. Honeydew melons are sometimes also shipped from South Africa as deck cargo.

Cantaloupe melons

The cantaloupes (musk melons) very much resemble the honeydew but are slightly smaller (diameter 10 to 15 cm). These melons are round or slightly flattened in shape. The skin may be divided into segments or covered with wart-like bumps. Their name is derived from the town of Cantaluppi in Italy, the place where this type of melon was first cultivated in Europe.

A well-known cantaloupe variety is the "Ogen melon". This melon variety is named after the kibbutz in Israel where it is grown. The Ogen is the smallest type of melon and is a cross between the cantaloupe and the net melon. It has a round shape and an orange-yellow skin with stripes running from stalk to blossom end. The fruit flesh is green and has a very tasty and strong aroma.

Cantaloupes destined for export are harvested when at a fully grown and hard-ripe stage. At a carrying temperature of between 3°C and 5°C and an RH of 85-90% they will keep for a maximum of 15 days. Temperatures lower than 3°C may cause chilling. Cantaloupes have a high ethylene production (10 to 100 rnicrolitres/kg/h) and are also sensitive to ethylene action
The carrying temperature for Ogen melons amounts to 6-7°C. At this temperature and at an RH of 85-95% they have a keeping time of 14 days.

Water melons

Water melons which originate from the Mediterranean area have a dark green skin and a pink to deep-red flesh. Water melons from America are more elongated and have a striped skin. The temperature limits range from 5°C to 10°C. At temperatures below4.5°C they are subject to chilling injury and at temperatures in excess of 10°C they are prone to decay.
At a transport temperature of approx. 10°C and 85% RH they will keep for 15 to 20 days. Their ethylene production and sensitivity to ethylene action is low.

Pumpkins

Pumpkins *(Cucurbita spp.)* also belong to the *Cucurbitaceae* (or cucumber-like) family, but pumpkins and squash are classed as vegetables. Just like melons, pumpkins also exist in a large number of varieties and sizes. They can be subdivided into two species: *Cucurbita maxima,* which mainly occurs in Europe and whose fruits can reach as much as 50 kg in weight, and *Cucurbita pepo* and its varieties which are much lighter in colour and have a more elongated shape. However, the smaller fruits of approx. 10 kg have a better taste. There are also Japanese varieties which weigh between 2 and 4 kg. One such variety has an orange skin and an orange fruit flesh, whilst there is also a variety with a green skin and an ochre-coloured flesh. Exotic pumpkin varieties which are pear-shaped also exist.

Major producers of pumpkins are: China, Egypt, Turkey and Argentina. Pumpkins are available all the year round but the peak supply period is in the autumn and at the beginning of the winter. Pumpkins on the EU market mainly come from France, as well as from South and Central America. A considerable proportion of the pumpkins are processed.

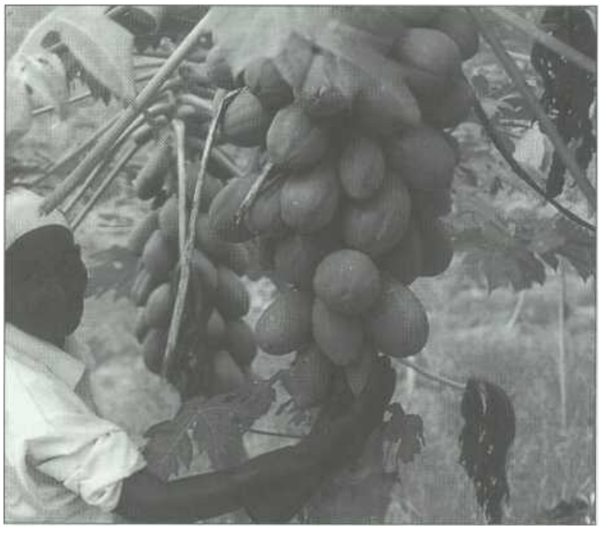
Squashes are any of the various vegetables of the genus *Cucurbita* resembling a marrow, pumpkin or the like. Squashes are chiefly cultivated in the USA.
Only the hard-shelled or winter pumpkins or squashes are suitable for long-term storage. Summer pumpkins and summer squashes and other soft-skinned types are fairly perishable and can only be held in storage for a short period. Pumpkins and (winter) squashes produce only very little ethylene and have hardly any ethylene-sensitivity. But they are sensitive to chilling. The transport temperature is between 10°Cand 13°C. At this temperature and at an RH of 70-75% they have a keeping time of 3 to 4 months.

Melons, water melons and pumpkins are climacteric fruits which must be harvested when mature-ripe. All the varieties described above are chilling sensitive. No international standards exist for this product category. Obviously, the products do have to comply with certain quality factors, e.g. maturity, firmness, freedom from decay, defects, sunscald, bruising, growth cracks, dry rot and insect damage.

PAPAYA

Description of the fruit

The papaya *(Carica papaya L.)* has its origins in South America. The papaya tree has a smooth-barked, straight trunk topped by a "wig" of green leaves. The fruits of this palm-like tree grow in bunches just underneath the leaves. The unusual feature is that the stalks of these fruits grow directly on the trunk.
Depending on the variety, the fruit may be shaped like a pear, a melon or an aubergine. Imported fruits mostly weigh between 300 and 500 grams and are about 30 cm long. In its country of origin the fruit can grow to a length of as much of 70 cm and a weight of 6 kg.
The colour of the smooth, thin skin varies from variety to variety. During ripening the skin generally changes colour from green to yellow-green-and-red speckled. But ripe papayas with a green skin also occur. The flesh colour of a ripened papaya is salmon pink to yellowish-orange. The soft-textured fruit flesh smells of apricots and has a sweet taste similar to that of a melon. In the hollow centre of the fruit there is a jelly-like mass containing the inedible black pips. The fruit contains vitamins A and C and has a nutritional value of 38 Kcal/100 g.



Papaya

The papaya is cultivated in India, Indonesia, the Philippines, Australia, South Africa, Cote d'Ivoire, Hawaii, Brazil, Mexico and Colombia.
The main exporting countries are Brazil and Cote d'Ivoire.

In the past few years a new import into Western Europe has been the "Babaco". The Babaco belongs to the same family as the papaya but has a cylindrical shape and is about 20-30 cm long. At harvest time the skin colour is green, changing to yellow during ripening. A ripe Babaco has a juicy yellow fruit flesh and is seedless.

Maturation and ripening

The papaya is a climacteric fruit and will therefore ripen normally after harvest when the sugars will increase and the flavour and aroma will develop further. During ripening the fruit flesh becomes softer but if the fruit is picked too early (whilst immature) it will not ripen any further. The fruit flesh will become softer but the sweetness and flavour will stay as they were upon harvesting.
The maturity and the harvest time can be determined by measuring the acid content and the sugar/acid ratio. If the papaya is destined for export, it is usually picked when the skin colour is starting to change from dark green to light green or when the fruit is just starting to turn yellow near the stem-end.

Papayas are susceptible to certain diseases. The most important ailment is anthracnose, which is caused by the fungus *Collectotrichum gloeosporioides.* Although the infection has usually taken place during growth, the disease only develops when the fruit flesh becomes softer and only becomes evident in ripening or ripe fruit. The minimum temperature for anthracnose disease is +3°C to +9°C. Another disease which affects this fruit is stem-end rot.

Though these diseases can be suppressed by fungicidal sprays, this method will not prevent them completely. For this reason the fruit is also subjected to a hot water treatment in some packing houses after washing and sorting.
This treatment involves immersing the fruit for 20 minutes in water with vigorous circulation and a temperature of approx. 46°C. Whichever method of heat treatment is applied, the water temperature and the treatment time always play an important role if the fruit is immersed in water. The warmer the water, the shorter the treatment time has to be so as to prevent heat injury. For example, if the water temperature is 52.5°C, the fruit may only be submerged for 6 minutes Isee also Chapter 6).
After the hot water dip the fruit is sometimes also fumigated to ensure insect destruction.

Carriage instructions

Papayas have a high ethylene production (>10 microlitres kg/h) and are also sensitive to ethylene.
The highest freezing point for papayas is -9°C.
Papayas will suffer from chilling injury if they are transported at temperatures below 7°C.
Particularly fruit which is picked early and is still completely green is highly sensitive to chilling and must therefore be transported at a temperature that is higher than the critical temperature.

As we mentioned earlier, chilling injury is time-temperature related, which means that the voyage duration and also the stage of ripeness of the fruit are factors which govern the correct transport temperature. Generally speaking, the prescribed delivery air temperature will be between 8°C and 13°C and the relative humidity will have to be 85% to 90%. At this temperature and RH the total transit and shelf life amounts to 2 to 3 weeks

For papayas which are harvested at the colour-break stage and are destined for transatlantic shipment the transport temperature must be higher (12°C to 13°C), as their resistance to alternaria rot decreases at a low temperature.
It may occur that, after discharge, papayas still need to be ripened at 22°C to 27°C to meet the requirements of the retail market. Chilled papayas, however, will no longer ripen normally. The fruit is ripe if the skin "gives" under gentle finger pressure.

Papayas are not subject to any prescribed international standards. Because of their fragile nature, however, papayas are vulnerable products for export. Pre-shipment quality control therefore mainly consists of checking for compression or impact bruises resulting from careless handling. Once the skin has been damaged it will not degreen when the fruit ripens. As is the customary practice with fruit cargoes, checks should also made to ensure that the fruit is fresh in appearance and shows no signs of attack by disease or pests or signs of mechanical damage, etc.

The specific heat at 10°C amounts to approx. 30 W/t. The stowage factor for papayas in boxes on pallets is approx. 3.3 cbm/t (116 cft/t).

PASSION FRUIT

Description of the product

The passion fruit *(Granadilla)* is the fruit of a climbing plant of the genus Passiflora, a family comprising more than 300 varieties, the best-known of which are the maracuja and the granadilla. The fruit probably originated from Southern Brazil. The main producer countries are: Brazil, Peru, Kenya, Cote d'Ivoire, South Africa, Zimbabwe, Australia, New Zealand and the USA.

The name "passion fruit" was given to the fruit in the 17th century by Spanish missionaries because the flower reminded them of the instruments of the Crucifixion: the crown of thorns and the nails of the cross. The fruit's other name, the "granadilla", was given to it by the Spaniards because they thought the fruit resembled a small pomegranate.

The most familiar type is the violet or purple passion fruit. This round to oval fruit is about 6 cm long and has a hard, deep purple or brown smooth skin, which soon wrinkles. The fruit has juicy, jelly-like yellow-green fruit flesh. Inside the fruit are soft seeds which are edible. The fruit flesh has a pleasantly refreshing, sweetish-sour taste and a rich aroma. The nutritional value amounts to 90 Kcal/100 g and the fruit contains vitamins A and C.
A substantial proportion of the passion fruit harvest is processed into fruit drinks and maracuja liqueur. The market for passion fruit juice is volatile. EU imports amount to 20,000 tonnes of concentrate and 15,000 tonnes of straight juice.

In addition to the purple type, there is a yellow passion fruit which is also known as the sweet or yellow granadilla. This fruit mainly originates from Colombia and Brazil. The sweet granadilla is bigger than the purple passion fruit and has a more oval shape. The fruit has a thick yellow or orange skin which gives it better protection against dehydration, but this fruit is less aromatic in flavour than the purple type.
There are also several varieties of the yellow passion fruit. Lastly, we would mention the "curuba". This is a passiflora fruit which is being supplied more and more, especially from Colombia. This yellow fruit has an elongated oval shape and is about 10 cm long. The jelly-like fruit flesh is orange-yellow in colour.

Carriage instructions

Passion fruit is a climacteric fruit. It has a high ethylene production (>100 microlitres/kg/h) and is sensitive to ethylene action and chilling injury. Its heat production at a transport temperature of 10°C amounts to approx. 60 W/t.
Depending on the variety and the ripeness, the transit temperature ranges from 8 to 12°C at an RH of 85-90%. For varieties which may become chilled at temperatures below 10°C the recommended transport temperature is between 10 and 13°C. At this temperature the transit and shelf life is about 3 weeks. There are no

Passion fruit

international standards for passion fruit. Inspection during loading should involve the same quality control measures as are applicable for, say, papayas. As mentioned earlier, the fruits wrinkle easily and care must therefore be taken to prevent them from drying out.

PEACHES AND NECTARINES

Origin and production

The peach *(Prunus persica)* originates in China where it was already under cultivation as long as 4000 years ago. From China it was taken to Japan and later to Persia. In Western Europe the peach became known some 2000 years ago. The peach, which belongs to the *Rosaceae* family, is a stone fruit with yellow, juicy flesh.

Very many varieties of peaches exist. Most varieties have a downy skin but there are also some peaches whose skin is smooth. These types are known as nectarines. The peaches which are destined for export can be divided into two groups, i.e. "freestone" and "clingstone" peaches. In recent years plantings of the clingstone variety have been steadily expanded.

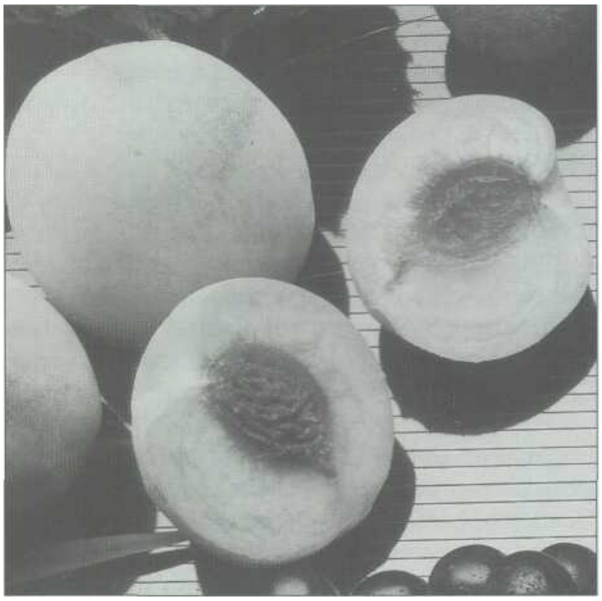
Of the total world crop, 26% is destined for processing and 11 % for fresh export. The annual world production of canned peaches, which is largely centred in the USA and Greece, stands at 1 million tonnes. Canned peaches are exported mainly by Greece (300,000 t per year), South Africa and Italy.
Other producers of peaches and nectarines are: Spain, France, China and the CIS.

Handling and diseases

Peaches and nectarines are climacteric fruits. Peaches are picked when firm and well matured. The picking stage of maturity is determined by the colour and also by measuring the firmness using a penetrometer.If an 11 mm plunger is used, the optimum pressure is 7 kg and the maximum pressure is 10 kg. Pre-cooling (to -0.5°C) must be commenced as soon as possible after harvest. To extend the storage life and reduce mealy breakdown, what is known as the "delay technique" is used for some types of peach. This involves storing the fruit for 48 hours at 20°C immediately after harvest; only then are the peaches cooled down to -0.5°C.
Peaches (and nectarines) are not chilling sensitive but they do have a high ethylene production (10 to 100 microlitres/kg/h) and are also very sensitive to ethylene action. A high humidity (90-95%) should be maintained during storage, primarily to minimise moisture losses which result in shrivelling and loss of turgidity in tissues. At a temperature of approx. 0°C peaches will have a shelf life of at most 3 to 4 weeks. If stored for longer, peaches will lose their flavour and fresh colour and their flesh may become "woolly", i.e. dry and mealy. Clingstone peaches do not suffer from woolliness, but are affected by fungal rot.
The most frequently occurring rots in peaches are brown rot (caused by mycelial infections) and grey mould rot. Blue mould, cladosporium and alternana rots may sporadically occur in high levels in cases where the fruit has been stored for longer than 4 weeks at 0°C. To prevent brown rot, the fruit is sometimes given a post-harvest application of benomyl.

Carriage instructions

The freezing temperature for nectarines is -0.9°C and for peaches it is -1 °C to -1.5°C. The temperature limits for nectarines are between



Peaches

-0.5°C and +0.5°C and for peaches -0.5°C/-1°C. In most cases a delivery air temperature of -0.5°C will be prescribed for both products. Though peaches and nectarines are not very chilling sensitive, they are temperature-sensitive. This means that precooling must have been carried out efficiently and that accurate control of the delivery air temperature (-0.5°C) during the voyage is essential. The required RH amounts to 90-95%. At this temperature and RH the storage time will be 3 to 4 weeks. The humidity level is important because peaches which have lost 3-4% of their original weight will usually tend to shrivel noticeably. For palletised cartons the stowage factor is approx. 4 cbm/t (140 cft/t). The heat production at 0°C amounts to 15 W/t.

Quality control

As always, the fruit must be inspected upon loading to make sure it is free from mechanical damage, growth cracks, insect damage, scars, bruises or other defects. As far as the maturity is concerned, the points to look out for are: firmness, shape, size and ground colour. In clingstone peaches the ground colour is green to yellow.
For trade within the European Union this fruit must comply with EEC Standard No. 6b.
Peaches which have not been cooled effectively or have been cooled for too long will lose their flavour and bright natural colour. Other symptoms of deterioration are a browning of the flesh, especially around the stone, and mealy breakdown.

PINEAPPLES

Origins and production

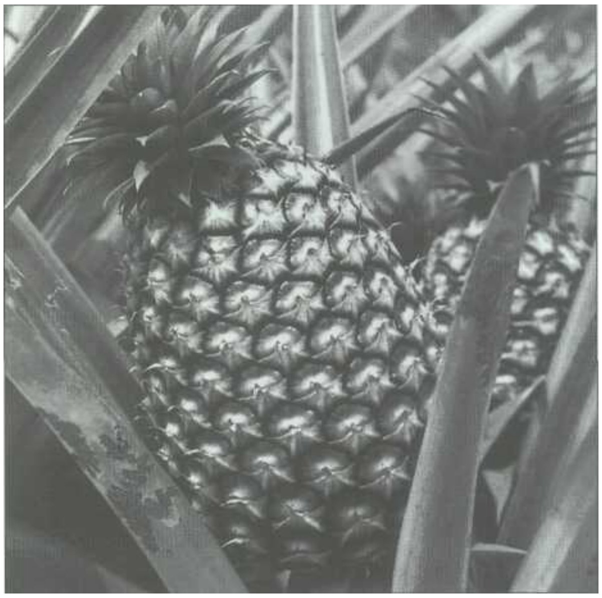
The pineapple *(Ananas comosus)* has its origins in Paraguay. There are many Ananas cultivars but the most prominent one is the "Smooth Cayenne".

Christopher Columbus was the first European to taste pineapple when he landed on the island of Guadeloupe in 1493. The pineapple was soon spread by travellers to other parts of the world. The pineapple proved easy to transplant to other regions, as its crown (the top of the fruit) will withstand drying-out very well and can therefore be used as planting material.
In the following centuries the pineapple was also seen in Africa, the East Indies and other tropical regions.
In Europe the pineapple was grown in greenhouses until the 19th century. After that imports started from the Azores, where the pineapples were also cultivated under glass.
It was not until the beginning of the 20th century that it became possible to ship the fruit from Kenya and the Ivory Coast to Europe.
In China the fruit was already being cultivated in 1640 in Guangdong, Jiangxi and Fujian, where it was known as Fam-Polo-Mie.

World pineapple production today amounts to 10 million tonnes.
The major producing countries are Thailand (1.9 million t), the Philippines (1.2 million t), China (0.9 million t), Brazil (0.8 million t), India (0.7 million t) and the USA (Hawaii) (0.5 million t).

Other producer countries are: Mali, Cameroon, Guinea, the Dominican Republic, Costa Rica, the Caribbean islands, Vietnam and South Africa.

Although exports of fresh pineapples have grown enormously in recent decades, by far the greater part of the world's pineapple production is still canned. The world production of canned



Pineapples

pineapple stood at 1 million tonnes in 1994. The annual traded volume is approximately 800,000 tonnes. The largest exporting countries of canned pineapple are: Thailand (55%), the Philippines (24%!, Kenya (8%), Malaysia (6.5%) and South Africa (4%).

Pineapples are also processed into concentrated and ordinary pineapple juice. The annual world production of pineapple juice concentrate is 160,000 tonnes and that of ordinary pineapple juice is 110,000 tonnes. The major producing countries of pineapple juice concentrate are: Thailand (55%}, the Philippines 130%), Kenya (7%), South Africa (6%) and Mexico (2%) In addition, South Africa and Cote d'Ivoire produce substantial quantities of pineapple juice

Description of the fruit

Large-scale cultivation of pineapples generally takes place at some distance away from the equator The only producer of pineapples in the humid tropics is Cote d'Ivoire. The pineapple is a tropical, perennial and herbaceous plant which will not withstand frost. This is why (with the exception of South Africa) it can only be cultivated in practically frostless regions located between latitudes 25°N and 25°S. On the other hand the pineapple does not like lengthy warm periods (over 35°C) as overheated fruits will suffer from "sun scald". The nights must not be too warm either and there must be at least 4°C difference between the daytime and the nighttime temperature.
The cultivar which is grown and exported most is the "Smooth Cayenne". Other varieties include: Queen, Spanish, Brazilian, Singapore and Mauritius. However, these varieties are predominantly of local importance.

The pineapple is a pseudo-fruit and the only edible fruit produced by plants of the *Bromeliaceae* genus. The pineapple is a non-climacteric fruit. The plant can have up to 70-80 leaves. The leaves are long and narrow and can reach 1 metre in length. Many cultivars have spines running all the way along the leaves, which makes harvesting more difficult. The fruit is formed around a short, stout meristem that shoots up from the middle of the plant. The "eyes" that can be seen on a pineapple's skin are the scars left behind on the places where the small purple flowers originally blossomed.

The plant grows to a size of about one metre high and 1.20 metres wide. One plant produces a single fruit weighing about 2 kilos. Subsequently, a secondary crop follows at intervals of about twelve months, but the successive fruits are smaller each time. To ensure good growth not only warmth and a rich soil are needed but also a great deal of moisture. Smooth Cayenne is mainly cultivated on sandy loam soils with a pH of approx. 6.

The fruit contains a lot of vitamin C (18 to 30 rng/100g) and also vitamins A and B1. Its nutritional value amounts to 50 Kcal/100 g.

Smooth Cayenne is highly popular because this plant has nearly spineless leaves and also has a high yield of very good quality fruit. Its biggest advantage, however, is that the fruit has the required cylindrical shape which makes this cultivar extremely suitable for canning.

Of the Queen cultivars the most familiar varieties are the "Natal Queen" and the "Ripley Queen". The Queen category has short leaves which carry many spines. As the fruit is conical in shape, it is not suitable for canning. The flesh of the Queen cultivars has an attractive colour and a good aroma, which makes them suitable for the fresh fruit market.

Pineapple handling and diseases

The time that elapses between the end of flowering and the ripening of the fruit is approximately 110 days. During the ripening process (i.e. the period after maturation) the SSC, and therefore the eating quality, increases considerably. In this same period the shell loses chlorophyll, a process which can initially be identified by the degreening of the fruit base. On the basis of these factors it is possible to determine when the fruit should be harvested.
If the fruit is destined for the cannery, it is harvested when it is ripe. Fruit destined for export is harvested when it is half-ripe. The correct time for harvesting can be determined by such factors as the colour of the skin and/or the size of the fruit. We would note, however, that

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the colour is dependent on the cultivar, the fruit size and the climatological conditions. The fruit may then harvested, for instance, when the colour of the base has changed from green to light-brown or when the skin of the fruit has coloured up to half way, but also taking into account the fruit's internal colour

Normally, pineapples are harvested by hand. The leaf-bearing growth at the top of the pineapple is known as the crown. The crown is a continuation of the plant's original menstem. In the case of export pineapples part of the crown has to be chopped off as it would otherwise take up too much room. If the pineapples are destined for canning, then the entire crown is cut off after harvesting. The crown can then be used again as planting material.

Diseases before and after harvest

The mealy bug is the most widely distributed and damaging sap-sucking insect, especially in "Smooth Cayenne". The roots of the attacked plant will stop growing, collapse and rot, causing the plant to wilt.
Another dangerous pest of pineapples, particularly in the Cote d'Ivoire are nematodes (tiny burrowing worms). Nematodes attack the roots, causing "root knots".
During pineapple cultivation a disease known as "yellow spot" also occurs. Yellow spot is caused by a virus and is transmitted by thrips from hosts such as the weed *Emelia.*
Other pineapple pests are: Syphihds (myriapods), mites, fruit flies, a type of moth (the same moth species which attacks bananas) and the butterfly. (These insects and the methods of controlling them were described in Chapter 7).

The post-harvest pathogen *Thielaviopsis paradoxa* gives rise to Thielaviopsis rot, e.g. water blister and black rot. The fungus enters the fruit via the wounds caused when the stem is severed at harvest and it develops rapidly throughout the fruit flesh. If left uncontrolled, the disease will be a serious problem in fruit after harvest. To control water blister disease the fruit is sprayed with or dipped in a benzimidazole fungicide before being sorted according to quality and weight.

Black rot is the most serious decay that occurs in pineapples during transport and subsequent marketing. The fungus spores grow slowly at low temperatures (8°C to 11 °C). This rot cannot develop at temperatures lower than 8°C but this storage temperature is only possible for semi-ripe to fully ripe fruit. In any event it is important to cool the fruit down to approx. 1*0°C* as soon as possible after harvest and to treat it with fungicide.

Another post-harvest problem is that of "chilling". Unripe, green pineapples are chilling sensitive at temperatures below 11°C. Pineapples for export, which are usually already halfway coloured, can withstand a lower temperature and are only chilling sensitive at temperatures below 6°C.
The consequences of chilling take the form of a brown or dull black discoloration of the skin and a flesh which turns darker or watery, especially around the cylindrical core. Chilled fruit is particularly prone to decay when removed from storage.

Endogenous brown spot (EBS) is a physiological condition that can often occur in pineapples. EBS mainly occurs in the winter and may then have been caused by chilling whilst the fruit was still in the field.
Endogenous brown spot may sometimes occur even when there has been no chilling. Its symptoms are a discoloration of the fruit flesh, mainly around the central cylinder.

Carriage instructions

The freezing temperature for pineapples is -1 °C. The fruit does not produce much ethylene (< 1 microhtre/kg/h) and also has a low ethylene-sensitivity. Vigorous ventilation is therefore not necessary and 1 air change per hour will suffice. The fruit generates little heat. At 8°C to 10°C the heat production amounts to 12 to 15 W/t.

Since pineapples are a non-climacteric fruit and (just like grapes) have no starch reserves, the post-harvest changes in the fruit remain limited to degreening and a decrease in acidity This also means that the fruit can only ripen a little further after harvest and that, because of the absence of a starch reserve, only very limited quality improvements will be possible after harvest.

Pineapples are highly sensitive to chilling injury The risk of chilling is closely linked to the fruit's stage of ripeness. Chilling injuries specifically occur at temperatures below 6°C.
A further problem is formed by the short storage time which amounts to at most 4 weeks. Under the most favourable conditions the period between harvesting and sale to the consumer can amount to at most 6 weeks.

The storage time and the transport temperature depend on the stage of ripeness. As a rough guide, we can say that the storage temperature for green (unripe) pineapples is 10°C to 12°C, whilst pineapples which are 50% yellow can be stored at 7-10°C. In both cases the R.H. should be 85-90%. Under these conditions the fruit will have a storage duration of 3 to 4 weeks.For half-coloured Smooth Cayenne, e.g. those cultivated in Hawaii, the Philippines, Honduras and Thailand, a transport temperature of 7°C is usually recommended.
Ripe pineapples should be stored at 4.5°C to 7°C, in which case their storage duration is 2-3 weeks.
Fruits of approximately identical ripeness and weight are packed into telescoping cartons. The stowage factor for palletised cartons is approx. 4cbm/t (140cft/t).

Quality control

No mandatory international standards have been issued for pineapples. During loading, however, inspections must be made to ensure that the fruit is fresh and firm and free from diseases or insect damage.
Pineapples bruise very easily. As we know, surface moulds are readily triggered by bruising injuries and this may result in damage which wilt specifically become manifest after discharge.

Compatibility with other cargoes

Some instruction manuals contain tables showing which products can be carried as mixed loads. Depending on what they have been treated with and the required transport temperature, such products can be carried in the same cooled compartment or otherwise in separate sections, each served by its own cooler unit.
Pineapples as a cargo are compatible, for example, with apples, apricots, bananas, grapefruit, grapes (provided the grapes have not been fumigated with $S0_2$), lemons, oranges (but not biphenyl-fumigated oranges), peaches, pears and plums.

Although it is in principle quite possible for certain products to be carried as mixed loads, practical experiences in several vessels have none the less shown that severe damage can occur because of cross-contamination between various types of products When damage occurs, people soon tend to assume that it is attributable to faulty design or layout of the cooling arrangements on board the reefer vessel. Possible causes that are mentioned include, hatch covers which were not tight, or contamination of the circulating air due to interaction of the ventilators during air changes But, obviously, another possibility is that the damage had already been caused prior to loading on board. Let us take one example from practice to illustrate this possibility in greater detail.

From the mixed loads table we can see that pineapples and bananas can be carried in combination with each other This also occurs in practice and the two products are sometimes carried in one and the same cooled compartment (temperature: 13.3°C). The more general practice, however, is for pineapples and bananas to be transported in separate cooled compartments, e.g for exports from West Africa (Cameroon and Cote d'Ivoire).
Pineapples from Cote d'Ivoire are treated with a product called *"Ethrel"* which, once absorbed by the sap of the fruit, helps to bring about a colour change in the fruits as a result of the ethylene that is released. The pineapples will then release ethylene over a period of 2-4 days following the treatment. This is the reason why the Ethrel treatment should take place on a date which has been accurately calculated, i.e. not less than seven days prior to harvest and shipment. On many an occasion it has been found that these treatment rules were not checked very effectively and that the fruit was treated with Ethrel at much too late a date. The outcome is that pineapples which have been subjected to this treatment too late can release substantial

quantities of artificial ethylene after harvesting. This means that, during carriage by truck to the port in the Ivorian capital of Abidjan, the ethylene released by the pineapples may contaminate pallets of bananas carried in the same truck. Contamination may also take place in the port if the pallets which are awaiting shipment are stored in the vicinity of each other or are adjacent to each other at the time of loading on board the vessel.
In view of the high temperatures of the fruits at the time of shipment, it is clear that even a very small dose of ethylene will be sufficient to trigger the climacteric period of the bananas. There have therefore been frequent cases in which a badly timed Ethrel treatment of pineapples has resulted in the ripening of bananas only a few days after the vessel's departure because of the ethylene released by the pineapples.

If bananas and pineapples are carried on board the same vessel, there will always be a potential risk in such cases, unless Ethrel treatment has been given in accordance with the directions for use and has been subjected to very strict controls if it was applied during production in the field.
In giving the above example our aim is to stress once more that, even though it is theoretically possible for some products to be carried as mixed loads, the cargo may still suffer damage because of certain pre-loading conditions or incorrect stowage. Time and time again it has been found that if damage has occurred as a result of combined loads it will be most difficult to apportion the blame.

POMEGRANATE

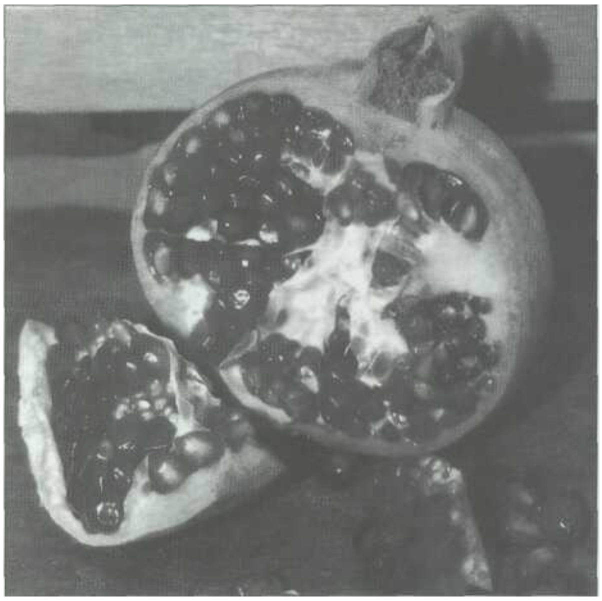
Description of the fruit

Most probably the pomegranate *(Punica granatum L.)* has its origins in Persia and Afghanistan. The fruit has been cultivated for thousands of years in the Middle East. The first pictorial representations of the pomegranate were found on Egyptian grave paintings dating from 2500 B.C. From the Middle East the plant was transferred to Spain where the city of Granada was named after it.

The fruit, which is a pseudo-berry, has a rather onion-like round shape and is about the size of an orange with a diameter of approx. 8 cm. The smooth, thick skin is leathery and has a yellowish-pink to reddish-brown colour. During the ripening process the fruit changes colour from yellowish-red to reddish-brown.
The skin bears a protruding remnant of the calyx. The thick skin protects the fruit against dehydration, which means that the fruit will keep for as long as 2 months at a temperature of 0° to 4°C.

The inside of the fruit is divided into 6 segments by 6 non-edible membranes. These segments contain the fruit flesh which in fact consists of numerous jelly-like globules coloured light to dark red which form the edible part of the pomegranate. These globules contain tiny edible white kernels. The juicy fruit flesh has a mild, tangy flavour.
The nutritional value amounts to 75 Kcal/100 g and the fruit is rich in vitamins C and beta-carotene and iron.

The pomegranate is nowadays cultivated in all countries with a subtropical climate. Most of the exported fruit comes from Peru in the months of January to end-June. From July through to January pomegranates are shipped in from Israel,



Pomegranate

Italy, Spain and Iran. Other producer areas are: South Africa, South America and the USA.

Carriage instructions

The pomegranate is a non-climacteric fruit, its ethylene production is very low, less than 0.1 microlitre/kg/h. The highest freezing point is -3°C If carried at the prescribed transport temperature the fruit is not chilling sensitive and it also has a low ethylene sensitivity.
The maturity and picking time are determined by reference to the size and external colour and also by measuring the acid content (chemical tests) or by using a refractometer to determine the sugar content.

The transport temperature varies from 0° to 4°C. Mostly, a delivery air temperature of 0° to 2"C is specified and an RH of 90-95%. The heat production at 0°C amounts to about 10 W/t.

There are no international standards for pomegranates. During loading the chief aspects that need to be checked are: freedom from diseases, pests, sunburn, growth cracks, cuts or bruises and decay. At the time the product is loaded the skin must not be dehydrated. The fruit must be juicy. After a while the fruit may dry up slightly on the outside, but that makes it even juicier. As a final comment, we would point out that pomegranate juice causes stains which are almost impossible to remove.

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CHAPTER 18

LOADING AND TRANSPORT OF PERISHABLES

We can define perishables as time and temperature sensitive commodities. They include fruits and vegetables, fish and fishery products, meat, flowers and plants In this chapter we will limit ourselves mainly to the transport of fruit. We have already described the transport of *frozen cargo* in detail in "Marine Refrigeration Manual" We shall deal in succession with where the responsibility for these products begins during storage or transport and where it ends and what that responsibility should entail.

In Chapter 25 a detailed description is given of the carrier's obligations and the conditions of carriage (Hague-Visby Rules). Here we will merely summarise a few key aspects of relevance to the present chapter.

1) The ship must be seaworthy.
   This not only means "tight, staunch and strong and in every way fitted for the voyage" but also that the ship must be able to carry the cargo safely. In practice this means that, prior to commencement of loading, the refrigerated holds must be made suitable for receipt of the cargo, i.e. the cooling installation must be checked and the holds must be clean and, where necessary, pre-cooled. Obviously, the ship must also have all the required valid (class) certificates.

2) The carrier is obliged to observe "due diligence" in making sure that the ship is seaworthy, properly manned and equipped for the proposed voyage and is suitable for shipping the cargo safely by sea. The ship may be unseaworthy not only because of, say, insufficient structural strength or faulty machinery but also because its crew is inadequate or unskilled. Regardless of the manning scales laid down by the flag state, therefore, owners should always make sure that adequate manning levels, including specialist reefer personnel, are maintained.

3) Stipulations aimed at limiting the carrier's liability never release the carrier from his obligation to prove that sufficient care has been devoted to the maintenance, the equipment or the manning level of the ship in cases where damage results from a defect in the vessel or its fittings.

We can briefly summarise the above aspects as follows;
The duty of care and the responsibility of the ship's master for the cargo starts a long time before the commencement of loading. The period during which the carrier has the obligation to deliver the cargo in the same state as it was received runs from the time of receipt to the time of delivery. Receipt of the cargo starts at the moment when the goods are placed on the hook on the quayside and ends at the moment when unloading is completed.
If the carrier is held liable for damage to the cargo, then the onus of proof lies on the carrier.

Care for the cargo before loading

Cleaning the holds

The typical feature of reefer operations is that both the nautical and the technical personnel are responsible for the cargo. Obviously, therefore, a good team spirit is a must!

How the holds should be cleaned depends on the cargo supplied and on the previous cargo carried or on the special wishes of the shipper or the cargo surveyor. Sometimes the products to be used for cleaning are prescribed. Usually cleaning is done by sweeping and, where necessary, the walls are given a dry wipe down. Particular attention must be paid to possible dirt under the gratings, as may for instance occur after a voyage with a load of potatoes. But even if the previous cargo was palletised, there may still be many waste stowage materials such as dunnage and boxes which will of course have to be removed before the hold can be swept out. If the previous voyage involved the transport of fish, then cleaning has to be done more thoroughly. In such a case the hold is hosed down with fresh water, mostly using a high pressure water jet, and the walls are scrubbed with fresh water containing a solution of a cleaning product (liquid soap or a chemical) and, if necessary, a disinfectant, or a combined disinfectant/ deodoriser such as "Amersan 20". The method of using these products is usually sufficiently clear from the instructions on the pack. After the holds have been cleaned, the whole area must be sprayed down again with clean water. The use of certain disinfectants and cleaners may leave behind a very strong odour. To remove those smells and any residual odours from the previous cargo, the holds must be effectively ventilated Air fresheners can also be used. The best way to disperse these throughout the holds is to spray some of the freshener inside the ventilator intake pipe.

To combat unwanted odours in the bilges, scuppers and water drains, a strong (30%) salt solution (brine) is poured into the drains of the tweendecks on vessels carrying frozen cargoes. Brine has a low freezing point and will remain in the "S" bend of the drain, thus working as an odour trap, filtering out smells but without preventing the drainage of leakage water.

If it is necessary to spray down the hold to get it clean, then the amount of water used should be kept to a strict minimum. This not only prevents moisture from penetrating the insulation but also makes it easier to dry out the hold after cleaning. In the case of plywood gratings in particular, however, the dirt on the gratings may be so ingrained that they cannot be cleaned in situ inside the hold, or only by using very powerful water jets. In those exceptional cases the gratings will have to be taken out and cleaned and dried on deck, weather and time permitting. Naturally, the gratings should be clearly numbered so that they can be put back in the correct position in the hold.

Ventilating

After the hold has been cleaned it must be sufficiently ventilated with fresh air. Sometimes it may be necessary to run the cargo hold fans at full speed during ventilation in order to change the air in the hold as often as possible. If the hold has also been washed down, it must be dried as quickly as possible. To do this, the hatch covers of all holds can be opened provided that the weather and the humidity of the ambient air permit this. If this is not possible, then the hold can of course only be dried by operating the fresh air ventilation system at full speed.

Survey and inspection

Where delivery air temperatures are below 0°C, it is clearly essential that the holds must be completely dry!
After the holds have been cleaned, they are subjected to a general inspection involving checking and/or testing the water tightness of hatch covers and side ports as well as the cargo hold insulation. Checks are also made of the gratings, air ducts, fans, return air grids and screens and of the proper functioning of the temperature recorders and the $C0_2$ monitoring equipment. Then the loading gear and all hydraulic systems for opening the hatches are inspected and tested
Obviously, the entire refrigeration installation and auxiliary equipment must be tested as well. The control and monitoring equipment of the installation should also be tested and a refrigerant leakage test conducted.

Temperature recorders

If damage is observed in the cargo upon outturn, the cargo surveyor will usually ask about the date of the last calibration of the temperature recording equipment (ice test) and may sometimes also carry out an ice test himself. It is therefore wise to conduct an ice test before starting to load each cargo If a cargo surveyor comes on board in the port of loading, he can be asked to sign the report on the ice test. In any event the fact that an ice test has been conducted must also be recorded in the logbook.

USDA Regulations

Fruit destined for the USA may only be carried on USDA approved vessels The ship should be in possession of an abstract of the most important

USDA regulations, specifically part 319 "foreign quarantine notices", subpart Fruits and Vegetables. Moreover, full and complete instructions should always be issued to the vessel at the time when the cargo is to be loaded.

The USDA Regulations are aimed at ensuring that a "cold treatment" is applied so as to prevent the importation of fruit flies such as the Mediterranean, Queensland and Mexican fruit fly and other injurious pests The cold treatment consists of two phases, i.e the cooling-down period and the period during which the fruit has to be stored at a prescribed temperature for a prescribed number of days. The USDA representative at the port of loading will give information concerning the temperatures and the period.
In Chapter 7 we have already indicated the prescribed temperatures and the relevant number of storage days for a cold treatment to combat the Mediterranean fruit fly.
Paragraph 319.56 of the USDA Regulations also lists the required temperatures and periods for the other types of fruit flies mentioned above For the Mexican fruit fly, for example, the prescribed values are 18 days at 0.6°C or 22 days at 1.7°C; for the Queensland fruit fly: 13 days at 0^{D}Cor 14daysat0.6^{D}C.
We would point out that the cold treatment only starts after all sensor readings have been brought down to the required temperature and must continue without interruptions until the USDA representative in the port of unloading has given permission for the cargo to be unloaded.

The USDA has also set requirements for the ship's refrigeration plant and, above all, for the temperature sensors and the temperature recording system. The number of required sensors, both fixed and movable, in each compartment are prescribed in the instructions. As an example we would mention here that for a compartment of 10,000 to 15,000 cubic feet, 5 movable sensors are prescribed, whilst for a compartment of 15,000 to 25,000 cubic feet 6 sensors must be present. The thermographs should register the temperature in the hold at least once every hour.
Before being certified for USDA cargoes, the thermograph and sensors must be checked under the supervision of the local USDA representative, who will also subsequently place the calibrated sensors at strategic positions in the stow whilst the cargo is being loaded.

The calibration test consists of the sensors being immersed in small plastic buckets filled with a mixture of crushed melting ice and fresh water, in which they are then left for a certain period of time. The measuring points are checked by one person who keeps in touch with another person in the hold by two-way portable phones or walkie-talkies. To make sure that the sensor registers accurately, the man in the hold stirs the slush in the bucket with the sensor during the test. If the deviation is greater than ±0.5°C, the sensors must, if possible, be recalibrated or replaced.

Pre-cooling

Some shippers require the holds to be pre-cooled before loading. The charterers/shippers provide instructions on the period prior to loading during which the holds have to be pre-cooled and on the temperature the hold has to be cooled down to. This temperature is of course not the same for each cargo and it may also depend on the requirements of the stevedores in the port. Dole, for example, prescribes that the cargo hold must be pre-cooled for 5 hours to a minimum of 13.3°C prior to opening of hatches when loading bananas in Guayaquil (Ecuador) and to 18.3°C when loading bananas in Turbo (Colombia).
In the carriage instructions for New Zealand kiwifruit the requirement is that the holds should be pre-cooled to 0.5°C two days prior to loading. It is in any event advisable to start the pre-cooling operation in good time so that, if any part of the installation does not function or not function in full, the fault can be put right in good time.

Care for the cargo during loading and transport

Well before the start of the voyage or at any rate before the start of loading, the master must have received the carrying instructions. It is important that the instructions concerning the stowage method and the desired temperatures are clearly worded Experience has shown that unclear wording of the carrying instructions can lead to

misunderstandings, e.g. about the required temperature, and may thus result in a damage claim.
To list a few examples: if reference is made to the "carrying temperature", this will generally mean the lowest acceptable temperature and should be the air delivery temperature It has been found, however, that the "carrying temperature" is sometimes interpreted to mean the hold temperature To rule out misunderstandings, it is clearer if the carrying instructions refer solely to the "air delivery temperature" and the "return air temperature".

In the case of fruit cargoes, not being USDA cargoes, the carrying instruction relating to the measuring of the "pulp temperature" in the hatches is sometimes interpreted and/or implemented in different ways in practice Although the instruction itself is of course clear, practice has shown that instead of being inserted into the fruit, the sensor is placed between the boxes. This is done so as not to damage the box and/or the plastic bag and also because there is a belief that this gives a more realistic picture of the temperature than measuring the pulp temperature of an individual piece of fruit. Leaving aside the question of which is the best method, the surveyor's comment in the event of any damage occurring will be that the set instruction (pulp temperature) was not complied with Here again, there must be clarity about which measuring method should be used and at which height in the stow the charterer/shipper wishes the sensors to be placed
As discussed in Chapter 14, the best method to get an accurate reading of the pulp temperature is to measure the pulp temperature of the cartons stowed on the grating and that of the boxes in the topmost tier. If no pulp temperature is required, then the thermometers can be placed between the two bottom boxes and the two top boxes. Normally there is a nearly constant difference of temperature of approximately 0.2°C between the fruit temperature in the bottom cartons and that in the top cartons.
In the case of frozen cargoes the temperature is always measured in the middle of the stow.

It sometimes happens that the carrying instructions for one and the same type of fruit from the same region may show differences in detail between the various shippers or that the instructions do not correspond to the crew's own observations and/or experiences during previous voyages. However, this does not alter the fact that the carrying instruction must always be followed to the letter. Prior to loading, therefore, the master and the chief engineer must have thoroughly studied and understood the carrying instructions. If there are unclear points in the instruction, the shipper and the shipping line must be contacted immediately. Once again, whatever the situation, the carrying instruction must be obeyed. Departure from an instruction is only possible after a "written" order from the charterer/shipper and with the approval of the shipping line.

Supervision during loading operations

Bunkering during loading and unloading should, where possible, be avoided because of the smell of the fuel. There must also be the greatest possible distance between the sounding pipes and air vents of the fuel tanks and the inlet and discharge ducts in the holds. Hydraulic oil likewise emits a strong odour which may be absorbed by the cargo. This is also the reason why precautions must be taken to prevent any leakage of oil from hydraulic equipment.

According to the Hague-Visby Rules the bills of lading must state "the apparent order and condition of the goods". When the cargo is accepted, therefore, it is essential to make a close check on the condition of the goods, at least in so far as this can be seen from their external appearance. Prior to departure the Master will generally sign a Clean Bill of Lading, which means that the B/L contains no clauses or annotations about defects in the cargo or the packaging. The B/L then carries the preprinted text "Shipped in apparent good order and condition".

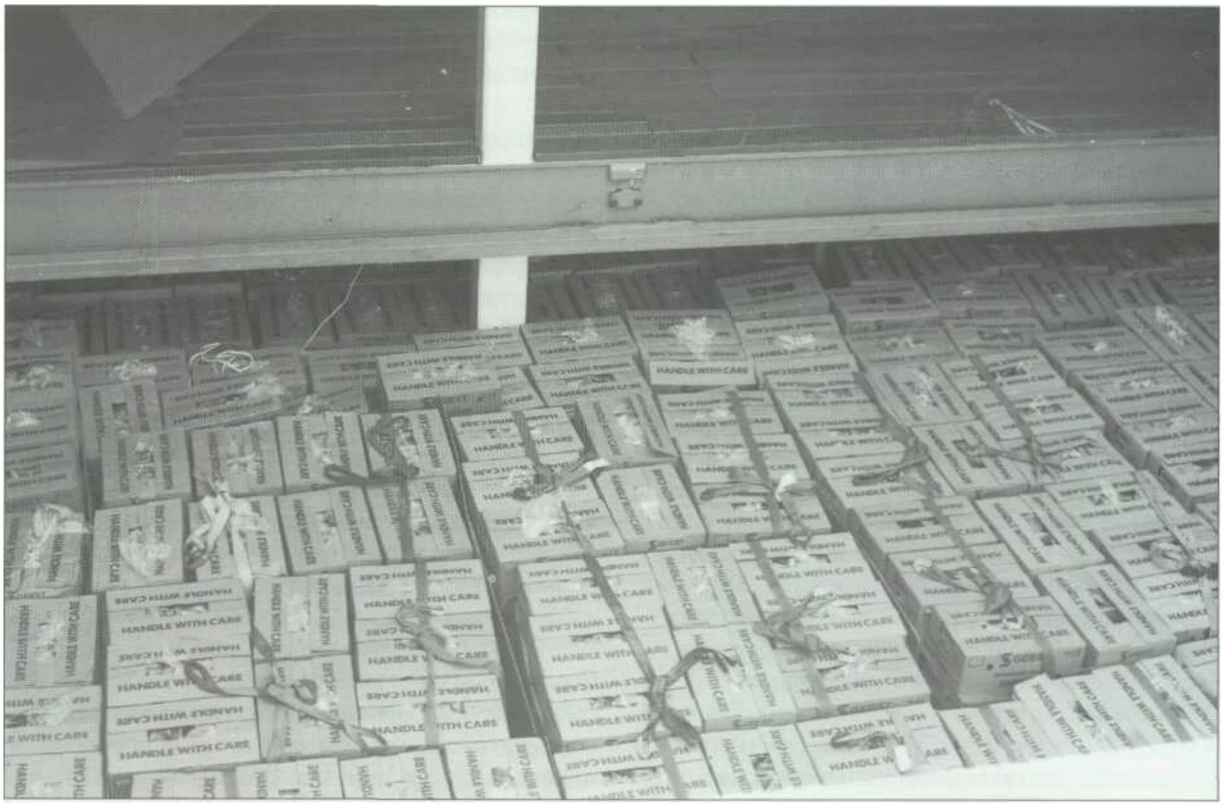
As we pointed out earlier, the ship's operator is obliged to observe due diligence and this also implies a ship which is fit to carry the cargo that has been supplied and a ship with a capable crew
In recent years in particular it has fortunately been the case that most of the major reefer operators have sent their officers to special

courses or seminars during which they are given lessons or presentations about the transport of perishables.
Besides, today's vessels are increasingly better stocked with manuals and publications about chilled and refrigerated transport and about the operation of shipboard reefer equipment.

Let us now return to the loading operation, to the time when the "apparent good order and condition" of the fruit has to be assessed. Since the ship's officers engaged in fruit transport are nowadays better educated or better informed, we must assume that their knowledge goes beyond, say, the ability to distinguish an apple from a pear.
On the other hand we cannot expect that the ship's officers have become fruit experts simply on the basis of their marine experience and their education. However, it can be assumed that the staff officers are able to carry out the quality controls, as described earlier for the various types of fruit (see Chapter 17), and to assess the "apparent good order" but, more specifically, the condition of a fruit cargo.
We would none the less make it clear here that, according to the Hague-Visby Rules, the carrier is not liable for damage resulting from the nature of the cargo, i.e. for hidden defects ("inherent vice") which are impossible to detect, not even for a reasonably trained eye.

Stowage of the cargo

In our discussion of banana transport (Chapter 14) we have already said something about stowing methods. Some of the aspects of stowage patterns described there, e.g. "stepping down", obviously also apply to other fruit cargoes. Another principle applicable to other fruit cargoes is that, to guarantee effective air circulation, the free space above the top of the cargo must amount to 114 to 2 times the height of the gratings.
In the case of palletised cargo the pallets must be stowed tightly together to prevent cold air



Free space above the cargo

"by-pass" and to ensure efficient air circulation through the cartons. Air bags and side shoring should be used to support a palletised cargo. Palletised cargo requires maximum air circulation because the temperature of fruit on pallets decreases more slowly than that of bulk cargoes. We shall not deal any further here with the stowage of the cargo, since we assume that the reader will be sufficiently familiar with this subject.

Ethylene and CO_2

The difference between climacteric and non-climacteric fruits and their related production of $C0_2$ and ethylene was described in Chapter 3. As we recall, all fruit produces minute quantities of ethylene during its development. However, concurrent with, their ripening process, climacteric fruits generate much larger quantities of ethylene than non-climacteric fruits. The internal ethylene concentration of climacteric fruits differs widely, though that of non-climacteric fruits shows little variation during their development and ripening. Exposure to an ethylene concentration of as low as 0.1 to 1.0 microlitres per litre for one day is normally sufficient to hasten full ripening of climacteric fruits, ultimately resulting in "soft" fruit.

To remove the ethylene gas that is given off by the fruit, a fresh air venting system is required. Since ethylene concentrations cannot be monitored on most ships, the risk of a build-up of ethylene must be avoided by increasing the level of ventilation so that the $C0_2$ levels remain below the prescribed value. Though $C0_2$ levels of less than 4% will have no adverse effect on the fruit's storage life, the principal reason for increasing the ventilation is that, if $C0_2$ levels increase, there will also be a likelihood that ethylene levels will rise as well. The required $C0_2$ concentration is indicated in the carrying instructions and will in most cases be between 0.1% and 1%. The supply of fresh air must be regulated step-by-step so as not to disrupt the hold temperature or the RH.

It should be noted that gas detectors are sometimes located high up in the compartments. This makes the system less reliable because CO_2, being a heavy gas, tends to move downwards in the hold and follow the current of the ventilation air.
The relative humidity in the hold plays a very important role, even though (too) little attention is in fact devoted to it. We will not deal with it further here, however, as this subject has already been discussed in depth in Chapters.

Care of the cargo during unloading

According to the provisions of the Hague-Visby Rules the carrier must ensure that unloading takes place properly so that the goods are delivered in an undamaged condition. The ship's officers are responsible for overseeing the whole of the discharge operation, which implies that if the goods or the packaging are damaged due to rough unloading or rough handling at the point of unloading, the carrier is liable for the damage. It is therefore wrong to assume that responsibility ceases as soon as the hoist has passed the ship's railing. If the ship's supervisory personnel see that the unloaded cargo is being roughly handled on the quayside, they must take measures to prevent the carrier from being later held liable for damage caused-during unloading.

Claims and quality control

By comparison with the tota number of voyages made during a certain period, the number of voyages during which the cargo is unloaded with substantial damage during that same period is not big. Unfortunately, however, damage has been on the increase in recent times and most cases of damage today involve enormously high damage claims.
Many damage surveyors (too often) tend to blame damage on a too-high or too-low temperature or relative humidity, or on an incorrect method of stowage. However, many defects which are attributed to the transport are present in the cargo itself, e.g. cargo which has been insufficiently pre-cooled or is over-ripe when loaded on board.

Especially in cases of serious damage, the collection of evidence and the identification of the party who is to blame or partly to blame results in a lengthy and complicated game of legal cat and mouse which can sometimes last many years.

Where the factual circumstances are concerned, there may be three types of damage, i.e. damage resulting from:

(a) bad stowage (including air circulation, combined loads);
(b) reefer failure (including incorrect temperature);
(c) nature of the product.

In the port of unloading, damage that has resulted from bad or incorrect stowage and reefer failure is self-evident in most cases and all that remains is to argue about the extent to which these two have been contributory causes of the damage. Damage resulting from the nature of the product itself is more difficult to establish, as pre-shipment circumstances can also play a big role here.
Examples of such pre-shipment factors are:

(al climatological influences during growth;
(W ripeness of the product at the time of harvest;
(c) time-gap between harvest and storage;
(d) method of cooling during storage;
(e) duration of storage;
(f) duration and method of transport to place of loading.

The impact that the above factors may have on the consistency of the fruit has already been sufficiently explained in previous chapters. We would merely like to emphasise yet again the great importance of cargo control and all the relevant observations noted down in reports made during loading. In fact, if damage occurs, then the surveyors in the unloading port can only guess about the condition of the fruit before and during loading if no observations made by the ship are available.
When we refer to observations, we are not only thinking of those observations which are of direct influence on the loading but also of the gathering of data which may only prove invaluable later on (e.g. in the event of latent damage).
For instance, it may be important to know when the fruit was harvested, whether the fruit was cooled as quickly as possible after harvesting, whether there had been a lot of rainfall in the preceding period (fruits containing a lot of water are physiologically unstable), whether the nights were colder than normal, how long it took to transport the fruit to the ship, whether the fruit was carried in a refrigerated truck or in ordinary open or closed trucks, etc.
The growth period, storage and transport represent a unique event. Since this situation can never be repeated again under exactly the same circumstances and since it will subsequently be impossible or extremely difficult to collect data and/or factual material about that period, the ship's officers must serve as the carrier's eyes and ears.

In previous chapters we have on several occasions discussed the aspect of quality control. Obviously, the pulp temperature of the fruit must be measured at random during the loading operation. The question that remains is: to what extent can skilled personnel also be expected to assess the maturity and quality of the fruit?
In various types of fruit, e.g. pome fruit and kiwis, the firmness of the fruit during loading plays an important role. It is of course easy to tell whether the fruit feels hard or soft, but this will obviously provide no more than a superficial picture. One aspect that is important, however, is to check whether there is any difference in consistency or size of the fruit originating from different packing stations.

We will use a couple of practical examples to illustrate this.
Export pears are harvested when the fruit is mature. They are then still hard and they will ripen off the tree. The pulp pressure then has a reading of between 18 and 21 Ibs (see Chapter 17). Especially towards the end of the season it often occurs that the pears are too ripe (prematurely ripel when unloaded. In such cases the pears are no longer hard and green but are more or less yellow in colour. If the pulp temperature has for some reason departed even slightly from the prescribed carrying temperature, then the surveyors will immediately tend to blame the damage on this.
The problem here is that it is no longer possible to check in the unloading port whether the fruit was picked in a mature but unripe state and whether it was stored at 0°C immediately after harvesting.
If the pears are already eating ripe when unloaded, then it will basically be clear that this cannot have been caused by a minor deviation in

the temperature. Naturally, every degree of temperature deviation affects the ripening process but, as the voyage duration represents only a small fraction of the total keeping time (4 to 6 months for Anjou pears), small temperature fluctuations will have no visible effect on the pears provided they were unripe when loaded on board. The onus of proof lies with the carrier. He will then have the difficult task of proving that the damage was actually due to the fact that the ripening process had already started prior to loading. And, as we know, once ripening has been initiated, it is irreversible. It can be slowed down, but not stopped.

The same example can also be applied to kiwifruit. The recommended requirements for satisfactory long-term storage of New Zealand kiwifruit are: fruit pulp temperature between -0.5°C and +0.5°C; relative humidity at least 95%; and no ethylene in the air around the fruit.
Under these conditions kiwifruit can be expected to have a storage life of 4-6 months.
If the fruit is found to be too soft when unloaded, then the surveyors will in most cases state that a small temperature deviation was the sole, or principal cause of the damage. Even if the temperature in the hold deviated by less than 0.5°C from the prescribed temperature, it will in practice no longer be possible for the carrier to prove that the cause may also have been the pre-shipment conditions.

In the case of some types of fruit (apples, pears, avocados, kiwis, oranges, plums and peachesl, measuring the fruit firmness during loading by using a fruit pressure tester may yield information which in some cases will serve well in tracing the cause of any damage.
It is a well-known fact that some carriers take the view that this results in the ship's officers taking on the role of surveyors, which means that the carrier's liability may perhaps be increased.
This conclusion, we feel, goes too far. In fact, the ship's officer does not become an expert fruit surveyor for the simple reason that he measures the fruit firmness as well as the temperature.
A fruit surveyor must be able to draw conclusions from the values measured using various techniques and a ship's officer cannot be expected to possess that know-how.
The observations by the ship's officers are expected to be an objective rather than a subjective evaluation.
As an example, let us look at the determination of the firmness of kiwifruit.
In Chapter 15 we have already explained that the physiological maturity of kiwifruit is not identical every year. The firmness measurement of mature ripe fruit may have 17 pounds-force in one season and 20 pounds-force in another season.
For this reason determining the maturity solely by measuring the firmness is not a satisfactory method for kiwifruit. To determine the maturity accurately, the soluble solids percentage should also be measured.
The question that now arises is: what useful purpose does it serve if the ship's officers determine the firmness of the fruit? The usefulness for them is that, by measuring the firmness, they can immediately see whether a difference in hardness exists between fruit in the same batch or fruit originating from different packing stations. The values measured are provisionally reported solely to the carrier and are recorded in the ship's log. The main reason is that, in the event of damage, the fruit surveyor will now have details about the temperature and the firmness of the fruit both during loading and during unloading.
On the basis of these figures and with the aid of existing graphs showing how the firmness develops, he will in some cases be able to establish whether the damage is attributable to a temperature deviation or to the fruit's consistency at the moment of loading. An even clearer picture can of course be obtained if the firmness at harvest time is known.

In Chapter 4 we described how the firmness test has to be carried out. However, the ability to make accurate measurements is best learnt in practice. If no on-the-job experience can be gained, then some further instruction can perhaps be obtained by attending a course or a one-day seminar on the subject.

We believe that it would be wise for the carrier and the shJp's personnel to consider whether controls and checks during loading should be carried out more intensively in future. More professional control measures may mean that in certain cases a claim can be rejected or the level of the amount claimed can be reduced.

Compatibility of cargoes

Particularly during lengthy storage or transport, damage may occur when mixed loads are involved.
There are lists which specify which commodities may or may not be loaded together, but these lists are not always applicable in practice because of the different circumstances which may occur in real life situations.
The possibility of carrying combined loads in a hatch with a common air supply or in compartments with separated refrigerated air supplies is largely determined by:

(a) transit time;
lb) carriage temperature;
(c) ethylene production rate;
(d) sensitivity to ethylene;
(e) relative humidity;
(f) emission of objectionable odours;
(g) sensitivity to odours from other products;
(h) pre-cooled or not pre-cooled.

If the above factors are borne in mind, then the decision on whether the commodity should be combined with another type is basically only a matter of common sense.

It goes without saying that products which give off a lot of ethylene, such as papayas, passion fruit and plums, should not be loaded together with ethylene-sensitive products like aubergines, Brussels sprouts or cucumbers. Bananas, pears and kiwifruit in particular should not be stored with other fruits which produce ethylene.

As we know, most commodities require a high relative humidity. But this does not apply to potatoes and onions, which should be carried at 70% R.H.
Other products, such as citrus fruit, apples, pineapples, potatoes, fresh onions, celery and fish, produce strong odours and cannot therefore be loaded together with products which are highly susceptible to odour absorption, e.g. dairy products, eggs, meats, butter, green leafy vegetables and melons.
Most types of vegetables are carried at a temperature which is close to 0°C. The freezing point for vegetables is generally around -0.5°C, which means that the delivery air must never be lower than 0°C. The ethylene production of most types of vegetables is very low (less than 0.1 microlitre/kg/h).
Within the delivery air temperature range between 0 and 1.1 °C the following commodities are compatible: artichokes, asparagus, beetroot, broccoli, carrots, lettuce, rhubarb and spinach.

Clearly, grapes which have been treated with sulphur dioxide and citrus that has been treated with biphenyl are incompatible with other products.

For economic reasons it may occur that the shipper who is transporting bananas may also want to transport other fruit, e.g. pineapples or grapefruit, in a separate air compartment. In such cases the fresh air intake and the exhaust from the holds must be arranged in such a manner that no exhaust air from the other fruit can enter the fresh air intake to the bananas. Even more risky is the carriage of apples and bananas in different compartments. In this case secure sealing of the hatch covers is needed to prevent any gas leakage. The apples must be loaded in the lower compartment, since the gas given off by apples is heavier than the gas from the bananas.

If the required transport temperatures for two commodities which are to be loaded together differ slightly, then a delivery air temperature must be chosen which is the most favourable for the two batches and which cannot cause the products to become chilled. In many cases the delivery air temperature will be that of the "warmest" product, though there are some exceptions to this.

Suppose that 80% of a certain batch has to be carried at 2°C and the remainder at 5°C. In view of the risk of damage it may be decided for purely economic reasons to set the transport temperature at 3°C, thus giving the greater protection to the bigger batch.

To close this chapter, one final point that you should bear in mind: if different products have to be carried in the same ship or if severs products have to be loaded together in the same compartments and if the combined load involves a risk of damage, then the products may only be loaded after consent has been obtained from the shipper and the carrier.

COOLER ROOM AND CARGO HOLD

Air system

When we refer to the "air system" in the hold we have to make a distinction between the "air renewal system" and the "air circulation system".
As we know, it must be possible to ventilate the air in the hold so as to supply the required oxygen and/or extract the $C0_2$. We also have to ventilate to remove bad air and/or unwanted odours or to maintain the moisture content of the air at a certain level. Depending on the "air renewal system" that has been chosen, the air can be fed in and extracted either naturally or mechanically. On a modern reefer the system mostly used is one in which the air is supplied and extracted mechanically. Manually or electrically controlled dampers allow accurate regulation of the quantity of air admitted. The supply and exhaust fans are fitted with two-speed electric motors so that the ventilation system can operate at both half speed and full speed. Full speed (e.g. 2 air renewals per hour! is used for cargoes which generate a lot of heat and/or for cargoes which are highly sensitive to ethylene action, such as bananas, avocados, kiwifruit and some types of vegetables.

Cargo hold fans

After loading, a rapid "air circulation" is needed to ensure that the hold temperature is brought down to the transport temperature within the shortest possible time. The cargo hold fans for air circulation are of course located in the cooler room. Generally, each cooler section has one or more fans, depending on the heat load of the compartment. The fans are equipped with motors which operate at several speeds, mainly two-speed but also three-speed motors, or with a frequency transformer so that the amount of air can be adapted to the type of cargo carried in the compartment. The air in the compartment is freely drawn in by the fans via the return air screen openings in the upper part of the cooler partition and enters the air ducts after passing through the evaporator.
As soon as the required temperature has been reached this high flow speed is no longer necessary and is even undesirable.
After the cargo has been cooled and the temperatures have reached their constant levels, the temperature difference between the delivery and the return air may amount to at most 1 °C to 1.5°C. If this is not the case, the culprit will often be a "short circuit" between the delivery and the return air.

Product cooling speed

The cooling of the cargo involves the transfer of heat from the cargo to the cooling air circulating in the hold. This causes the cooling air to increase in temperature and thus become unsaturated. Moisture then evaporates from the cargo and this means weight loss through dehydration. The bigger the temperature difference between the cargo and the cooling air, the greater the dehydration. We can rapidly reduce the temperature difference and, consequently, the dehydration in the following ways:

(a) by increasing the temperature of the cooling air;
(bi by increasing the heat transfer of the surface to be cooled.

Rapid cooling requires high air-flow speeds but it also means that a thin surface layer of the product will dry out. This is not such a disadvantage in the cooling of meat and may even inhibit bacterial growth because of the localised shortage of surface moisture. However, this does not apply to cooled fish, since dehydration here causes loss of the attractive shiny appearance. As the heat transport within the cooled cargo itself takes place more slowly than the release of the heat from the outermost layer of the product, the temperature of the cooling air must never become so low that it causes localised freezing of the cooled cargo. When this occurs, we refer to "freezer burns".

Normally, "live" products which cannot become "chilled" are carried at just above their freezing point. The air velocity required in the cooled hold cannot be precisely specified. Once the cargo has reached the required temperature, the speed of the air flow is generally between 0.1 and 0.2 m/sec. During pre-cooling much higher flow speeds are used, sometimes even as high as 0.3 m/sec.

Obviously, the air circulating through the hold will transport moisture from the hold to the coolers. That moisture will be deposited on the air-cooler in the form of frost or ice. As the layer of frost or ice gets thicker the coefficient of thermal conductivity decreases, thus reducing the capacity of the cooler.

Refreshing the air

Many foodstuffs, especially those containing fat, readily absorb unwanted odours. These odours may include: a fishy smell, a smell of petroleum, benzene, gas-oil, etc. The accumulated build-up of certain gases which may be formed during the voyage can be a cause of chemical spoilage. In the worst case chemical spoilage will lead to a substantial loss of nutrients or, where the air is contaminated by unwanted odours, will give rise to a product that is unpalatable. As we know, the breathing of a "live" cargo produces carbon dioxide ($C0_2$) as a combustion product. If the $C0_2$ concentration in the hold gets too high, live produce may be suffocated and may then die. During the transport of some types of fruit, gases may be released which speed up the ripening process. As we know, ripening bananas emit ethylene (C_2H_4). Even in extremely small quantities this gas accelerates the ripening process of the bananas in the vicinity, setting in motion a sort of "chain reaction". To prevent this

View into a refrigerated cargo hold

happening, attempts must be made to keep the concentration below 0.5 ppm.

We can largely prevent food spoilage by repeatedly "refreshing" the air which has been contaminated by products of metabolism such as carbon dioxide, ethylene, and other volatiles. Normal maximum refreshing rates are 1.5-2.5 volumes per hour of the empty hold. As a general rule, fresh air is allowed to circulate through the hold if there is a risk that the carbon dioxide content may increase to more than 0.5 to 1 %. In many cases the shipper requires even lower percentages, e.g. for kiwis. When cooling warm tropical fruit such as bananas, fresh air ventilation is inhibited during the cooling-down phase.

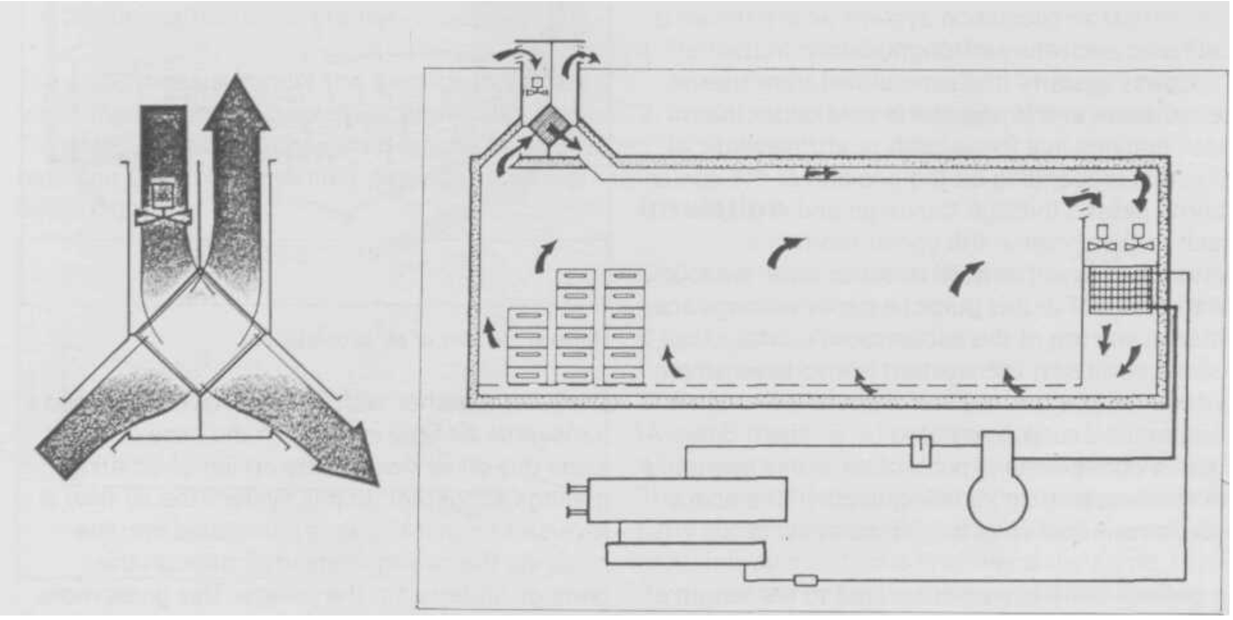
Heat exchangers

Particularly with a cargo of bananas the large number of air renewals calls for a great deal of energy. Various methods have evolved to limit the cooling load arising from ventilation, including air to air exchangers.
Heat exchangers work according to two different systems: the "recuperative" version and the "regenerative" version.

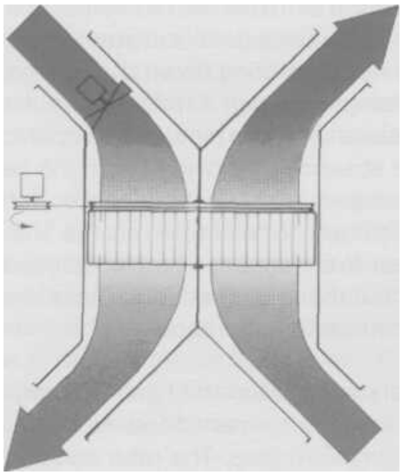
In the recuperative (cross-flow) system the heat exchanger consists of one or more finned blocks through which the air blown out to ventilate the hold which is to be cooled. This system uses a cross-flow principle to bring down the fresh air in the heat exchanger to such a temperature that it virtually coincides with the blow-out temperature. Owing to the absence of moving parts, the heat exchanger occupies relatively little space. If the fresh air \s admitted, for example, via the ship's mast, this heat exchanger can be placed inside the mast so that there is no need to make any additional provisions on the deck.

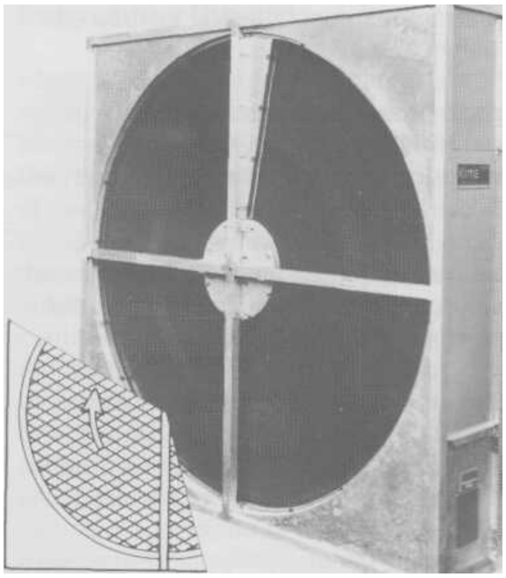
In the regenerative system the heat exchanger consists of a rotating element filled with corrugated aluminium strip. The rotor can be divided into two parts.

The corrugated aluminium strip in one part of the rotor is surrounded by the outgoing air flow; the other part is surrounded by the incoming air flow. The part surrounded by the outgoing air flow collects the energy thus offered and moves slowly by rotation to the part surrounded by the incoming air flow, where the energy stored is given off. In the meantime, the part now surrounded by the outgoing air flow collects energy again, and so on.
Consequently, the element rotates continuously at a very low speed. This system can cool down the fresh air temperature from 35°C to 18°C.



Recuperative system





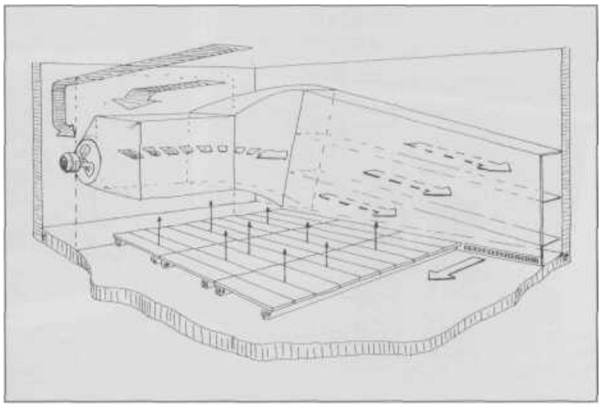
Regenerative system

A major advantage of this system is that an exchange of moisture occurs, with the result that the air becomes drier.

Cargo hold air systems

On a modern reefer the maximum rate of air circulation amounts to 90 air changes of the empty volume of the hold per hour, although this may increase to 100 or be as low as 70.
The most common air flow system on ships is the vertical air circulation system where the air is delivered and returned longitudinally. In this "ductless system" the air is blown from the cooler room at the end of the hold under the deck gratings in a forward/aft or aft/forward direction (depending on the position of the cooler room), passes through the cargo and is drawn back to the cooler in the cooler room in a forward/aft or aft/forward direction over the top of the cargo. For this purpose big air gratings are fitted at the top of the cooler room bulkhead (cooler partition). This system is also used when two decks in the same hold form a "common" temperature zone, separated by a "spar" deck. From a constructional point of view this system is much cheaper than installing ducts in the ship's side, as are applied in the "Robson system".

In general there is a practical limit to the length of a cargo space, the actual dimension largely depending on the depth of the floor grating and static pressure recovery. In the case of long holds, as are found on big reefer ships, the system described above therefore used to be less practicable. We will be discussing this system in more detail in our description of the m.v. 'Albemarle Island' (Chapter 23).



Robson system of air circulation

Danyard, together with Sabroe, have developed a transverse air flow system. In the case of pallet loads this gives owners the option of omitting gratings altogether. In this system the air flow is reversed so that the air is introduced into the holds via the ceiling, instead of through the gratings underneath the pallets. This gives more square holds which suit pallet stowing better, whilst omission of the gratings makes cleaning of the holds much easier. The system can also work with a grating if this is necessary to permit flexibility in handling the different types of cargo, depending on the specific trade in which the ship is going to operate.

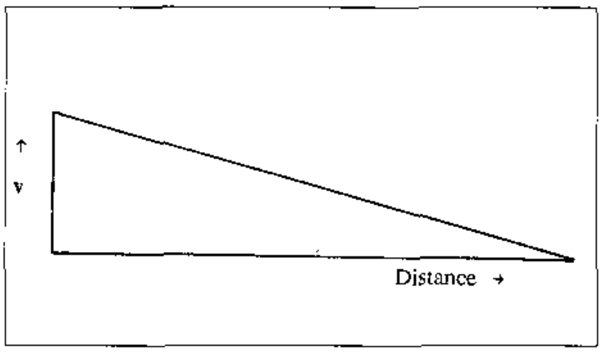
The hatch

The most important factor is the air distribution in the hold. Good air distribution is necessary to cool the cargo uniformly and to avoid excessive temperature gradients once the cargo is in equilibrium. Since a rectangular hatch minimises short circuits, this shape of hatch is preferred. There should also be as few obstacles, e.g. pillars, as possible. It will be clear that, aside from other advantages, it is favourable for the engine room to be located aft, with all cargo holds forward of the superstructure, so that there is only one "awkward" end of the ship to be dealt with. In the case of palletised cargo the flare at the ship's side in the foremost hold is filled up using inflatable bags or sliding shutters.

To summarise in brief: an even air distribution is influenced by:

- type of grating;
- height under the grating;
- size and shape of the compartment;
- number of air circulations per hour;
- total static pressure of the fan.

The static pressure under the gratings increases when the air velocity decreases (Bernoulli's Law). The static pressure decreases because of friction between the air and the floor passages (see Fig. below).



Air velocity in the passages under the grating

An even air distribution may be obtained by balancing these two phenomena. To calculate the most ideal grating height a computer program is sometimes used to find an optimal balance between floor height, air velocity and energy consumption.

The height of the 'tweendecks on modern reefers is today generally 2.3 metres and, on older vessels where this was still not the case, the deck height has in most cases been modified later where this was possible.
Obviously, if the deck height has to be increased for pallet transport, the cheapest solution is to lower the height of the gratings, This is, of course, not always possible and suppliers and fitters of refrigeration installations have therefore looked for systems which will enable a reduced height of floor gratings in some cases. One example of such a supplier is Grenco (a subsidiary of the Grasso Group of 's-Hertogenbosch, the Netherlands, which in turn forms part of the German multinational GEA A.G.). Grenco has developed a computer-aided engineering (CAE) program to calculate the optimum height and hole pattern of a floor grating. This computer program guarantees a uniform air distribution throughout the cargo hold and allows a reduction of the height of the grating and a reduction in the absorbed fan power. In newly-built vessels the principal benefits of Grenco's CAE program are as follows:

1. Reduced total height of the vessel of up to five times the reduction in height of the grating;
2. improved flotational stability of the vessel (scantling).

Insulation

On fruit ships it is uncommon to have a gas-tight separation between adjacent decks. If a hold has 4 decks, then it is customary to make one gas-tight division for the two lower decks (C and D deck) and the same for the two upper decks (A and B deck]. The hold then consists of 4 compartments split into two gas-tight divisions. This boosts the flexibility and makes it possible to carry some incompatible cargoes in the same hold, but obviously not in one and the same cargo compartment. In our example the upper cargo spaces can be used to carry, say, bananas.

whilst the lower compartments can be used for transporting, say, grapes or pineapples.
We described the insulation of the hold previously in "Marine Refrigeration Manual", Chapter 5. In brief, the insulation method usually looks as follows:


Warkaus gratings

To insulate the ship's side polyurethane (PU) foam is sprayed on the shell plating (mainly to provide a coating for the steel). After that glass wool slabs are fitted against the preserved shell and between the frames. A boundary of galvanised wire mesh is placed on top of the glass wool and this wire mesh is in turn sprayed with a thin (approx. 4-5 cm) coating of PU foam. The entire insulation layer is then finished off by fitting cover plates which may be made of aluminium or plywood. In more or less the same manner the bottoms of the decks are also insulated and the glass wool slabs are in most cases covered by seawater-resistant aluminium plating.

Insulation of the tank tops

The insulation of the tank tops may be applied as follows:
As a means of coating the steel, PU foam will first be sprayed on the tank top plating. Then, wooden beams (5x15 cm), spaced approx. 61 cm apart, are affixed in a lengthwise direction. Between this framework of wooden beams a layer of PU foam, about 12 cm thick, is applied.

This framework is then covered by boards of waterproof-bonded plywood which are nailed to the wooden beams. Holes are drilled in the plywood and the remaining layer (3 cm thick) of PU foam is injected through these. The result is a compact insulated mass firmly fixed to both the plywood and the steel. A layer of polyester is applied on the plywood and this is then covered by another plywood board (2 cm). Once the polyester has hardened, the result is a vapour-proof layer!

On top of this layer, aluminium girders (e.g. approx. 10 cm high) are placed athwartships at a distance of 50 cm apart. The gratings are then laid on top of these girders.

The expansion valve

The Carrying Instructions specify the carrying temperature and sometimes also the required pulp temperatures. For a variety of reasons the control of pulp temperatures is difficult to achieve. The only absolute temperature control possible on board a reefer ship is of the delivery air temperature.
To obtain the highest degree of accuracy of the delivery air temperature, the delivery air temperature has to be stable. As will be known, the proper operation of the expansion valve plays an important role in this respect.

Thermostatic expansion valve (T.E.V.)

Converts the liquid at the higher condenser pressure into low pressure by means of expansion. During this process no heat exchange occurs with the surroundings and the enthalpy of the refrigerant remains constant.

The sensor

The thermostatic expansion valve consists of the sensor (a small reservoir, usually referred to as a "bulb") which is attached to the suction line of the cooler (upstream of the back pressure valve) and to the valve, which is located at the beginning of the evaporator. The valve is divided into two parts by a diaphragm. On the one side of the diaphragm the sensor pressure is active via the capillary tube. On the other side the suction pressure and spring force create the required balance.

Air cooler

In the cooler (evaporator) the injected refrigerant is converted into vapour at a constant low temperature and constant pressure. The vapour that is formed has a low pressure and a high volume. However, many of the alternative refrigerants are non-azeotropic mixtures and have different saturated vapour and saturated liquid conditions. This means that in practice there may be a slight temperature gradient in the evaporator. This phenomenon is known as temperature glide.

Superheated vapour

Vapour is superheated if the vapour has a higher temperature than its saturated vapour temperature (SVT) at the prevailing pressure. Note: for refrigerants without glide, this is the boiling point.

Superheating

Superheat is controlled by the thermostatic expansion valve. The setting of the T.E.V. to the correct superheat is important for correct system performance. Superheating is necessary to ensure that liquid refrigerant does not return to the compressor, as otherwise this would cause mechanical damage to the compressor. Too much superheating reduces the effectiveness of the evaporator (cooling load).

Equalising line

In a larger cooler the gas will encounter resistance as a result of friction inside the cooler piping and in the capillary tubes between expansion valve and cooler. To overcome this resistance, the initial pressure downstream of the T.E.V. has to be slightly higher than in the final section of the cooler. This is the reason why a T.E.V. also has a third connection point, destined for the equalising line. The end section of the evaporator is then connected via the equalising line to the space underneath the diaphragm, so that the valve is regulated by the final pressure of the cooler whilst maintaining the set superheat.

Liquid hammer

Liquid hammer in the compressor may be caused by one of the following factors:

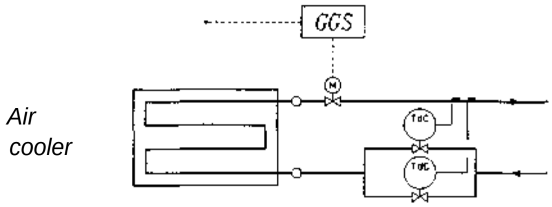
- liquid carry-over to the suction line through the pressure equalising line;
- refrigerant will condense in the suction line because the line passes through spaces which have too low a temperature;
- sensor is incorrectly located or has a poor thermal contact;
- the expansion valve is wrongly sized;
- the superheat is set at too low a value.

Summary:

If the temperature in the hold increases, the liquid in the evaporator will evaporate at an earlier stage; the superheat will increase, thus causing the expansion valve to admit more liquid to the cooler.
If the hold temperature is lower, the liquid in the cooler will take longer to evaporate; the superheat will decrease and the expansion valve will therefore allow less liquid to enter into the cooler.
The operation of the thermostatic expansion valve (T.E.V.) is based on the difference between the pressure in the cooler and the pressure corresponding to the temperature inside the sensor. This means that, where a T.E.V. is used, the superheat will increase with the cooler capacity (load). At full load, therefore, the cooler capacity is entirely used.

Temperature control systems

The conventional system incorporates two thermostatic expansion valves to control the



Conventional system

refrigerant superheat and a back pressure valve to control the delivery temperature.

To obtain a stable superheat at the air-cooler outlet, thus avoiding liquid hammer to the compressor, a superheat of approximately 7°C at minimum part load is required. This results in a low evaporating temperature and a low ' Coefficient of Performance (C.O.P.)

The superheat obtained with a T.E.V. increases proportional to the required capacity: at high loads, the superheat will be more than necessary to prevent liquid hammer to the compressors. This unnecessarily reduces the air-cooler surface area used for evaporation. The consequences are a reduced evaporating temperature and a lower C.O.P.

The range of operation of a T.E.V. is limited, Ideally, a different T.E.V. should be applied for each combination of evaporating temperature, condensing temperature and heat load. A compromise is to use two T.E.V.'s. However, these need to be adjusted from time to time and this may disturb proper operation of the two separate valves. Adjusting two T.E.V.'s always causes difficulties.

Back pressure valve

In order to achieve the required accuracy of the delivery air temperature at a minimum part load, the back pressure valve needs to be correctly sized. If its size is wrong, the consequences are; high pressure drop at all other operating conditions, giving a slow "pull-down" during cooling down and during transport.
In order to obtain a stable delivery temperature, the superheat needs to be very stable.
At minimum part load, therefore, the superheat needs to be increased to 10°C, resulting in a further reduction in the C.O.P.

Disadvantages of temperature control with a back pressure valve

In conventional ways of controlling the delivery air temperature of an air cooler, the air cooler is locked between two control devices. These may easily affect each other and cause unstable operation (hunting).

The disadvantages of this system are:

(1) Small C.O.P. of the entire refrigerating plant
(2) Large refrigerant contents of the plant
(3) Difficult to operate and adjust
(4) Unstable operation may occur under certain operating conditions
(5) Low reliability
(6) High maintenance costs

At minimum part load, the air cooler fills up with liquid refrigerant. This means that the refrigerant content of the entire plant needs to be higher.

Electronic expansion valves

The fundamental difference between electronic expansion valves and the conventional type is formed by the method of valve opening. Electronic valves are not dependent on the small pressure differences which can be produced by a thermal element in a conventional valve. The big external opening force makes the electronically controlled expansion valve independent of:

- refrigerant
- liquid sub-cooling
- condensation pressure

The main points in which the valve differs from the thermostatic version are:

- external moving force
- quick-acting
- easy adjustment
- actual function-check

The external moving force for an electronic expansion valve can be supplied by an electrically driven servo-motor, an electrically controlled thermo-motor or a magnetic coil,
An electronic expansion valve reacts faster to any change in the temperature of the return gas. In a traditional valve a relatively big sensor has to be warmed up first. This increases the pressure in the sensor. This higher pressure is then used to move the diaphragm so that the valve opens further. During cooling-down or freezing a conventional valve reacts too slowly. An electronic valve has a return gas temperature sensor with a low mass and thus a low time-constant. The change in temperature is

converted directly into a resistance and passes on the reaction instantly via the electronics to the valve.

In refrigeration plants the expansion valves are often located in virtually inaccessible places and the contact thermometers are usually difficult to read at low temperatures. The electronics of a "modern" expansion valve can be installed in a warm place. The temperature data can be read off there, whilst setting the superheat requires only a simple turn of a knob. Obviously, this makes it much more attractive to give a valve a truly optimal setting.

The electronic system can also indicate whether the valve is maintaining the required value. In addition to the optimum setting, therefore, an actual function-check of the operation of the electronic valve is also possible.

Operating principles

The frequently used system with modulating opening degree bears the greatest resemblance to the conventional system as regards design. A regulator needle moves within an opening, so that the quantity of refrigerant is constantly adjusted in line with the effective load. The regulator needle or disk can be driven by a servo-motor or a thermo-hydraulic motor. The servo-motor is controlled by a microprocessor. The input signal for the microprocessor is supplied by the sensors, one at the evaporator intake and the other in the suction line. A PI controller converts the signals into a command for the servo-motor.

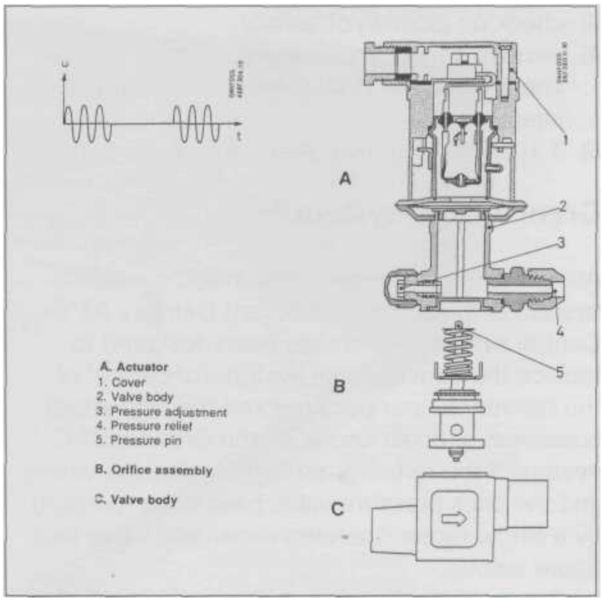
In the Danfoss system an electronic controller which measures the temperature differential between evaporator inlet and outlet or pressure inlet and temperature outlet forms the basis for driving a thermo-hydraulic motor. The diaphragm of this motor forces the control spindle away at a higher temperature or higher pressure of the thermo-motor. In this way the regulator needle can be placed very accurately in any position, thus guaranteeing a wide control range.

Application of the electronic expansion valve

It would be very wrong to look upon the electronic expansion valve as being merely an improved version of the thermostatic expansion valve. Although it indeed serves to achieve the same objective, the many possibilities offered by the techniques incorporated in it make the electronic expansion valve technologically a more sophisticated product.

When we look at all the electronics used to control such a valve, we soon get the feeling that the servicing of refrigeration plant should in future be left to fitters who are trained in electronics. But that would be wrong. It is not a matter of the electronic system itself but of what it produces and that can best be judged by the operating personnel.

Danfoss thermo-motor driven valves



Cross-section of Danfoss TQ thermo-motor driven expansion valve

As an example of a breakdown diagnosis let us take the following complaint:

insufficient liquid injection, return pressure too low, the plant was previously operating without problems.
In the case of an electronic expansion valve the steps that have to be taken to remedy this situation are practically the same as those for a conventional valve:

1) check delivery pressure and flash gas upstream of the valve.
2) measure the superheat at the relevant connection points in the electronic controller.
3) measure sensors separately and then check whether this is in line with measuring 2;
4) set controller to zero K superheat and check whether more refrigerant is injected;
5) if checks 1) and 4) are negative, then check that mains voltage and wiring are in accordance with manufacturer's specifications. If necessary, replace controller or valve.

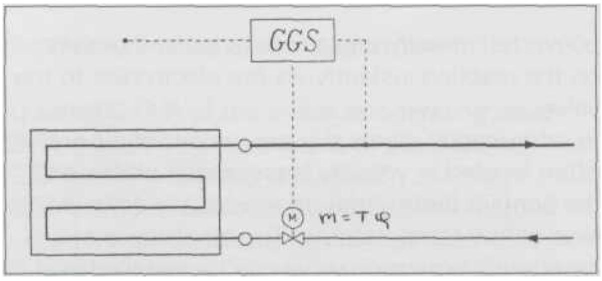
For a thermostatic expansion valve the steps to be taken would have been as follows:

1) check delivery pressure and flash gas upstream of the valve;
2) measure superheat at the evaporator;
3) check on location of sensor;
4) remove sensor and warm up in the hand and check whether more refrigerant is then injected;
5) if 1) and 4) negative, then replace element.

Grenco IDAC system™

An example of a modern, optimised control system is the Grenco Intelligent Delivery Air Control system, which has been designed to replace the conventional system for control of the delivery air temperature and the refrigerant superheat of an air cooler. In the Grenco IDAC system™ the two thermostatic expansion valves and the back pressure valve have been replaced by a single motor operated expansion valve (see figure below).

With this system the superheat is independent of the air cooler load. Secondly, a motor operated



Grenco IDAC system™

expansion valve only requires 4°C superheat. This results in an increased evaporating temperature and a higher C.O.P.

One motor operated expansion valve is sufficient to handle all operating conditions. This eliminates possible interference between expansion valves. The motor operated expansion valve does not require a minimum condensing pressure. This reduces the condensing temperature at part load and increases the C.O.P. It also avoids the need to increase the superheat to ensure stable and accurate control.

In this system there is only one control device to control both delivery air temperature and refrigerant superheat. No interference is possible between separate control devices affecting the same process.
The motor operated expansion valve is computer-controlled, which means:

- no manual adjustments;
- maximum control accuracy;
- continuous optimisation of process parameters for minimum energy consumption.

The advantages of the Grenco IDAC system™ can be summarised as follows:

1. Energy efficient. The increased C.O.P. yields energy savings of up to 48% compared with systems with a back pressure valve.
2. Less compressor capacity required. Compressor capacity is used more effectively during cooling down.
3. Less air-cooler surface are required. Less area required to generate superheat.
4. Less refrigerant required (30% less).
5. Easy to operate, no adjustments required.
6. Very accurate temperature control.
7. High reliability and low maintenance costs.

Choice of gratings

The general requirements that gratings have to meet are:

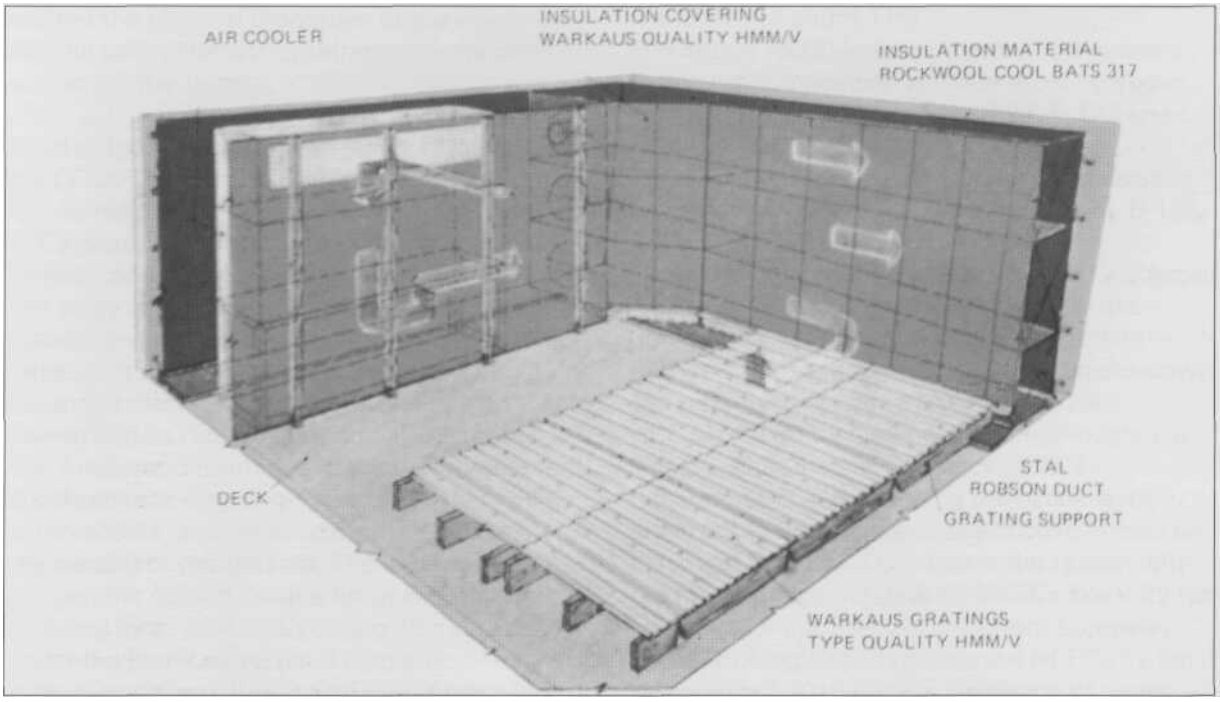
1. Least possible height but allowing greatest possible throughflow of the cooled air.
2. Handy size and light weight with a view to cleaning the holds.
3. Sufficiently strong to withstand cargo pressure and point loads.
4. Hygienically acceptable from a bacteriological viewpoint.
5. Durable, corrosion-resistant material.
6. Insensitive to temperature fluctuations or the effects of moisture.

During the preliminary discussions between the owner and the shipbuilder about the structural design of the ship, the following questions will therefore need to be answered:

a) What sort of cargo will the ship be carrying and what sort of load pressure will be exerted on the deck?
b) What type of gratings need to be used in order to minimise the loss of cargo space, and how does their cost compare with that of other available types?

Note that a gain in cargo space means not only that we can carry more cargo but also that the decks can, if necessary, be located in a lower position. In this connection the advantages of a lower deck level are: lower costs for the shell plating, whilst still offering the same cargo capacity.

Generally, the choice is between aluminium gratings and "Warkaus" gratings.
As against the high initial cost of aluminium gratings there is the permanent advantage that they bring in the form of a gain in cargo space and a minimum of maintenance.
Perhaps because their initial cost is lower than that of aluminium gratings, "Warkaus" (Wisa-ply) gratings are used on many reefers. Wisa-ply gratings are made in Finland. The basic plywood is Finnish birch manufactured from only 1.5 mm thick plies. The bonding of the panels is weatherproof and boilproof. The basic plywood is also impregnated against rot, fungi and wood-destroying insects.
The gratings are not affected by changes in humidity or temperature and have a good resistance to mechanical damage. They are also easy to handle and clean because of their relatively light weight.



Air circulation Robson system

CHAPTER 20

THE MONTREAL PROTOCOL AND THE USE OF CFCs

INTRODUCTION

In Chapters 1 and 6 of "Marine Refrigeration Manual" we gave some information about the uses and applications of (marine) refrigerants. However, as a result of the Montreal Protocol of 1990 and 1992 and the U.S. Clean Air Act Amendments (1990) we need to devote more attention to the use of refrigerants which consist of chlorofluorocarbons (CFCs).
As will be known, the Montreal Protocol is an international agreement aimed at limiting the use of ozone depleting substances. The most significant group of ozone depleting substances are the fully halogenated halocarbons ("Halons") and the CFCs widely used in refrigeration. This agreement on substances that deplete the ozone layer entered into force on 1 st January 1989 after it had been ratified by 70 countries.
This chapter discusses the refrigerants which are currently used in practice. In the following chapter the physical properties of the existing and the new (alternative] refrigerants are dealt with in greater detail.

Most of today's refrigerants (or liquid coolants) are CFCs. The term "CFC" is used to refer solely to fully halogenated chlorofluorocarbons.
CFCs were formerly used as propellant gases in aerosol cans (e.g. for hairsprays) and are still in use today as coolants in refrigerators, freezing installations and air conditioning systems. Their other uses include as blowing agents for expanded plastics (polystyrene and polyurethane foams! and as cleaning fluids (solvent cleaning).
The American Society for Heating, Refrigeration and Airconditioning Engineers (ASHRAE) has established a code to simplify and standardise the naming of refrigerants. The code for all refrigerants consists of the letter R (Refrigerant! followed by a number. CFCs are also known under the brand name used by their manufacturer, e.g. Freon (DuPont), Arcton (ICI) or Frigen (Hoechst).

Prior to 1930 the only substances in use as refrigerants were; ammonia gas, carbon dioxide, sulphur dioxide and methyl chloroform. Their drawbacks were that they were either toxic or flammable, or that they required excessively high working pressures.
This is what caused the engineer T. Midgeley to start looking for a completely new refrigerant. In 1928 he synthesised a product based on dichlorodifluoromethane, the product now known as R 12. This refrigerant was the first substance which could be used with absolute safety for cooling purposes, i.e. it was non-flammable, non-explosive, non-toxic and non-corrosive.
In 1929 DuPont started manufacturing this product, followed by a number of other CFCs in the subsequent decades.

The letters CFC stand for a compound with a molecular composition consisting of chlorine, fluorine and carbon (e.g. R 11 and R 12, and P 113, R 114and R 115).
The letters HCFC indicate that the refrigerant's molecular composition is made up of hydrogen, chlorine, fluorine and carbon (R 22, R 123 and R141).
HFC is used to describe a refrigerant consisting of hydrogen, fluorine and carbon (R 134a, R 125, P 32 and R 152al.
As we will see later on in this chapter, CFC gases which are emitted into the atmosphere are transported to the stratosphere where they release chlorine, a substance which breaks down and destroys the ozone layer,
HCFCs also contain some chlorine, though to a lesser extent than CFCs. Since HCFCs decompose before reaching the ozone layer, however, they have a less destructive impact on that layer than do CFCs. This is the reason why the target phase-out date for HCFCs like R 22 has been set for the year 2020. Current European Union (EU) legislation phases out HCFCs by the beginning of 2015 but the legislation of some European countries is even more stringent. Until

the phase-out deadline, however, R 22 can serve as a possible replacement for R 12. Another environmentally safer alternative to CFCs in cooling installations is HFC 134a. This refrigerant is discussed in greater detail in the next chapter.

The Montreal Protocol lays down limits for the production of the CFCs (11, 12, 113, 114, 115 etc.), the Halons (1211, 1301, 2402 etc.) and also the HCFCs (R 22] with a view to minimising their impact on the ozone layer. Halons are bromofluorocarbons which are used, for example, as fire extinguishing agents. HCFCs, like P 22, are partially halogenated compounds.

The Montreal Protocol initially required that CFCs should be phased out by the year 2000. However, since data from the US space agency NASA have shown that the ozone layer is being depleted faster than had been revealed by earlier measurements, the phase-out date has been brought forward to 1.1.1995 for Europe (EU Regulations) and to 1.1.1996 for the rest of the world (except for the less developed countries which are allowed to manufacture for a further 10 years).

Damage to the environment

CFCs have been found to cause great damage to the environment because they attack the ozone (0_3) layer. The ozone layer, whose core is located some 20-25 kilometres above the earth's surface, forms a protective barrier against dangerous ultraviolet radiation from the sun.

The use of refrigerants therefore gives rise to two environmental issues, i.e.:

1) The contribution of CFCs and HCFCs to depletion of the ozone layer. This is known as the ozone depletion potential (OOP).
2) The fact that halocarbons also contribute to global warming (the "greenhouse effect"). It should be remembered, however, that many other substances, both natural and man-made, are also "global warmers". Carbon dioxide is the major contributor to global warming.

To enable a mutual comparison of the effects of the various refrigerants on the ozone layer an ODP Index is used. In this index R 11 has been given the value of 1 (per pound basis). A measure of the impact of refrigerants on global warming is the Halocarbon Global Warming Potential (HGWP), measured by reference to R 11 which has been given a value of 1. Currently, the impact of the refrigerant on the "greenhouse effect" is evaluated by means of the TEWI (Total Environmental Warming Impact), which also takes into consideration the energy used (= the carbon dioxide generated) by the cooling system, together with the effect caused by the refrigerant lost from the system.
The following table gives the ODP and HGWP values for the principal refrigerants which are currently used in cooling installations or may be used in future.

Table 1: ODP and HGWP for CFCs and some alternatives

Substance	ODP (relative tc	HGWP CFC 11)
CFC11	1.00	1.00
CFC12	1.00	3.10
HCFC 22	0.05	0.34
HCFC 123	0.02	0.02
HCFC 141b	0.15	0.15
HCFC 142b	0.06	0.36
HFC 125	0.00	0.84
HFC 134a	0.00	0.28
R 500 (CFC)	0.74	2.30
R 502 (CFC)	0.34	3.75
Carbon tetrachtoride	1.11	0.34
Methyl chloroform	0.11	0.02

(Sources: UNEP Report of the Technology Review Panel, August 1989, IPCC Scientific Assessment Climate Change, W92).

ODP = ozone depletion potential
HGWP - halocarbon global warming potential
UNEP = United Nations Environmental Programme

Effect of CFCs on the ozone layer

Ozone (0_3) is a three-atom form of oxygen which is highly reactive because of its unstable bond. It can effectively absorb high-energy ultraviolet solar radiation. Ozone is created in the atmosphere because of its reaction effects with a certain portion of the sun's ultraviolet radiation. This radiation decomposes the oxygen molecules (0_2i and converts them into ozone molecules. The ozone layer is found in the stratosphere and is located approximately at a height of between 10 and 50 kilometres above the earth's surface, The core of the ozone layer is at a height of between 20 and 25 kilometres. At greater heights the formation of ozone decreases as the air becomes thinner and at lower heights it decreases because of the lower levels of ultraviolet solar radiation.

The ozone problem involves two completely different facets: the depletion of the - desired - presence of ozone in the stratosphere, and the formation of - undesired - quantities of ozone in the lowest strata of the atmosphere (the troposphere).
The ozone layer in the stratosphere protects life on earth against the harmful components of the ultraviolet radiation which reaches us from the sun. A big decrease in the quantity of ozone in the stratosphere leads to skin cancer and is believed to affect the growth-rate of agricultural crops. Recent satellite observations have shown that the ozone layer is decreasing everywhere, but particularly above the North and South poles. This decrease has been correlated with the presence of CFCs and brominated organic substances in the upper atmosphere.

Mainly, this relates to two CFCs, viz. R 11: fluorotrichloromethane (CCI_3F) and R 12: difluorodichloromethane (CCI_2F_2). Since these gases are colourless, odourless, stable, chemically inert and non-toxic, they are used not only in cooling installations but were also used, until the ban on their production, as a propellent gas in aerosols and in the production of foam plastic (polystyrene, polyethylene and polyurethane). From a biological point of view these virtually insoluble gases are excellent. However, specifically because of their low reactivity, it is impossible to remove them from the atmosphere by applying chemical or biological techniques. If these gases reach the stratosphere, they decompose under the influence of ultraviolet radiation. This releases chlorine which breaks down the ozone molecules in a chain reaction.

Ozone is needed in the higher air strata because it serves to filter out ultraviolet radiation. In the lower air strata, however, ozone is in fact undesirable because of its toxicity for humans and plants. In the lower air strata ozone is mainly formed by photochemical conversion of industrial emissions of nitrogen oxides and hydrocarbons. These include vehicle exhaust gases. To a lesser extent, other emission sources are high electrical voltage and spark discharges (e.g. during welding).
The maximum acceptable concentration (MAC value] for ozone has been set at 0.24 mg per m^3. The average ozone concentration in the outdoor air has already reached a level of 0.06 mg per m^3. It is wrong to assume, however, that ozone depletion in the stratosphere can be made good by the formation of ozone at lower heights!
Another problem is the "greenhouse effect". The big quantities of carbon dioxide we produce cause the atmosphere to heat up. Because of the decreasing ozone content in the higher air strata and the increase in the ozone content in the lower air strata, the stratosphere will become slightly colder and the troposphere slightly warmer. In future this is expected to cause a further intensification of the greenhouse effect.

Clearly, producers of refrigerants all over the world, including such companies as DuPont in the U.S.A., have been diligently searching for improved-performance refrigerants which can serve as replacements for CFCs at an acceptable price.
The limitation or prohibition of the use of CFCs is largely based on the fact that the CFC molecule contains a number of chlorine atoms. The stability of the molecule is also especially important. If it is stable, it will reach the stratosphere where chlorine atoms are generated which destroy the ozone. By adding one hydrogen atom to the chlorofluorocarbon molecule, manufacturers are attempting to reduce the stability of the molecule in such a way that it cannot accumulate in the ambient air (the

environment). The stability of CFCs allows relatively high concentrations to exist in the atmosphere, thus promoting global warming. This is another reason why it is better if the molecule is less stable. A further requirement that has to be met by an alternative refrigerant is that it should contain no chlorine atom or, if it does, that the molecule should comprise at least one hydrogen atom. In addition to an acceptable price, a new, alternative refrigerant will obviously also have to meet the same requirements as CFCs, e.g. odourless, workable delivery and return pressures, favourable refrigeration capacity, non-toxic, non-flammable and non-explosive.

CO_2 and the greenhouse effect

The strong increase in the concentration of substances through which sunlight can pass but which absorb the heat reflected from the earth in the infrared spectrum stimulates the greenhouse effect in the lowest air strata. As a result, the temperature in the troposphere could increase, causing the polar ice-caps to melt and disrupting the biology of life on earth. The greenhouse effect is largely governed by the $C0_2$ content of the atmosphere. The burning of fossil fuels raises the $C0_2$ concentration, which in turn increases the greenhouse effect and results in further warming of the atmosphere.

Scientists have established that emissions of halogenated hydrocarbons also have a negative impact on this process. The extent to which a number of substances affect global warming has been studied, with R 11 being chosen as the reference substance.
The values found are as follows:

R12	3.0
R11	1.0
R 22	0.34
R 134a	0.28

As these figures show, R 22 is safer than R 11 and R 12, whilst R 134a is as safe as R 22. Carbon dioxide is mainly released during the combustion of fossil fuels but also results from the conversion of oxygen during respiration. The per capita rate of $C0_2$ emission increases with the level of development of a country. If we realise that combustion of one tankful of petrol will discharge a quantity of carbon dioxide into the air which is more than the weight of the petrol itself, then we can understand why the per capita emission rate in Western Europe is approx. 3 tonnes per annum. The per capita CO; emission rate in developing countries is only about one-sixth of that in the industrialised countries. The industrialised nations can reduce carbon dioxide emissions via energy-saving measures, more efficient use of fuels and the development of clean energy sources. However, the biggest problem is formed by the increasingly higher energy demand in the developing countries. In Third World countries the growth of the energy problem stems largely from population growth rates and the increase in the average energy consumption per inhabitant.

Ozone friendly refrigerants

As they contain no chlorine, MFCs do not affect the ozone layer. These substances are permitted by the Montreal Protocol. Many chemical manufacturers have constructed HFC plants. The ICI chemicals group, for example, has built a factory in the U.S. state of Louisiana to produce the alternative refrigerant Klea [1]). The Klea-HFC blends are meant as replacements for the CFCs currently used in domestic refrigerators and air-conditioning systems. However, it is important to consider refrigerant efficiency when selecting alternative refrigerants. A number of alternatives to CFCs do require a higher energy consumption, which means that more fossil fuels will have to be consumed, thus releasing more CQ_2 into the atmosphere. It is therefore essential to ensure that the benefits of alternative refrigerants are not cancelled out by an increase in $C0_2$ emissions.
Depending on the operating conditions, the replacement of R 12 by R 22 leads to an increase of 2-7% in energy consumption, whilst R 134a has a 5% lower yield than R 12.

Refrigerants currently used in marine activities

In the present chapter we will focus above all on the refrigerants such as R 11, R 12 and R 22

') Klea is a registered trademark of ICI which are used in seagoing and reefer container transport. First, a brief profile of these refrigerants.

CFC 77:

Chemical name: trichlorofluoromethane (CCl_3F|. This refrigerant is mainly used as a coolant in centrifugal compressors for air-conditioning systems, for brine cooling and for temperature control in industrial processes.
It is also used as a solvent for the degreasing or cleaning of machinery. (Incidentally, CFC 113 is also used for this purpose).
One of the main applications of CFC 11, however, is as a blowing agent during the manufacture of polyurethane foam, a product which is also used as insulating material in reefer containers.

CFC 12:

Chemical name: dichlorofluoromethane (CCl_2F_2).This is the coolant most commonly used both in domestic appliances and for industrial and commercial cooling applications. It is also used for air-conditioning systems in cars and buses. It can be used in all types of compressors.
R 12 is specifically used in the cooling units of reefercontainers,

*HCF*C 22:

Chemical name: chlorodifluoromethane ($CHClF_2$). This coolant is used for domestic air conditioning and in commercial and industrial air treatment systems.
Its specific uses are in commercial and industrial cooling, e.g. in coldstores and on board ships.

ft 502:

R 502 is an azeotrope of R 22 and R 115, Because of its CFC 115 content it is classified as a CFC. R 502 currently serves a wide range of applications in the refrigeration industry. It is used widely in supermarket applications and for refrigerated containers. It offers good capacity and efficiency without suffering from the high compressor temperatures that can be seen with HCFC 22 single-stage equipment.

The world fleet comprises more than 1,400 refrigerated cargo and container ships and more than 4,000 larger fishing vessels. About 87% of these vessels use R 22 in their cooling installation. This is estimated to be equivalent to about 2,700 tonnes of R 22 on a worldwide basis. On some older vessels R 12 is occasionally also used as a coolant. However, the number of vessels involved is small and they will probably go to the breaker's yard in the years ahead. The remaining ships use ammonia as a refrigerant.

For refrigeration applications the potential substitutes for CFCs include ammonia, HCFC 22, HFC 134a and other commercial refrigerant blends. Generally speaking, however, these alternatives can only be used in newly designed equipment. The expectation is that by the year 2000 the CFCs which are in use today will have been completely replaced by environmentally friendly refrigerants. However, the biggest problem over the next few years will be the replacement of the CFCs, especially R 12, which are used in transport refrigeration. To keep things in perspective, however, we should not lose sight of the fact that transport refrigeration uses less than 0.2% of world CFC production.

Refrigerated containers

It is estimated that there are currently more than 300,000 containers with integral refrigeration machinery throughout the world. This translates into the equivalent of a total of some 1,700 tonnes of R 12 and R 502. The population of integral reefer containers is expected to increase to around 400,000 in the coming years.

The two CFCs used in reefer containers are R 12 and R 502.
A container has a useful lifetime of more than 15 years and, since it has now been decided that CFCs are to be phased out by the year 2000, the refrigerated container industry in particular is struggling to corne to terms with the implications of the Montreal Protocol on curbing the use of chlorofluorocarbons.

Several alternatives to R 12 have been identified by the reefer industry. Two refrigerants in particular are widely considered as potential replacements: R 22 ($CHClF_2$), a hydrochlorofluorocarbon which is due to be phased out by the year 2020, and R 134a, a hydrofluorocarbon (HFC). A widely used HFC alternative for R 502 is R 404A. This is a mixture of three MFCs. Performance is very close to that of R 502. We should note, however, that though R 134a and R 404A contain no chlorine and hence have no ozone-depleting properties, they are both global warming gases. One of the main concerns of the container industry is that once the ozone issue has been dealt with, attention will be refocused on the global warming problem.

"Low-CFC" polyurethane foam is already being used as insulating material, for example in the "Seacold" 320/240 container series newly developed by Sea Containers. After a minor adaptation these containers can be cooled using R 12 and R 22 as well as R 134a. "Thermo King" has also developed container cooling units which will operate using R 22 and R 134a. "Carrier" has produced units which work with R 22 as the coolant. Because of improvements in the construction of the cooling unit, modern units reveal a marked reduction in coolant loss through leakages. The expected refrigerant leakage loss for a modern container is 3% per year.

Refrigerated cargo ships

R 22 is the refrigerant most commonly used on board specialised reefer vessels. R 22 is also an ozone-depleting agent but has a much less severe impact than R 12. It is considered to be about 20 times less harmful than R 12, the refrigerant mostly used in reefer containers. Until the year 2020, therefore, there is no immediate need to replace R 22. However, particularly in the case of newly built vessels, allowance must be made for the fact that R 22 will no longer be available in future. Now that new data show that the ozone layer is being depleted at a much faster rate than previously thought, it is certainly not inconceivable that demands will be made for a quicker phase-out of HCFCs such as R 22. Chemical companies like ICI and DuPont are developing environmentally friendly, "drop-in" substitutes for R 22.
Currently an HFC refrigerant blend R 407C is available from DuPont (SUVA 9000P) and ICI (Klea 66) for use in certain R 22 applications (it is not suitable for centrifugal compressors). R 407C is a good match for R 22 in direct expansion cooling systems for medium temperature refrigeration (down to approx. -10°C service temperature). It has been extensively tested in stationary refrigeration systems and is being evaluated for marine applications. The tests undertaken in marine applications to date show that for medium temperature systems (down to approximately -10°C evaporating temperature, or around zero °C service temperature) R 407C (SUVA 9000 or Klea 66) performs very similarly to R 22 and can be used satisfactorily as a substitute for R 22. However, as discussed later in this chapter (see heading "Practical alternatives for CFCs over the short term") it does require a change of lubricant.

For low temperature installations R 404A is a more effective refrigerant. R 404A is available from many suppliers and should be considered as a replacement for refrigeration systems which currently use R 22 and R 502 and also for reefer container applications.
For the time being, however, one good solution, especially for newly buiit vessels, would seem to be to fit an ammonia cooling installation, since ammonia (NH_3) has no OOP or direct global warming potential. One point that should be borne in mind is that ammonia systems are significantly more expensive to install; they may also have a higher energy consumption (and therefore a higher overall TEWI - total environmental warming impact) than direct expansion HFC refrigerant systems.

Ammonia as a primary refrigerant

In July 1993 the first of an innovative new class of reefer ship, the first for about 20 years to use ammonia in the refrigeration plant, was delivered for the Ecuadorian trade. This high-tech 627,000 cbft capacity reefer ship 'Albernarle Island' is the first in a series of five ships ordered from Danyard A/S (Denmark) by Noboa-owned Ecuadorian Line of Antwerp which has operational responsibility for the vessel.
The 14,000 dwt 'Albemarle Island' is therefore

') Suva is a registered trademark of DuPont for alternative refrigerants.

the first vessel in recent times to use ammonia as a primary refrigerant as an alternative to R 22. Brine is used as the secondary refrigerant. In passing, we would also note that the vessel incorporates CA arrangements in the cargo section which comply with Lloyd's Register's requirements for its special CA class notation. The expectation is that these five Danyard-built vessels will serve as models for future ammonia-based reefers.

Guidelines for refrigerant selection

There are two situations which we need to consider:
- new vessels;
- existing vessels.

New vessels

The existing, widely used refrigerants (CFC 12 and HCFC 22) will be phased out within the economic lifetime of any vessel which is under construction today. This is why it is important to make a careful selection of the refrigerant. The refrigeration system should also be designed to make due allowance for refrigerant possibilities over the long term, even if the system currently operates using an existing commercial refrigerant.

At the moment the basic options are:
- ammonia
- HFC 134a (not efficient at low temperature}
- R 404A (for low to medium temperature)
- R 407C (for medium to high temperature).

Existing vessels

With the exception of R 404A (the replacement for R 502), the long-term alternative refrigerants are not ideal substitutes for CFC and HCFC refrigerants because their performance does not match that of the CFCs and HCFCs over the whole range of their current applications (even though a good match does exist for certain segments of their application ranges). For example, HFC 134a matches and even improves on R 12 performance at medium/high temperatures but it does not perform acceptably at low evaporating temperatures, HFC 134a cannot therefore be considered as a retrofit refrigerant option for low temperature R 12 systems, as significant equipment changes would be needed to ensure that HFC 134a could perform adequately. However, what are known as 'service refrigerants' have been developed. These are based on HCFCs (i.e. they will remain available until the current phase-out deadline of 2015). These provide a better match of CFC performance and will allow the refrigeration equipment to operate without major refit after the phase-out of CFCs. In deciding whether to use one of these 'service refrigerants', one factor to be considered is their logistical availability along the vesse 's operating route.

A table of options is given below:

Table 2: Refrigerant Retrofit Options

Current application	Option	Comments
R12 medium to high temperature	HFC 134a R 401A* (Suva MP 39] R22*	Requires lubricant flush Rapid drop-in One oil change Equipment change needed
R12 low temperature	R 4018* (Suva MP 66) R22*	Rapid drop-in One oil change Equipment change needed
R12 medium temperature	R407C	Requires oil flush. Cannot be used with centrifugal compressor or flooded evaporator
R22 low temperature	R404A	Requires oil flush
R502 medium to low temperature	R 402A* (Suwa HP 80) R404A	Easy drop-in Requires oil flush

'service refrigerant' (- HCFC-based refrigerant)

Refrigerant recovery and recycling

As will have become clear, the replacement of CFCs by environmentally friendly coolants will still take a long time. At present it is not possible to mix the new coolants with the existing ones. Until such time as a new "drop-in" refrigerant becomes available, therefore, we will in any event have to protect the environment by preventing needless wastage of the existing coolants. A significant amount of the environmental "pollution" is attributable to leakage; in most cases leakages are caused by inadequate maintenance.

There are three areas in which we can help to minimise emissions from the current installations:

a) Take preventive measures during maintenance of existing units so as to obviate leakage as much as possible.
b) Design new installations in such a way that leakage is cut to a minimum.
c) Recover recycle used refrigerant.

Prevention of liquid leakage

Obviously, the first step to be taken to prevent coolant loss through a leakage is to close off as many pipes as possible.
Leaks can be detected using a solution of soapy water or an electronic detector with adjustable sensitivity. However, electronic detectors are insufficient for use in an enclosed area where large-scale leakage has already occurred.
The use of torches for detecting leaks must be avoided, as decomposition of the refrigerant leads to the release of dangerous gases (hydrogen fluoride!.

A better method is to use an ultraviolet (UV| lamp. In this method an indicator is first added to the system where it mixes fully with the compressor oil. To check for leakages it is then sufficient to walk along the system with the UV lamp which will reveal the presence of the indicator.

Precautions

Refrigerants are classified in three groups based on the degree of hazard they present because of their toxicity and flammability.
Group 1 comprises refrigerants which are non-flammable and non-toxic or only slightly toxic. This group includes R 11, R 12, R 22 and R 502. Ammonia is classed in group 3. The use of ammonia as a refrigerant is discussed in more detail in Chapter 21.

The maximum quantity of refrigerant that a cooling installation is allowed to contain is governed by the volume of the smallest compartment in which the installation or part of the installation is located. The refrigerant charge must be such that in the event of a major leakage the concentration of refrigerant in the relevant compartment does not exceed the permitted level. If various compartments are cooled by air from one central system, the combined volumes of all these compartments must be used as a basis for calculating the permitted maximum refrigerant charge in the installation, provided that the air supply to each compartment cannot be reduced to less than 25% of the total supply. The table below shows the safe concentration percentages for group 1 refrigerants.

Table 3: Concentration thresholds, group 1 refrigerants

symbol	concentration considered safe in practice as regards toxicity	
	% (V/V)	g/m^3
R 11	10	570
R 12	10	500
R13	10	440
R 13B1	10	610
R21	2.5	100
R22	10	360
R 113	2.5	185
R 114	10	720
R 115	10	640
RC318	10	800
R500	10	410
R502	10	460
CO_2	5	95

We would point out once more that the vapours released by CFCs are usually odourless, colourless and heavier than air. The latter implies that the oxygen in the air is immediately displaced. The resultant higher vapour concentrations will cause a shortage of oxygen and thus bring the danger of suffocation.

Chlorine-containing refrigerants which come into contact with naked flames or hot surfaces may decompose and form extremely toxic gases such as hydrogen fluoride and hydrogen chloride. These can be immediately detected by their pungent and irritating smell. The MAC values for hydrogen fluoride gas are as low as 0.05 ppm.

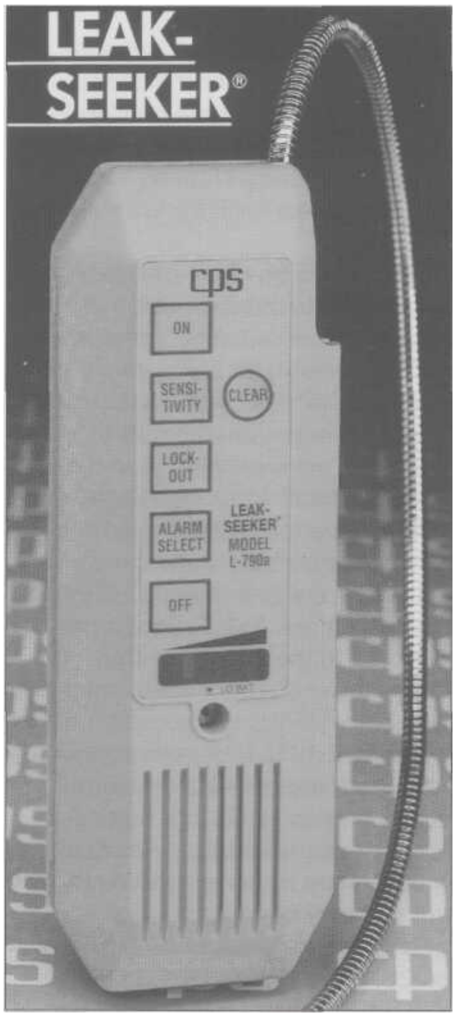
Lastly, we would emphasise that smoking, soldering or welding in a room with high concentrations of CFCs is strictly prohibited! In the event of liquid leakages always wear safety goggles, gloves and protective clothing because of the danger of freeze burns to the skin.

Draining the system

When draining the system, try wherever possible to prevent CFC gases from escaping. The gases must be pumped back to the condenser, liquid receiver or empty cylinders.
Nowadays, new systems are fitted with separate tanks with enough capacity to hold the entire refrigerant charge.
It is possible to re-use recovered R 12 and R 22, provided that the gas is "pure" and has not been mixed with other refrigerants. A mixture of R 12 and R 22, for instance, will have to be destroyed. It will not be possible for all systems currently in use to be drained and converted within the near future. For this reason "Halon banks" and "CFC banks" will have to be established to handle storage and/or destruction of these refrigerants.

Refrigeration service stations

Refrigeration service stations have also adapted their services in line with the new situation. Unitor, for example, has started marketing refrigerant charging equipment which helps prevent leakages. The same firm also offers a recovery unit for draining spent refrigerant from refrigeration systems during servicing of the plant. Another product supplied by this firm is the



Battery powered leak detector

"recovery cylinder". This can be used to collect old or contaminated refrigerant which can then be returned to the supplier. The shipowner can also ask for an "Enviro-Check" to be carried out by Unitor Shipservice. The system is then regularly subjected to preventive maintenance and completely leak tested. After leak testing a Refrigerant Leak Test Certificate is issued.

Practical alternatives for CFCs over the short term

Existing shipboard systems for air conditioning and for cooling of provisions stores mostly operate using R 12 and R 22, though there are also installations which use R 11 or R 502.

A temporary solution would be to switch from R 12 to R 22, since the OOP of R 22 is "only"

2-15% of that of CFCs and since R 22 is also naturally bio-degraded over a period of some 15 years. R 22 has about 50% more cooling capacity than R 12, it has a higher pressure level and its final compression temperatures are therefore higher than those for R 12.

If an R 12 installation is to be converted for use with R 22, all components must first be thoroughly inspected. Even supposing that the compressor and the evaporator are suitable for R 22, it will always be necessary to modify the cooling capacity and the power rating. In any event the compressor oil, expansion valves and driers will have to be modified or exchanged and an oil separator will have to be fitted. Freezing installations may suffer problems after conversion because of the higher final compression temperatures. Extra attention must therefore be devoted to the cooling of the cylinder head.

As mentioned earlier, R 134a is also an alternative to R 12 and possesses practically the same thermodynamic properties as R 12, It has no ODP, and its HGWP is significantly lower than that of R 12. Its relatively higher pressure ratio will give a lower capacity during operation at lower evaporation temperatures. R 134a has a boiling point of -26.1°C at 1 aim. (101.3 kPa), as compared to -29.8°C for R 12. This may cause problems when cargoes of frozen meat and fish are being carried. At -18°C service temperature the suction pressure will drop to below that at 1 atm. In the event of leakages this will lead to excessive air in the system and rapid failure of the installation.

One major problem in changing refrigerants to MFCs (R 134a, R 404A, R 407C} is that of the lubricating oil. New lubricants, e.g. those based on ester oils, will have to be used because existing mineral oils are not miscible with the HFC refrigerant. When retrofitting to HFC refrigerants, therefore, ester oils have to be used. It is important to remove from the system all but minute traces (< 3%) of the original mineral oil, The reason is that any residual mineral oil will be immiscible in the ester oil and in the HFC and will accumulate at the coldest point in the system, i.e. in the evaporator. This will have an adverse impact on heat absorption to the extent that the installation will no longer function efficiently. To achieve these low levels of mineral oil, it is necessary to flush the system. The most common "flushing" technique involves making repeated successive oil changes with the ester lubricant before changing the refrigerant. The mineral oil is then removed from the system by dilution.

Measures to reduce leakage losses

We are currently faced with three different situations in the reefer transport industry;

- existing installations;
- modifications to existing installations;
- new installations fitted after the ban entered into force.

Since leakage losses from existing cooling installations can amount to as much as 20-50% on an annual basis, it is clear that measures must be taken straight away to minimise these losses. The measures already taken by various countries include the following:

1) The mechanics who carry out maintenance or installation work on cooling systems must possess a specific level of skilled training.

2) Only recognised contractors are allowed to have work carried out on cooling installations by mechanics who are in their employ.

31 In designing an installation, allowance must be made for the possibility of carrying out maintenance and inspection work in such a way that no refrigerant emission occurs,

4| The system should be designed to operate using the smallest possible refrigerant charge.

5) Tin-based soldering compounds must not be used because of the risk of "tin plague".

61 Soft solder may only be used for soldering screw connections on piping joints.

7) Welding work should be carried out by properly skilled welders under the supervision and responsibility of a person who holds a CFC certificate.

8) in every cooling system it must be possible for the refrigerant charge to be collected within the system, e.g. in the condenser or the liquid receiver.

9) Refrigerants must not be vented into the outside air and are only allowed to be transferred to a tank or cylinder which is suitable for storage of the relevant refrigerant.

10) In addition to the normal inspections applicable to pressurised equipment, a "leak-tightness inspection certificate" is now required. For new installations and conversions of existing installations, the checking of the installation is followed by the issue of a Certificate of Inspection and an Installation Control Certificate.

11) Owners of a cooling system must make sure that the most important parameters are recorded at regular intervals.

12) A record must be kept of the proper functioning and location of all alarms.

13) Ships must keep a "Refrigeration Log" in which records can be kept about the inspection and use of the refrigerants.

14) Filling and draining of the refrigerant and all work on the circuit and the equipment must be recorded in the Refrigeration Log.

15) Equipment used for leakage detection (gas alarms, etc.) must be inspected at least every 6 months. This inspection must be carried out by the manufacturer or supplier of such equipment or by a specialised inspection institute. The results of the inspections should be recorded in the Refrigeration Log.

16) Leak checks should be carried out at least once a year for cooling systems which have a total charge in excess of 300 kg.
For cooling systems with a charge of more than 30 kg, leak detection should be carried out at least 4 times a year and the findings should be recorded in the Refrigeration Log.

CHAPTER 21

PROPERTIES OF THE ALTERNATIVE REFRIGERANTS

INTRODUCTION

In the previous chapter we mainly discussed the practical applications of refrigerants. In this chapter we shall deal in more detail with the physical properties of the refrigerants which are currently (still) in use as well as those of the newly developed alternative refrigerants. Our comments are restricted to those refrigerants which are used in reefer transport.

For many years chlorofiuorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) have been used successfully as refrigerants, In the previous chapter we saw that CFCs were considered to be the ideal choice due to their unique combination of properties; however, the exceptional stability of these compounds, coupled with their chlorine content, has linked them to the depletion of the earth's protective ozone layer. As is known, the Montreal Protocol originally required a complete phase-out of the production and use of CFCs by 1996. Some countries advocate an accelerated CFC phase-out by 1 January, 1995. The phase-out deadline for HCFCs such as R 22 has been set for the year 2020.

SUVA') refrigerants

As a result of the Montreal Protocol many companies, including DuPont, are developing alternative refrigerants to replace CFCs.
As an alternative for the CFC 12 (R 12) refrigerant used in the cooling units of reefer containers DuPont has developed the alternative coolant HFC 134a under the brand name SUVA Cold MP (formula CH_2FCF_3 with the chemical name of 1,1,1,2-tetrafluoroethane) and as a replacement for R 502 (and low temperature R 22) it has developed SUVA HP62 (R 404A).
These two refrigerants contain no chlorine and therefore have an OOP (ozone depletion potential) of zero.
Tests have shown that these newly developed refrigerants (HFCs) possess properties and performance characteristics similar to CFCs, yet have a greatly reduced environmental impact. They offer acceptable toxicity, in-use stability, non-flam inability and low photochemical reactivity.

Safety of the refrigerant

The crucial questions that have to be answered by a newly developed refrigerant are: is it economical, practical and - above all - is it safe when in use? Since the physical and chemical properties of HFC 134a are very similar to those of R 12, it has to comply with the same safety considerations as those for R 12.

Under the "Program for Alternative Fluorocarbon Toxicity Testing" (PAFTT), a cooperative research effort sponsored by 15 leading CFC producers, research has also been conducted into the toxicity of HFC 134a. All available results show that under normal operating conditions this refrigerant is certainly as safe as R 12. However, just as in the case of R 12, certain safety precautions must be observed, e.g. the prevention of over-exposure.

Safety limits for exposure to chemical substances

There are two principal types of exposure limitations to airborne concentrations of chemicals which are set to ensure that there is minimum risk to the health and safety of persons exposed to these substances.
The first, the IDLH (Immediately Dangerous to Life and Health) limit, is used for those substances which have a pronounced immediate toxic effect. In no circumstance should anyone

') SUVA is DuPoni's registered brand name for its environmentally enlightened family of refrigerants which represent safe effective alternatives to existing CFCs.

be exposed to atmospheric concentrations at or above the IDLH.

The second limit is the maximum atmospheric concentration level to which a person can be exposed for long periods (in practice established as the normal lifetime) without suffering ill effects. This limit is usually set as an 8 hour time-weighted average (TWA) concentration for a five day week for 40 years. The chronic exposure limit is known as the TLV (Threshold Limit Value) or AEL (Acceptable Exposure Level! in the USA. Other countries have different designations.

In practice, short-term exposures should not exceed three times the established exposure limit for more than 30 minutes on aggregate during a working day. Under no circumstances should exposures ever be allowed to exceed five times the AEL!
The table below gives a comparison of the physical properties of R 12 and R 134a.

Table 1: **Property** Comparisons

	CFC12	HFC 134a
Boiling point °C(°F)	-30°C (-21.6°F)	-26°C I-15.7°F)
Flammability	None	None
IDLH level, ppm (v/v)	50.000	50,000
Chronic Exposure Limit, ppm (v/v)	1,000 TLV	1,000 AEL
Ozone Depletion Potential	1.0	0.0
Global Warming Potential	3.0	0.28

Because of inhalation of high concentrations of refrigerant vapour, exposure levels in excess of the AEL may cause temporary depression of the central nervous system, resulting in narcosis, lethargy and anaesthetic effects. Other possible effects are: dizziness, a feeling of intoxication and loss of coordination.
Continued breathing of vapour concentrations well in excess of the AEL may produce cardiac irregularities, unconsciousness and, in the case of gross over-exposure, even death.
Clearly, anyone suffering from breathing difficulties should be taken out into the fresh air as quickly as possible. In some cases it may even be necessary to administer oxygen and, if breathing has stopped, artificial respiration must be applied.
Provided that exposures are kept at or below the AEL limits, the refrigerant poses no acute or chronichazard.

Always remember that in the event of spillage or a major leak, a large quantity of vapour will be released, Most of the vapours will remain at a lower level and will displace the oxygen there, bringing the risk of suffocation. In such cases everyone must leave the enclosed area until it has been adequately vented. Do not re-enter the affected area unless you are wearing a self-contained respirator unit and are carrying a lifeline.

Leak detectors

Halogen-selective detectors use a specialised sensor which allows the monitor to detect compounds containing fluorine, chlorine, bromine and iodine with no interference from other gases. Most of these detectors are easy to use and very durable. Due to the partial specificity of the detector, such instruments are also easy to calibrate. It is recommended that the supplier be consulted regarding the detector's sensitivity to each specific refrigerant.

Another method which has been in use for several years now to trace leaks in refrigeration systems involves the addition of fluorescent dyes. These indicator dyes, though invisible when exposed to ordinary lighting, will show up under ultraviolet (UV) light and can therefore be used to pinpoint leaks in the system. The normal method is to add these dyes to the refrigeration lubricant when the system is being serviced.

Leaks are then detected by using an UV lamp to search for any dye that has escaped from the system. Before adding dyes to the system, the manufacturer should be consulted to verify the compatibility of the relevant dye with the lubricant and the refrigerant.

Flammability and pressure

R 134a is non-flammable at ambient temperature and atmospheric pressure. Tests, however, have shown it to be combustible at pressures as low

as 5.5 psi (at 177^{C}C) when mixed with air at concentrations of more than 60% v/v. At lower temperatures, higher pressures are required to cause combustibility. Obviously, refrigerants should never be exposed to open flames or electrical heating elements,
An overfilled container or *a* pipeline whose temperature is raised will make the container "liquid full" and immediately cause a dangerous increase in hydrostatic pressure.
Even a correctly filled returnable or disposable cylinder may, if heated to above the recommended maximum temperature of 52°C, result in dangerously high pressures in excess of the cylinder design pressure.

Skin and eye contact

At room temperatures refrigerant vapours have little or no effect on the skin or eyes. However, refrigerants in liquid form cause dryness and irritation, particularly after prolonged or repeated contact. If there is a risk of splashing, always wear eye protection and a face shield. If your eyes are splashed, rinse them out with plenty of water. In liquid form at low and medium temperatures the refrigerant can freeze skin or eyes on contact, causing frostbite. If this occurs, soak the exposed area in lukewarm water. Do not use cold or hot water! In all cases of frostbite, seek medical attention as soon as possible.

Operating characteristics of HFC 134a

A decision to retrofit CFC equipment with alternative refrigerants must be based on a comparison between the cost to retrofit, the expected lifetime of the equipment and the anticipated efficiency of the system after retrofit. Careful consideration must also be given to the differences between refrigerant properties, since systems designed for CFCs may perform inefficiently or even fail completely if improperly retrofitted with an alternative refrigerant.
A comparison of the properties listed in Table 1 shows that the boiling point of R 134a is close to that of R 12. This means that R 134a will develop system operating pressures similar to those of R 12. We can also see from the table that both refrigerants are non-flammable, whilst the 1,000 ppm AEL also shows that R 134a has the same degree of safety as R 12.

In general, alternative refrigerants cannot simply be "dropped into" a system designed to use CFCs. Depending on the specifics of the machine, certain components may need to be replaced. In most cases the compressor will not have to be modified [2]). However, the lubricant will have to be changed. As can be seen from the table below, the performance characteristics of R 134a are similar to those of R 12. Chillers converted to R 134a will therefore operate about the same as they did on R 12.

Table 2: Typical Performance Ranges of HFC 134a versus CFC 12

Capacity	**+2% to-10%**
Coefficient of Performance	**+2% to -8%**
Evaporator Pressure	**0 to -3 psi**
Difference	**0 to -0.2 bar**
Condenser Pressure	**+15 to+25 psi**
Difference	**+1 to -1-1.7 bar**
Discharge Temperature	**Oto-10°F**
Difference	**0 to -5.6°C**

Note: Actual performance will depend on the specific equipment and operating conditions used.

Lubricant/refrigerant solubility

In many refrigeration and air conditioning systems, some lubricant escapes from the compressor discharge area, is entrained with the refrigerant and circulated through the system (see Chapter 6, "Marine Refrigeration Manual"!. Most compressors require a lubricant to protect internal moving parts. The compressor manufacturer usually recommends the type of lubricant and the viscosity required to ensure acceptable operation and equipment durability. Ideally, the refrigerant/lubricant pair should be completely miscible with each other, as this will allow the lubricant to flow with the liquid refrigerant and return to the compressor. However, low-chlorine refrigerants may exhibit reduced miscibihty with many lubricants. For this reason lubricants have been developed for use with MFCs. These oils are practically non-reactive

[J]) Centrifugal compressors usually have to be modified for the use of R 134a.

and have a stability similar to that of the alternative refrigerant. (Their generic name is polyolester oil).
Acceptable plastics and elastomers have been found for use with existing CFCs. However, an elastomer or plastic which is acceptable with one refrigerant may not perform well with another. Elastomers should therefore be assessed on an application by application basis.

Compatibility

R 134a and R 12 are chemically compatible with each other: they do not react with each other or form other compounds. However, when the two substances are mixed together, they form what is known as an "azeotrope". An azeotrope is a mixture of two components that acts like a single compound but has physical and thermodynamic properties which differ from those of either of the two components. One example is R 502, which is an azeotrope of HCFC 22 and CFC 115.
When R 134a and R 12 are mixed in certain concentrations, they form a high pressure (low boiling) azeotrope.
Another characteristic of an azeotrope is that it is very difficult to separate into its individual components. A mixture of R 134a and R 12 cannot therefore be separated in a recycling machine and will usually have to be disposed of by incineration.

SUVA MP39 (R 401A) and SUVA MP66 (R401B)

R 134a may require some extensive system modifications if it is to be retrofitted in an existing R 12 system. The cost of these modifications may be prohibitive for some systems. SUVA MP39 and SUVA MP66 provide a very cost effective solution for retrofitting an existing R 12 system to use an alternative refrigerant. MP39 and MP66 will be available to service the equipment for the remainder of its useful life. These alternative refrigerants are three-component mixtures of R 22, R 152a and R 124. They are near-azeotropic blends. Both refrigerants offer improved environmental benefits as compared to R 12, with significantly lower OOP and GWP.

Most R 12 systems which use reciprocating compressors can be easily and economically retrofitted to operate with MP39 and MP66. SUVA MP39 is the recommended alternative for most medium temperature R 12 systems. SUVA MP66 provides comparable capacity to R 12 in systems operating at evaporator temperatures below around -20°C, making it suitable for use in transport refrigeration equipment.

SUVA HP62 (R 404A)

SUVA HP62 has become the standard long term alternative refrigerant for low temperature applications, replacing both R 22 and R 502. It is an HFC refrigerant (composed of HFC 125, HFC 143a and HFC 134a! and therefore has a zero OOP.
SUVA HP62 does require the use of polyolester lubricant and has only a very low miscibility with hydrocarbon based oils. Retrofitting R 22 or R 502 systems will require extensive flushing to remove all but minor traces of the old oil from the system. SUVA HP62 has a very low temperature glide, i.e. it can be used without problems in very many equipment configurations.

Table 3: Property Comparisons

	R22	R502	R404A
Boiling Point °C m	-40.8 (-41.4)	-45.4 (-49.7)	-46.7 (-52.1)
Flammability	none	none	none
Exposure Limit, ppm (v/v)	1,000	1,000	1,000
Ozone Depletion Potential	0.05	0.3	0.0
Global Warming Potential (HGWP)	0.34	3.7	0.94

SUVA HP80 (R 402A)

This refrigerant is a near azeotropic blend of HCFC 22, HFC 125 and a small amount (2%) of propane and has been formulated as a retrofit refrigerant for R 502 systems. It is non-flammable and is a very good performance match for R 502. Condensing-pressuresare, however, slightly higher than for R 502. (This may require readjustment of pressure switches in some situations!. It is recommended that this refrigerant be used with either an alkyl-benzene or polyolester lubricant. In a retrofit situation (from R 502| only one oil change is needed. This can be carried out simultaneously with the refrigerant gas change, leading to a very cost-effective retrofit.

Table 4: Typical Performance Comparisons

Comparison with R 502 (-3S°C Evaporating)

	R402A	R404A
Capacity	+10%	same
Coefficient of Performance	0 to -3%	+2 to -3%
Evaporator Pressure	+3 psi	same
Condenser Pressure	+20 to +40 psi	+10to+30psi
Discharge Temperature	same	-5to-10°C

Ammonia as a refrigerant

As we have already explained, the days of R 22 are numbered and it will be replaced. But the question is: when, how and by what? Its excellent refrigerant properties have helped facilitate the transition from the use of R 12. However, as environmental groups and some countries (specifically Germany] continue to tighten up the regulations aimed at the protection of the ozone layer, R 22 will eventually be phased out of production as well.
Some countries are urging its phase-out by the year 2000 for new installations. DuPont has announced that it will stop producing R 22 for new equipment in 2005 and completely discontinue the manufacture of R 22 in 2020.

Brief history of ammonia in reefer shipping

In Chapter 1 we read that as long ago as 1860 the Frenchman Ferdinand Carre developed a cooling machine which operated using ammonia as a cooling medium. Later in that chapter we learnt that in 1877 another Frenchman, Charles Tellier, shipped a cargo of frozen beef from Argentina to France in the s.s. 'Le Frigorifique', which was also equipped with an ammonia-compression refrigerating plant.
Perhaps it was specifically because of the problems with ammonia leakages and their consequences for health that the French, despite their initial successes, left the further development of refrigerated shipping to the British.
The first "cold-air" cooling machine had in fact been designed in 1873 by the Frenchman Paul Giffard. On the basis of that same compression-expansion principle, the cold-air machine was made suitable for marine purposes by the Bell brothers and Mr Coleman in Glasgow. The first marine cold-air machine was installed on board the s.s. 'Circassis' in 1879.

The cold-air machine, however, proved to be a short-lived success. Attempts were then made to find a cooling machine which could achieve lower temperatures and, above all, one in which the temperature could be better regulated. After the turn of the century dry-air cooling was completely ousted and replaced by the new high-pressure $C0_2$ system, which dominated the marine market until the advent of CFCs in the early 1940s.
In about 1915, when banana shipping (United Fruit Company} started to grow in significance, ammonia came into more general use as a coolant in the banana trade.

In 1940 the percentage use of the main primary refrigerants in existing marine cargo installations classified by Lloyd's Register was as follows: $C0_2$ = 90%, NH_3 = 18%, P 12 = 2%.

In 1965 the ratio was as follows:
R 12 = 57%, $C0_2$ = 15%, NH_3 = 12%,
R22 = 12%.

By 1990 the percentage breakdown had changed to:
R22 = 92%, R 12 = 11%, NH_3 = 1%.

Ammonia: its advantages and disadvantages

Ammonia is a compound of nitrogen and hydrogen and is highly soluble in water. It is colourless, pungent, suffocating gas. The chemical formula for ammonia is NH_3 and its

refrigerant number is R 717. When we refer to ammonia in refrigeration contexts we mean anhydrous ammonia. "Anhydrous" means that it contains no water.
At room temperature and atmospheric pressure ammonia is about 40% lighter than air. When compressed and cooled, ammonia gas condenses into a colourless liquid. Liquid ammonia has approximately 68% of the weight of water. At atmospheric pressure liquid ammonia boils at-33.5°C and one litre of liquid would evaporate to give about 750 litres of ammonia gas.

A modern ammonia installation is designed as a refrigeration plant for indirect evaporation of R 717 refrigerant using brine (usually a solution of propylene glycol in water] as a secondary refrigerant. If a titanium or special stainless steel Plate Heat Exchanger (PHE) is used as a condenser in a modern ammonia installation, this will save considerably on the initially required refrigerant charge. On a middle-size reefer (approx. 400,000 cuft) the required refrigerant charge will in this case only amount to approx. 230 kg.

Many objections can be made against the use of NH_3, Even many of its supporters claim that its drawbacks outweigh its benefits. Obviously, in a modern installation many of these drawbacks can be eliminated, Against this, the advocates of a Freon installation will place more emphasis on the disadvantages of NH_3.
We will therefore first take a look at the disadvantages:

The disadvantages

1) An ammonia/air mixture is flammable at a concentration in the range between 16 and 26% (v/v). Explosions can occur if flammable mixtures are ignited, although ignition is more difficult than for fuel gases and requires an ignition temperature of approximately 650°C. Since ammonia is already detectible to the human sense of smell at a concentration of 10 ppm (v/v) and can be traced using special detectors at a concentration of 25 ppm (v/v), it is relatively simple to take measures to rule out ignition of an explosive mixture in the event of leakage from the refrigerant system.
Oil entrained by the ammonia vapour lowers this level considerably and, generally, 4% v/v is considered the safe limit to prevent the risk of explosion.

2) Another disadvantage is the toxicity of ammonia gas. Inhalation of the gas in a high concentration can be fatal. But the pungent smell of the gas makes sure that a very timely warning is given even at a concentration of as low as 10 ppm.
Short term exposure to concentrations of about 200 ppm has no harmful effects but does cause a feeling of discomfort and irritation to the eyes.
Exposure to concentrations in excess of 1500 ppm will damage or destroy body tissue, whilst exposure to 2500 ppm and above increases the risk of fatality. The U.S. NIOSH has set a value of 500 ppm for the IDLH of ammonia.
This is the reason why some countries have issued regulations on the maximum admissible concentration (MAC! in the working area. Germany, for instance, applies a MAC[3]] of 50 ppm (parts per million by volume) for eight working hours. The limits for permissible concentration levels are specified in the USA and the UK as TLVs (threshold limit values) which are referred to in those countries as TWA and STEL respectively.
In the USA and the UK the TWA value amounts to 25 ppm. In the United States a TWA of 25 ppm stands for the time-weighted average concentration for a normal 8-hour work day and a 40-hour work week which causes no adverse effect, even if this level is repeated week after week.

3} Liquid ammonia is hazardous in the event of skin or eye contact. If splashed on the skin, the liquid may cause both chemical and frostbite burns, particularly after prolonged or repeated contact. The severity of the injury depends more than anything on the quantity splashed. As far as the eyes are concerned, even a small quantity is enough to cause permanent damage.
Always wear protective clothing if there is

[a]) MAC = Maximum working Area Concentration for 8 working hours

a risk of exposure to liquid ammonia. Where splashing may occur, always wear eye protection and a face shield. If the eyes are splashed, rinse them out immediately with water.

4) As mentioned earlier, ammonia is highly soluble in water. At 16°C, 700 litres of the gas will dissolve in 1 litre of water. When ammonia dissolves in water, heat is created and a strong alkaline (basic) solution is formed.

5) Ammonia with trace water has practically no effect on steel but causes corrosion of copper, zinc and tin and most of their alloys. This is why copper, brass and bronze cannot be used in an NH_3 installation. Ammonia also attacks rubbers and plastics.

6) A complicated method is needed to separate the lubricant because it is not soluble in the NH_3 refrigerant.

7) The requirement that ammonia should only be used in indirect refrigeration systems adds substantially to capital cost. Besides, using an indirect system instead of direct expansion will increase the energy consumption, resulting in additional operating costs.

81 The machinery must be installed in a separate room which is equipped with fixed leak detectors and water sprinkler systems.

The advantages

The advocates of an ammonia installation will, quite rightly, point to the following advantages:

1) Though an NH_3 plant operates at higher pressures, ammonia does offer a high volumetric refrigeration capacity given a comparatively small circulation mass flow. Some of the pros and cons become immediately apparent from a study of the figures given in the Vapour Tables for Freon and ammonia.
One significant benefit is the high latent heat of vaporisation of NH_3. As a result, the mass circulation rate of NH_3 is about 15% lower than that of R 22.
Since NH_3 has the lowest volume rate flow per tonne of refrigerant, the compressor displacement is 7-9% smaller as compared to the use of R 22 as a refrigerant.

2) The Coefficient of Performance (COP) of a modern ammonia installation is measurably higher than that of an R 22 installation. In the cooling range from 15°C to -25°C the COP of an NH3 installation is, on average, 3% higher. At 0°C the COP is approx. 4.5% higher

3) The specific heat of ammonia, in both vapour and liquid form, is about 4 times that of R 22. Because of the many advantageous properties of NH3 as compared to R 22, the surface area of the brine evaporator can be about 2.5 times smaller and that of the condenser about 3 times smaller than in an R 22 installation. Obviously, this also means that piping and fittings will have smaller dimensions as well.

4) NH_3 has a zero OOP and is very favourable as regards its direct GWP It has excellent thermodynamic properties. It is available throughout the world and at a low price. It is very simple to manufacture. We should remark here, however, that some countries apply certain restrictions to ammonia, which might cause problems for a ship which trades world-wide.

At this juncture we would like to make it clear that, although ammonia has practically no impact on global warming, it is classified as an environmental hazard. Ammonia and ammonium compounds may have a direct influence on the health and diversity of vegetation.
This is the reason why the European Union Dangerous Substances Directive (76/464/EEC) classifies ammonia as a list 11 dangerous substance which can have a deleterious effect on the environment and whose discharge to both fresh and salt water should be restricted.

Above a certain concentration in water, ammonia causes faster plankton growth and fish mortality. Concentrations of as low as 0.3 mg/litre have been known to be toxic to fish.

It will be clear that the possible adverse effects of ammonia discharged into water will depend on the quantity involved and the speed at which it is dispersed. In the open sea, however, even large quantities of ammonia will disperse so quickly that this will have hardly any impact on the aqueous environment.

5) Those who advocate the use of an ammonia installation feel that its specific advantage is that oil does not mix with NH_3. Since oil readily separates and settles on the bottom of flooded evaporators and LP/HP receivers, it is a relatively simple process to dram and recuperate the oil.

Refrigerant choice considerations

The decisive question is whether the ultimate cost of an ammonia refrigerant plant will be higher than that of an R 22 plant (or one using an
R 22 alternative such as R 407C). For the time 5)
being at least, ammonia refrigerant is 3-5 times cheaper than R 22 and considerably cheaper than R 407C. Moreover, as we have already seen, a modern ammonia plant is more compact and
more efficient than an R 22 plant. Recent 6)
development work on R 407C shows that energy efficiencies equivalent to ammonia can be achieved using special component designs.

7)

The decision between ammonia and R 407C for new ships will depend on their relative installation costs (their energy efficiencies will be similar!. These costs will include the appropriate containment/alarm systems. As this area is undergoing rapid development, we recommend that refrigeration equipment suppliers be consulted at the design stage to ensure that the most cost-effective solution is adopted.

A comparison of the properties of ammonia, R 22 and R 407C is given below.

Table 5: Property Comparisons

	R717	R22	R407C
Boiling point (°Cj	-33.35	-40.8	-43,6
Freezing point (°C)	-77.9	-160.0	n/a
Critical temperature (°C)	132,4	96.0	86.7
Critical pressure (bar)	112.97	49.8	46.0
Pressure at 30°C	11.67	11.92	13,5
Enthalpy vapour (U/kg)	1,684.84	405.4	413.5
Enthalpy liquid (kJ/kg)	423.76	200.0	200.0
Specific heat liquid (10^3J/kgK)	4.6	1.16	1.33
Specific heat vapour (10^3 J/kgK)	2.68	0.72	0.87
Density liquid (kg/dm^a)	0.68	1,41	1.38
Density vapour (kg/m^a)	0.89	4.69	3.21
Thermal conductivity liquid (x10^3W/mk>	540.0	100.0	100.0
Thermal conductivity vapour(x10^3W/mk)	22.3	9.4	11.4
Compression ratio at30°/-30°C	9.76	7,29	8.03

Guidance Notes for Ammonia

Lloyd's Register of Shipping has published Guidance Notes for ammonia as a supplement to its rules for ships.
The rules ("Refrigerated Cargo Installations, Part 6, Chapter 3") mainly relate to safety, especially
to the prevention of leakages and the 8)
containment and safe disposal of ammonia in the event of a leak.

Of the main precautionary measures that are
recommended, the following are particularly 9]
important:

1) The ammonia charge is to be kept to a minimum by the use of compact heat transfer equipment and a secondary refrigerant such as brine.

2) An automatic air purger should be fitted and the plant should be of absolutely air-tight design.

3) 10% of all welds must be x-rayed.

4) The complete plant should be located in a separate compartment reserved solely for its use. This compartment must have two self-closing doors opening outwards to access ways leading to the open deck.

5) Outside each access way an eye wash and water spray facility are to be provided for the immediate use of persons exposed to ammonia.

6} Sumps or other forms of containment devices must be present on the floor of the compartment around each refrigerating unit.

7) The compartment must also be fitted with an effective ventilation system consisting of a supply and an exhaust fan, booster fan and a gas absorption unit. The function of the supply and exhaust fans is to remove the heat generated by the equipment installed in the refrigeration machinery compartment and also to maintain the ammonia concentration at acceptable limits under normal operating conditions.
The function of the booster fan (a part of the ammonia scrubber) is to remove the ammonia vapour quickly in the event of a major leakage. The scrubber itself serves to remove ammonia vapour from the air exhaust before it is discharged to the atmosphere.

8) The ventilation system is to be provided with an alarm system which will activate audible and visual alarm signals if there is any abnormal stoppage of the fans.

9) A water dump tank must be installed below the level of the refrigeration machinery compartment. This tank serves as a storage space for the ammonia-contaminated seawater when the ship is in harbour or in other confined waters.

10) Ammonia vapour detectors must be installed in the refrigeration machinery compartment as well as in the scrubber outlet duct, the ammonia store room and the discharge pipes from pressure relief valves. If the detected concentration of ammonia exceeds 500 ppm by volume, the refrigeration plant must automatically stop and the booster fans and audible and visual alarms must be activated.

Hydrocarbons

In many refrigeration applications the use of hydrocarbon refrigerant fluids is currently being evaluated due to their attractive environmental properties.
These fluids can be blended to give appropriate pressure/temperature properties to match those of R 12, R 502, etc. They perform acceptably as refrigerant gases in many situations. Their flammabihty however is a problem. We are not aware of any current trials of these products in marine applications.

To conclude this chapter on the alternative refrigerants:

the MFCs (refrigerants consisting of hydrogen, fluorine and carbon, such as R 134a, R 404A and R 407C) and ammonia are currently still the best solutions that will help to achieve a chlorine-free environment. We can foresee that some newly built vessels will be forced by necessity to use ammonia as a refrigerant, but we do not believe that this is the ultimate solution for the future.

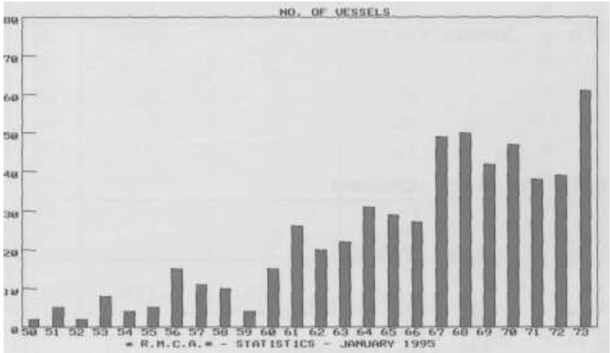
CHAPTER 22

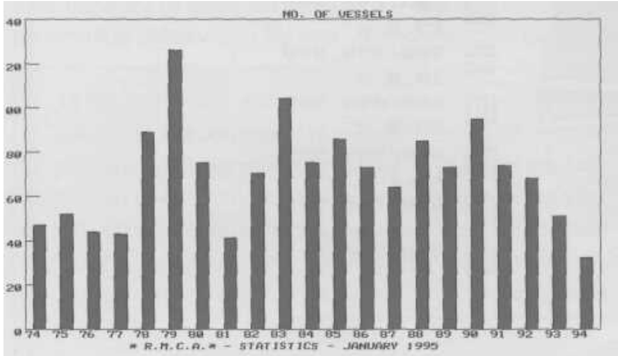
THE WORLD REEFER FLEET

PROFILE OF THE WORLD REEFER FLEET

This chapter contains an analysis of the world reefer fleet as at the first of January 1995. This analysis, however, does not include the specialised reefer container vessels such as those used, for instance, by the "Great White Fleet" (Chiquita), Dole and the French CGM Line. In other words, we are looking at full perishable cargo carriers of conventional design, sophisticated as they may be.

At the beginning of 1995 the world reefer fleet totalled 2,042 vessels of all sizes and ages with a total volume of 403.7 million cubic feet, and graphically represented here below by number of vessels per annum.





Profile of the World Reefer Fleet

As a matter of interest, the oldest vessel still trading was built in 1921 ...(Perhaps this is where the expression "an iron lady" originates from) In this statistical report we have left out this kind of extreme example. We commence from the year 1960, starting with the size of 10,000 cubic feet upwards. This selection gives a total of 1,754 vessels with a combined carrying capacity of 398.15 million cubic feet.

Subdivision by category, number and capacity.

As such, the world reefer fleet can be subdivided into two categories.

A) Vessels that are capable of maintaining certain temperatures both above and below zero °C. (Reefers)

B) Vessels that are capable of maintaining temperatures below zero °C only. (Freezers)

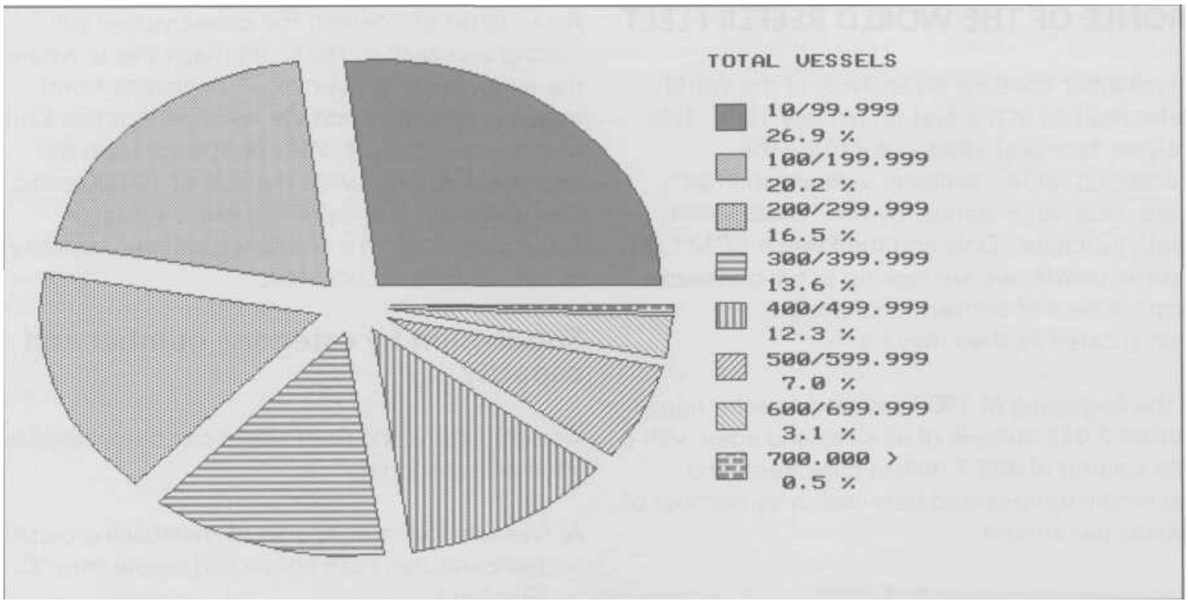
	Number	%	Million Cbft	%
Category A)	1,270	72.4	319.7	80.3
Category B)	484	27.6	78.4	19.7
Total	1,754	100	398.1	100

The majority of the freezers are under the control of the CIS countries. (The former U.S.S.R.). Historically these vessels are employed in own trades and generally ignored in any market evaluation as not being active on international markets. During the last few years, however, these vessels are being seen more and more in the open market, obviously driven by economic necessity.

Considering the fact that the seaborne transportation of frozen products presently represents approximately 30 per cent of the total trade-demand, the above figures show that the CIS freezers are a force to be reckoned with.

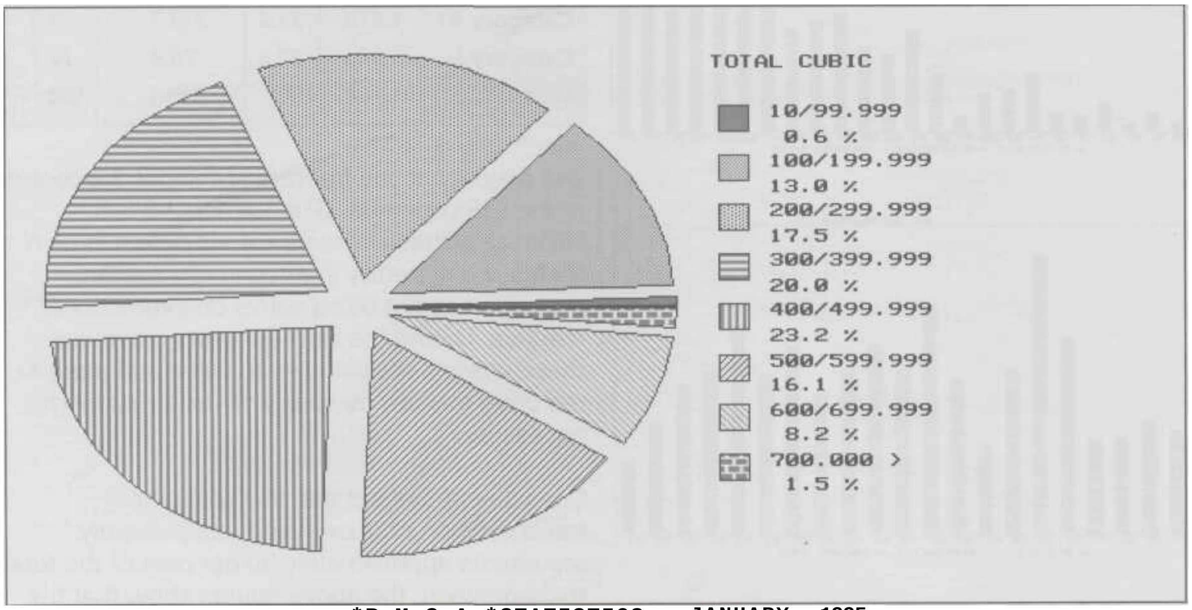
Let us turn to a statistical/graphical presentation of the reefers (Category A), subdivided in capacity groups of 100.000 cubic feet bale.

REEFER FLEET- PERCENTAGE OF SIZE GROUPS



R.M.C.A. STATISTICS - JANUARY 1995

REEFER FLEET- PERCENTAGE OF SIZE GROUPS



*R.M.C.A.*STATISTICS JANUARY 1995

WORLD REEFER FLEET - NUMBER OF VESSELS BY SIZE/YEAR BUILT

YR	10/99,999	100/199,999	200/299,999	300/399,999	400/499,999	500/599,999	600/699,999	700,000 >	TOTAL
60	6			1					7
61	10	2	1						13
62	10		1						11
63	10		1						11
64	9	1	1						11
65	10	1							11
66	9		1						10
67	13	6	1			2			22
68	12	6	3	4	2	2			29
69	14	5	1	6					21
70	6	8	1	2	6	3			26
71	9	7		3	5	4			28
72	5	9		5	3	2	4		28
73	14	11	7	10	4	2	3		51
74	16	1	6	3	5	1	1		33
75	5		11	4	6	1			27
76	6	2	4	2	5				19
77	6	5	3	3	3				20
78	14	17	10	9	4	3			57
79	23	30	7	11	12	4	5		92
80	16	23	4	6	2	5	2		58
81	10	5	1	2	4	4			26
82	14	26	3	6	4				53
83	19	14	17	17	14		1		82
84	12	7	8	6	18	3	4		58
85	11	14	10	2	5	5	3		50
86	4	8	19	8	9				48
87	10	8	5	6	2		1		32
88	4	12	10	7	6		1	2	42
89	8	9	14	5	8	3			47
90	8	6	20	10	7	10	1	2	64
91	6	6	21	6	1	5	2	2	49
92	7	2	8	9	7	14	4		51
93	1	1	6	12	11	11	6		48
94	4	4	5	8	3	5	1		30
	341	256	210	173	156	89	39	6	raiuiMMiittaagia

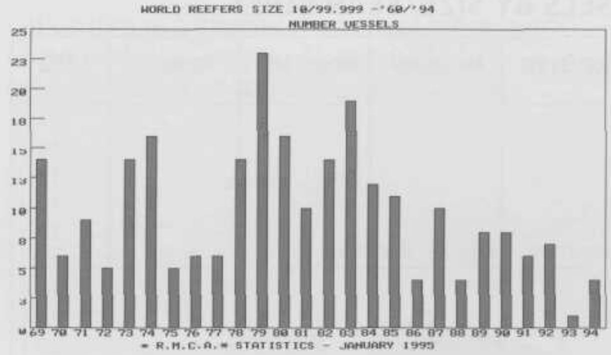
STATISTICS JANUARY 1995 - ROTTERDAM MARINE CHARTERING AGENTS B.V.

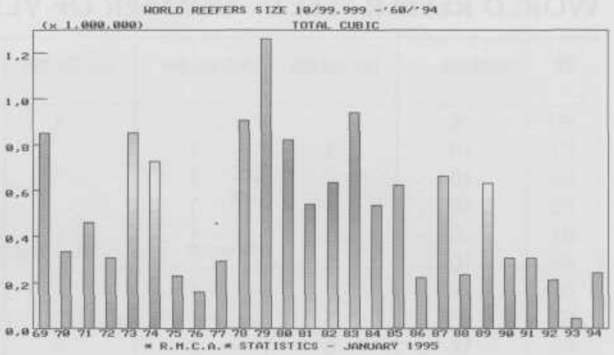
The foregoing statistics show that at the start of 1995 the world reefer fleet consisted of 1,270 reefers with a total capacity of approximately 320 million cubic feet. From this we can compile now the following rough percentage subdivision by size category and by cargo capacity:

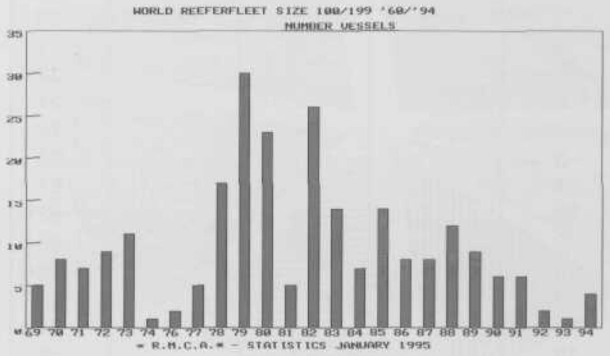
1) 10,000to 1 99,000 cbft	597 reefers	47.1 %	of the fleet
2) 200,000 to 299,000 cbft	210 reefers	16.5%	of the fleet
3) 300,000 to 399,000 cbft	173 reefers	13.6%	of the fleet
3) 400,000 to 499,000 cbft	156 reefers	12.3%	of the fleet
4} 500,000 to 599,000 cbft	89 reefers	7.0%	of the fleet
5} 600,000 to 699,000 Cbft	39 reefers	3.1%	of the fleet
6) 700,000 cbft and over	6 reefers	0.5%	of the fleet
	1270 reefers	100%	

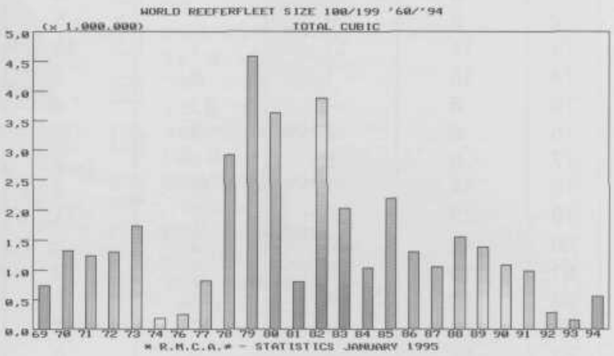
1) 10,000 to 199,000 cbft	43.2 rnln cbft	135%	of total cbft
2) 200,000 to 299,000 cbft	560 rnln cbft	175%	of total cbft
3) 300,000 to 399,000 cbft	640 rnln cbft	200%	of total cbft
4) 400,000 to 499,000 cbft	74.2 mln cbft	23.2%	of total cbft
5) 500,000 to 599,000 cbft	51.5 mln cbft	16 1%	of total cbft
6) 600,000 to 699,000 cbft	26.2 mln cbft	82%	of total cbft
7) 700,000 cbft and over	4.9 mln cbft	1.5%	of total cbft
	320 rnln cbft	100%	

A further representation of the above table in the form of a bar graph is given on the next pages together with a graph showing the annual cubic involved for each of the size groups.


WORLD REEFERS SIZE 10/99.999 -'60/'94
NUMBER VESSELS
* R.M.C.A.* STATISTICS - JANUARY 1995


WORLD REEFERS SIZE 10/99.999 -'60/'94
(x 1.000.000)
TOTAL CUBIC
* R.M.C.A.* STATISTICS - JANUARY 1995


WORLD REEFERFLEET SIZE 100/199 '60/'94
NUMBER VESSELS
* R.M.C.A.* - STATISTICS JANUARY 1995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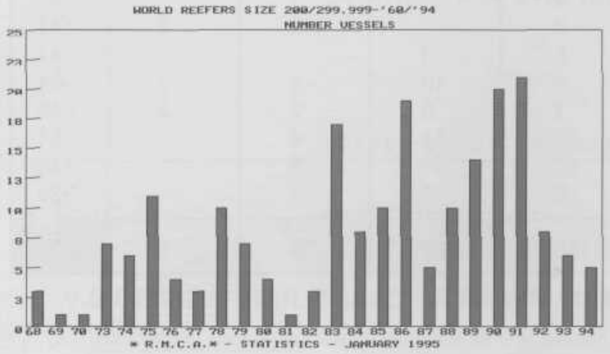
TOTAL CUBIC
* R.M.C.A.* - STATISTICS JANUARY 1995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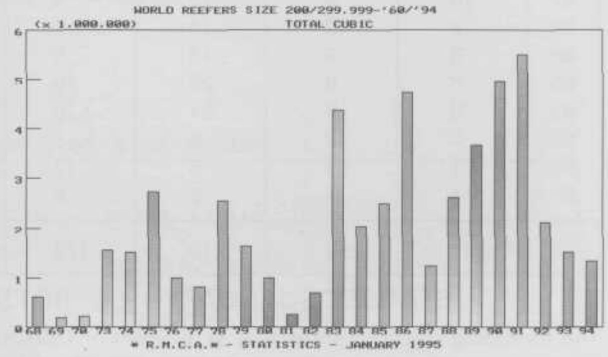
WORLD REEFERS SIZE 200/299.999-'60/'94
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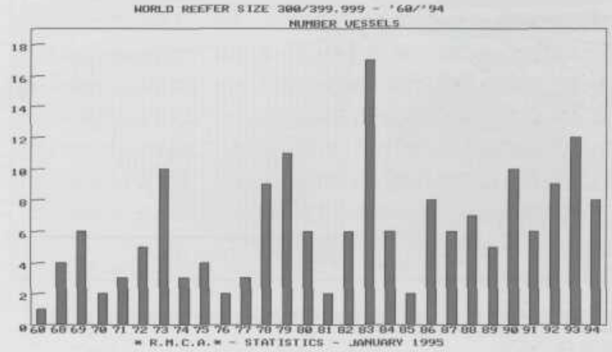
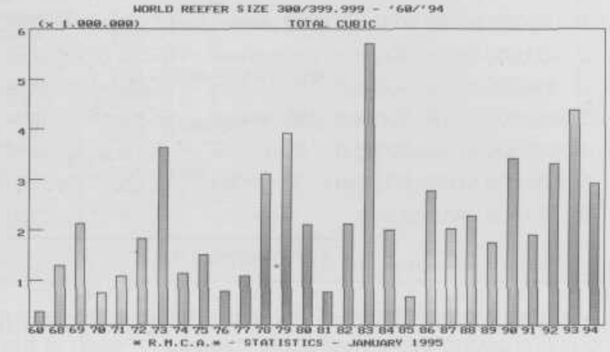
TOTAL CUBIC
* R.M.C.A.* - STATISTICS - JANUARY 1995


WORLD REEFER SIZE 300/399.999 - '60/'94
NUMBER VESSELS
* R.M.C.A.* - STATISTICS - JANUARY 1995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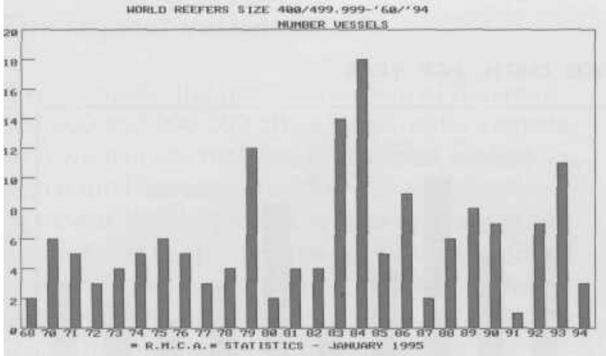
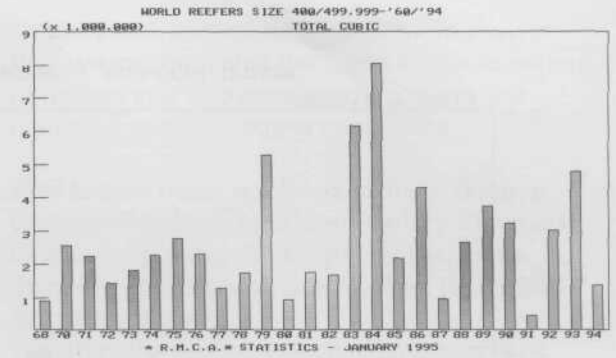
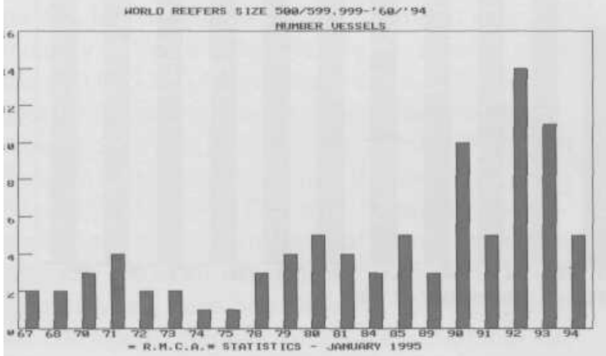
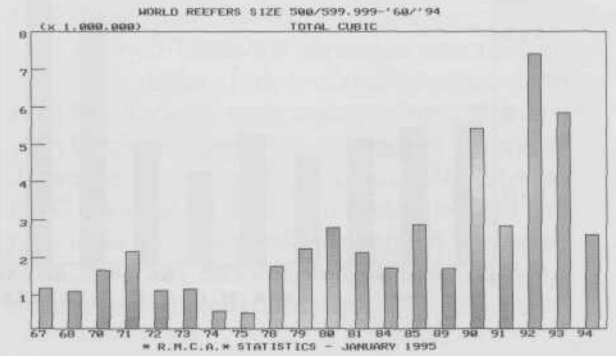
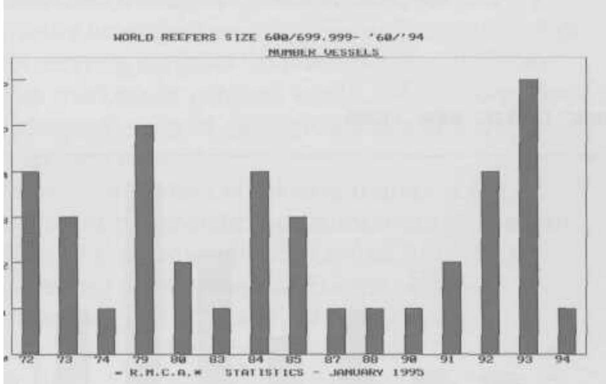
TOTAL CUBIC
* R.M.C.A.* - STATISTICS - JANUARY 1995

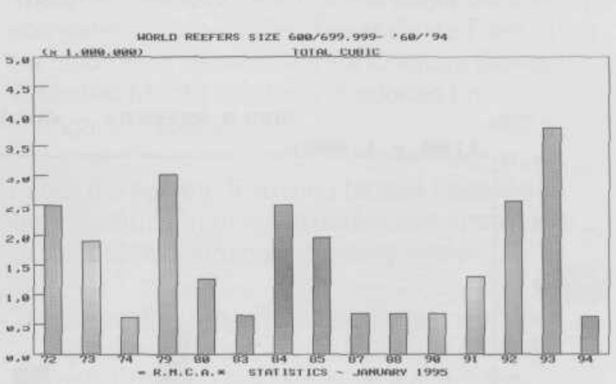


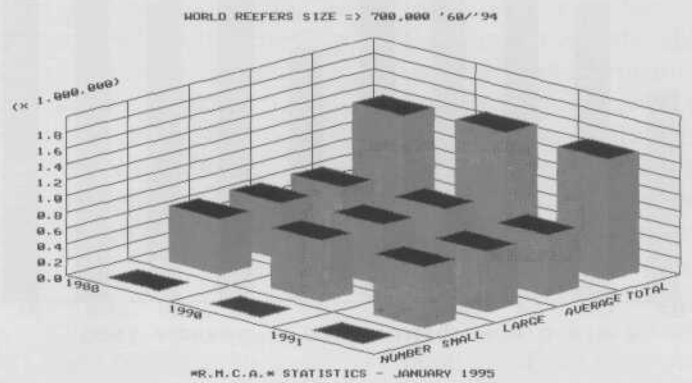






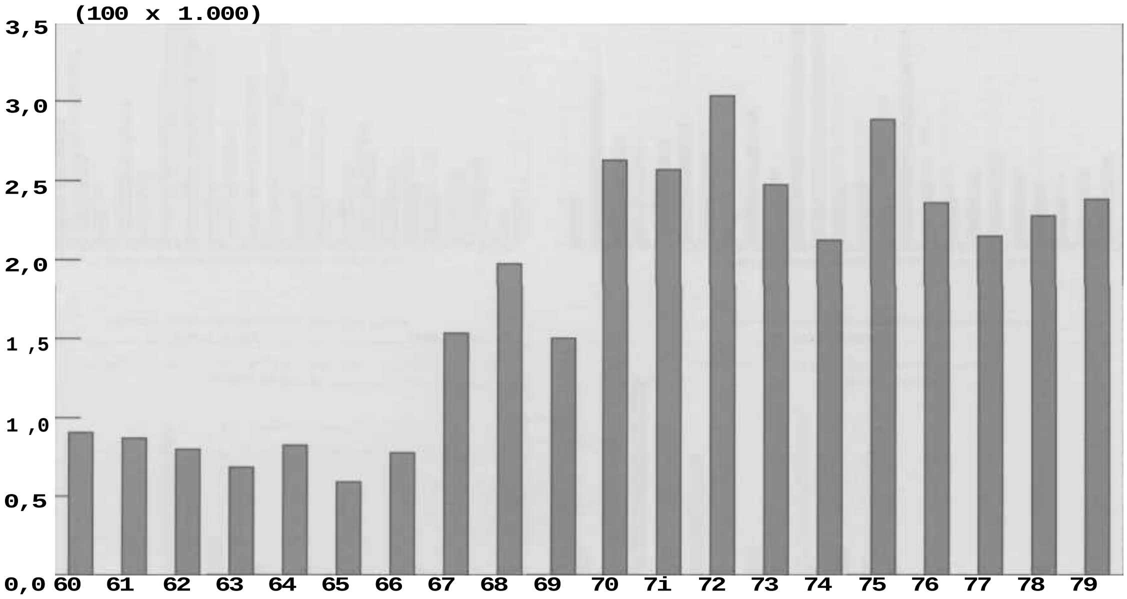






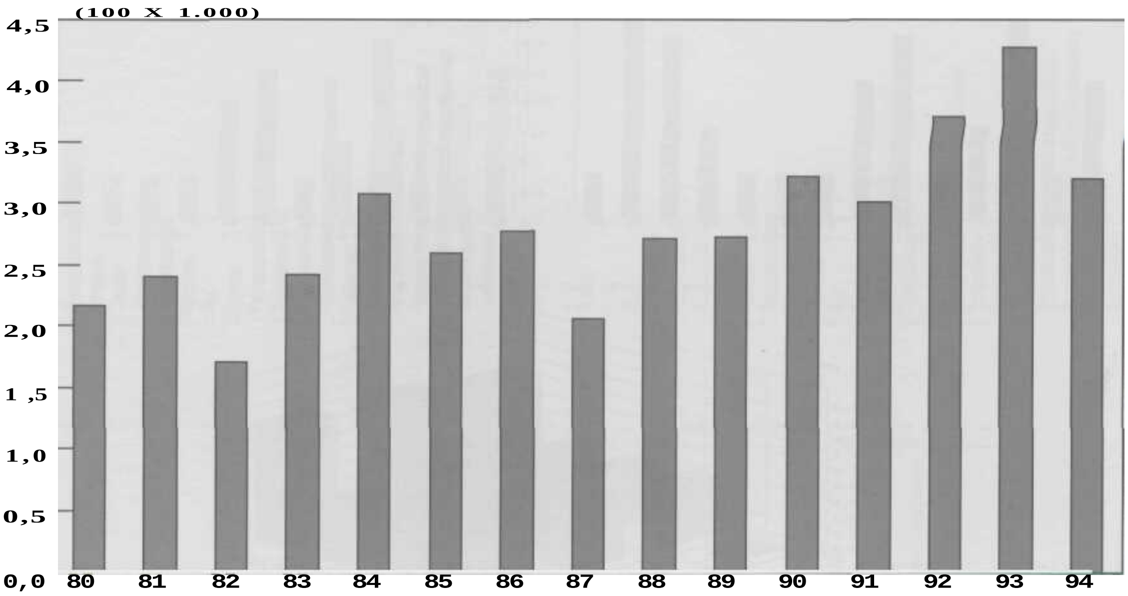
One will have noted that the largest reefers of 700,000 cubic feet and over, as shown in the above 3-D graph, were introduced in 1988 and onwards. The last ones were commissioned during 1991. Although there were discussions at that time to reach a capacity of one million cubic feet, the columns in the above graph (smallest, largest and average size) show that to the present day they are all just over the 700,000 cubic feet capacity.

WORLD REEFERS - AVERAGE CUBIC PER YEAR



* R.M.C.A.* STATISTICS - JANUARY 1995

WORLD REEFERS - AVERAGE CUBIC PER YEAR



* R.M.C.A.* STATISTICS - JANUARY 1995

The smaller vessels

If we consider the group of reefers of between 100,000 and 300,000 eft as small reefer vessels, then we can say that these 470 small reefers, with a total capacity of approx. 95 million eft, represent about 30% of the total capacity of the world reefer fleet. Of these vessels, only 1/5 are pallet-friendly. 'Pallet-friendly' means that the deck height of all holds is at least 2.2 metres. This is the minimum height required for the efficient stowage and handling of standard-sized pallets. We must also bear in mind that the majority of these pallet-friendly vessels fall within the 250,000-300,000 eft size range. In recent years, however, some smaller, pallet-friendly reefers have also been built, e.g. the 265,000 eft Penguin class (Lauritzen) and the 283,000 eft Blue Sky class (Cool Carriers). In general terms we can say that the majority of the ships in this category are older vessels of the break-bulk type or, otherwise, have been specially constructed for the carriage of cargoes which are unsuitable for palletised transport, These smaller reefers are mostly employed on short sea shipping routes or for carrying cargoes from the traditional break-bulk markets or cargoes which are not normally palletised, such as dairy products and frozen meat and fish.
Another important break-bulk market is the transport of bananas. At the moment only about 10% of the bananas from Central America are palletised for transport to Europe. Although this trade, too, will ultimately change over to palletisation and/or containerisation, the smaller break-bulk vessels will provisionally continue to find work in this sector. As we remarked earlier, Japan currently imports approx. 620,000 tonnes of bananas a year from the Philippines. In most cases these bananas are loaded in shallow loading ports where work is still done using conventional loading methods. No wonder, therefore, that many small break-bulk vessels can also find employment in this sector.

The new-buildings

Especially in recent years there has been an upward trend in the cargo capacity of the newly built reefers.
The question that therefore arises is: who specifically ordered these bigger-capacity ships in recent years, and for what reason? To answer this, we can best split the users and/or operators of reefers into two principal groups, viz. the operators and the banana companies.

Well-known major operators include: Cool Carriers (Sweden); Lauritzen Reefers (Denmark); Lavinia Corporation (managed by Laskaridis Shipping Co,, Greece); Star Reefers (U.K.); and Seatrade (Holland).
Together, the reefers operated by these pool managers represent approx. 85 million cubic feet of reefer space.
Until the mid-1980s the Japanese operators and owners of reefers mainly concentrated on their own fish trade or, alternatively, placed their ships with European operators. Nowadays the major Japanese operators (incl. Kyokuyo, Nissui and NYK) have set up their own trading pattern and now offer their services direct to the shippers who previously had their cargo transported mainly by European operators.

The other group consists of the major banana companies, such as the "Great White Fleet" (the transportation department for Chiquita Brands), Dole, Del Monte and the Ecuadorian Fruit Company "Noboa".

In our opinion the following factors have led to the construction of new reefers and specifically to the building of bigger-capacity reefers:

II Generally speaking, a need has arisen for highly versatile reefers which are not only pallet-friendly but also have a high capacity for carrying containers on deck. Another requirement was the ability to unload in all weathers, which meant that the ships had to be equipped with an all weather loader and discharger. In addition to the more general requirements for lower operational costs, these ships must also be designed in such a way that they can operate with low crew numbers. A further important factor as regards new-buildings is that fact that, in recent years in particular, great progress has been booked in the construction of fuel economic engines.
Especially the bigger reefers can be deployed particularly well on the long-haul routes, e.g. from South America and Australia to Europe.

View of weather deck and cranes (Chiquita Deutschland class)

2) The major banana companies, such as Del Monte and Chiquita Brands, wanted to exercise a greater degree of control over the shipping operations and the distribution chain in the banana trade. Today, the fruit companies own only about 5% of the world reefer fleet and it is possible that they would like to expand this share to around 15%.

View of cargo hold (Chiquita Deutschland class)

The big volume of bananas that has to be shipped all the year round therefore warrants the construction of bigger and more economical ships for the fruit trade. One example is formed by the 6 reefers in the "Chiquita Deutschland" class. These vessels of 640,000 eft can carry 100 FEU reefer containers on deck. Their service speed is 22 knots.

MS Chiquita Belgie

Another example is provided by the Geest Line (U.K.). This line now also operates on the Southern European trades (Italy, France and Spain) and in 1993 it had the 640,000-cft "Geest St. Lucia" and "Geest Dominica" specifically built to serve these markets. These ships can carry around 108 loaded 40 ft containers in two tiers on deck. The ships have a top speed of 20.8 and 19.8 knots for banana and banana/container conditions respectively. Just like the ships recently delivered to Chiquita and the Ecuadorian banana exporting group, the vessels feature a state-of-the-art, integrated shipboard monitoring and control system. We will describe this system in greater detail later when we discuss the "Albemarle Island" class of reefers.

3) If independent operators do not have sufficiently efficient tonnage at their disposal at the moment, then the developments outlined above may in the long term form a threat to their business. It is therefore logical that the pool operators have not lagged behind in the area of these new developments and have also boosted their flexibility.

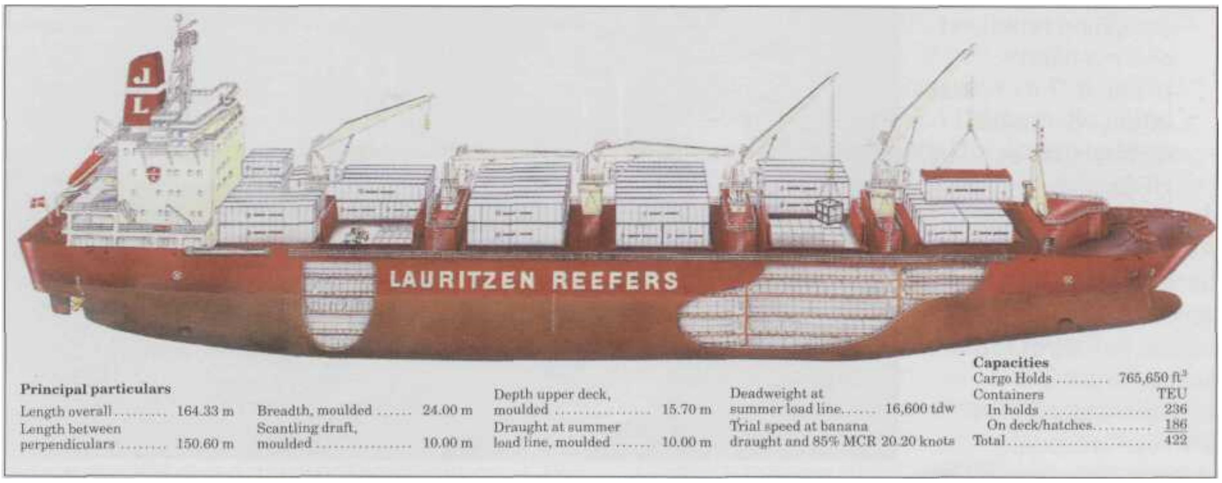
One good example of this is Lauritzen Reefers (LR) which had four of the most advanced vessels built in the "Ditlev Lauritzen" class in 1990/91. These automated reefers of 765,000 eft (16,950 dwt) have a capacity of 422 TEU or 196 FEU, of which 236 TEU can be carried on deck. Each of the vessels incorporates an Integrated Ship Control System (ISCS), which allows just

Control centre in wheel house (MS Ditlev Lauritzen)

one man to supervise the vessel's navigation and to control all machinery and cargo systems. As a result, these four ships are approved to operate with a crew of only six persons!

Seatrade has also boosted the flexibility of its reefer tonnage by adding the Japanese-built m.s. "Cold Stream" (456,000 eft) to its fleet in 1994.

Between 1989 and 1991 Cool Carriers also enlarged their fleet, with a further 4 ships (each of 527,000 eft) in the Ivory class and 4 ships (each of 589,000 eft) in the Hansa class.
The special feature of these vessels is that they are all pre-arranged for full scale controlled atmosphere treatment of the cargo in all holds. In 1991/1992 Cool Carriers had 4 ships built in the Crystal class (365,000 eft). These ships are aimed primarily at pallet-dominated trades. All four



MS *Ditlev Lauritzen*

feature a specially adapted combination of side-mounted cranes, fitted for swinging-cage operation, with side-folding mini-hatches. The Crystal class will be able to accommodate 72 TEU of containers, including 29 40-ft units. One specific design aspect is formed by the inclusion of cargo hatches which double as weather protection systems. All four of these vessels are likewise pre-arranged for CA treatment of the cargo in all holds.

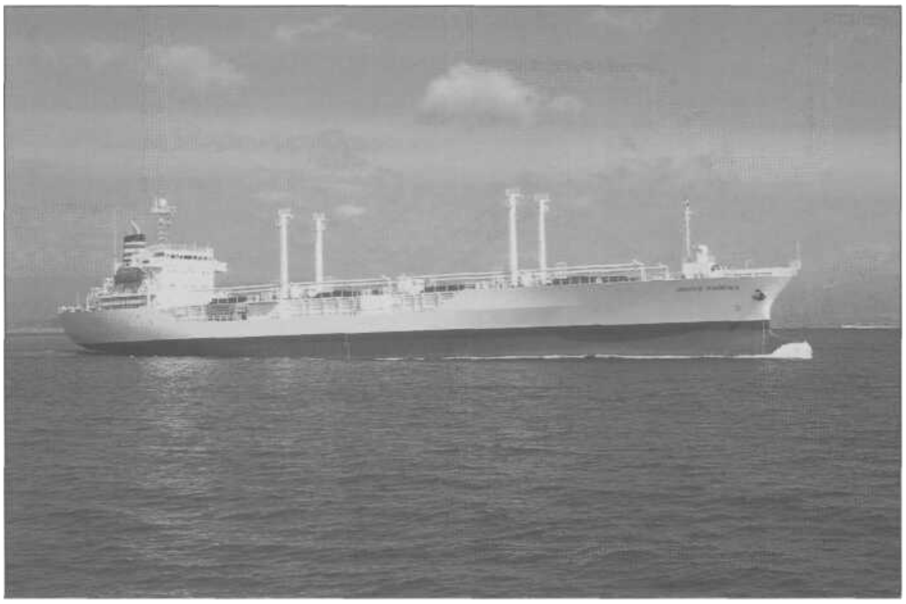
In 1992 Star Reefers had two ships built whose design is virtually the same as that of the Ivory class ships of Cool Carriers. These reefer ships, with a capacity of 520,000 eft, will be able to carry up to 4,800 standard ISO pallets (1.2 m by 1 m). Up to 162 TEU of containers can be accommodated in the holds and on the hatch covers. The operating speed of these ships amounts to 20.5 knots.

Shipbuilding in the future

Obviously, we will not make an attempt here to predict the future of shipbuilding. We can, however, list some factors which may play an important role when a building order is given. These factors include:

a) Political and economic developments world-wide.
b) The new-building prices (in 1994 approx. $55 to $75 per cubic foot).
c) The level of scrapping rates and second-hand prices.d)The impact of environmental factors such as MFCs.

At present the annual banana volume accounts for about 9.5 million tonnes of reefer space, which is approximately 38% of the total shipping volume. The demand for other commodities, such as kiwis, apples and grapes, has also increased in recent years. An important question here is the extent to which the cargo volume of bananas and other fruit will still be able to grow further in future. We would point here to the possibility that EU regulations may reduce the imports of "dollar bananas". Despite these measures and the lower demand for refrigerated produce due to the present recession, it is still expected that in the longer run the world trade in perishable cargoes will increase.
Another important aspect is whether the vessel is still modern enough to be operated profitably. .At the moment only 45% of the reefer fleet is younger than 10 years. More than 30% of the reefer fleet under discussion here is older than 15 years. If we assume that a reefer has a useful lifetime of 20 to at most 25 years, then it will be clear that in the years ahead the reefer tonnage constructed in and around 1975 will be due for replacement. A further role is played by the fact that non-pallet reefers will find it increasingly difficult to obtain work. In addition, the conventional break-bulk types have a poor fuel efficiency and their insurance and P&I premiums are considerably higher, which means that these ships will also have to be replaced by more efficient tonnage in the near future. The growing demand for palletised vessels will gradually make non-palletised vessels obsolete, and so there will



MS *Dover Phoenix*

be more scrappings of older units in the years ahead. Nevertheless, if the scrap prices remain low, owners will have no real incentive to withdraw these older vessels from commercial operation.

In the case of the bigger reefers which were built in about 1980 but are not pallet-friendly, it is sometimes possible to raise the height of the compartments to 2.20 metres. Such a rebuilding operation will perhaps pay its way, provided that it can be done simply by replacing the gratings by gratings of a lower height or by using a different type of insulating material below the decks. The situation looks different if the vessel's decks or girders would have to be changed to enable this conversion. It is then doubtful whether this expensive rebuilding job will ultimately prove profitable and whether the ship will also be able to compete in the longer run with the modern, efficient reefers.
Apart from the general economic motive for replacing an old ship, a major role is also played by the tightening of the classification procedures.

At present a category still exists for older "pallet capable" reefers, i.e. vessels which, though they have a sufficient deck height, have a very poor square metre to cubic ratio. Clearly, several years from now it will no longer be possible to operate these ships economically and they, too, will therefore disappear from the market.

As we remarked earlier, some of the break-bulk ships will none the less continue to find employment, e.g. in the frozen fish and meat • trade and certain banana trades. Besides, there are still many ports in which efficient handling of cargoes is of comparatively less importance. This does not alter the fact, however, that increasingly more ports will be able to handle modern 'pallet-friendly' and 'container-friendly' ships in future. This also applies to the ports in the developing regions, e.g. in West Africa.

Reefers of the future

The statistics show that in the period between 1979 and 1993 the rate of new-buildings averaged 5.5% p.a., whilst the average rate of depletion (through scrappings/losses) was 2.3% during the same period. This results in an average fleet growth of 3.2% p.a. In 1994 more reefer space was taken off the market than was added to the fleet in the form of newly built tonnage. In view of these figures and what was mentioned above about the possible and desired scrapping of old reefers, it is reasonable to assume that an average of 4% of the fleet will have to be replaced on an annual basis so as to maintain the size of the fleet.

In the near future we can expect the market itself to become totally unitised, with products being shipped by more flexible, cargo friendly types of vessels. 'Unitised' means that the shipments will be fully containerised or palletised. In this context the term 'flexible ship' is used to describe a ship which can carry boxed palletised cargo below deck, can also carry containers on deck and has an all weather loader and discharger so that the ship can be loaded and unloaded under all weather conditions.

It seems likely that, when they replace their older vessels, the independent owners will focus on Ships of the size between 350,000 and 500,000 eft, with clear 'tweendeck heights of at least 2.20 m to cater for the pallets.
The major fruit companies in particular will focus more on non-traditionally designed ships in excess of 500,000 eft with high speed, good fuel economy, and with pallet-friendly and container-friendly characteristics. The future changes and trends — and specifically those in the construction of the bigger reefers — can be summarised as follows:

A) The expectation is that in the years ahead increasing numbers of new vessels will be built with an ammonia plant. In this respect the Danyard-built ships ("Albemarle Island" class) will be the model for others to follow.

B) An increasing number of reefers will be equipped with controlled atmosphere systems. We have already discussed such systems in detail in Chapter 11.

C) Ships which regularly sail to ports with modern quayside handling facilities will be fitted with side doors as well as the more and more popular pallet swingers for the cargo handling of pallets.

Both the side doors and the pallet swingers make it possible to handle pallets with a speed of about 150 pallets per hour per door using much smaller openings than the normal weather deck hatches on traditional reefers. The latest development in this field is the pallet swinger lift-on/lift-off concept.

Competitive position

Of the approx. 30 million tonnes refrigerated cargoes which are transported each year, about 9 million are shipped in reefer containers. Transport of meat products in containers amounts to more than 4 million tonnes, but a substantial proportion of containerised transport is also represented by bananas, chiefly from Central America to the USA (Chiquita and Dole) and from the Caribbean to France (CGM).
The question is whether containerisation will increase further in future. In view of the types of cargo, any increase will probably remain limited only to several liner companies and then principally on the short haul routes. Containerised operations are in principle too capital intensive for the transport of seasonal produce.

In certain trades we are nowadays seeing signs of a shift from container to conventional reefer modes. Container shipping lines have lost part of the meat trade from New Zealand to the U.S. to sophisticated conventional reefers (e.g. those of Lauritzen Reefers) which now carry this cargo in palletised form. In addition, there is considerable competition between conventional and container operators in the Australia - US trades (e.g. Cool Carriers).
As we can see from the above, the unitised concept allows the modern reefer to compete head-to-head with containerised cargo modes.

Today, the traditional West European pool operators are faced by keen competition from the fleets of other countries. Their market share is being threatened not only by the major fruit companies but, more especially, also by reefer tonnage from Japan, Korea and, above all, by vessels from Russia and the former Eastern bloc countries. These fleets not only reveal different operating patterns than previously but are also offering these services at highly competitive prices.

Containerisation

In Chapter 9 we already explained that we can subdivide reefer containers into two groups, viz. Porthole (or blown-air system) containers and Integrated containers. The Porthole containers are generally 20 ft containers, whilst most of the Integrated containers are 40 ft containers, the trend here being towards High-Cube containers (9 ft 6 ins).

Porthole containers account for approximately 46,500 TEU of container slots on vessels, as against approx. 165,000 TEU of container slots for Integrated containers.

Most of the Porthole container vessels were built in the 1970s. These vessels are meanwhile due for replacement. The question that now arises is: will these replacement ships still be designed as Porthole container reefers or will there be a preference for Integrated container vessels? The advantage of the Porthole system is that the slot costs about 20% less than an Integrated system. An additional consideration is that, despite having the same external dimensions, a Porthole container has an earning capacity about 7%

higher than that of an Integrated container.
The most important difference between the two systems is the fact that Integrated containers can be leased world-wide, whilst no such facilities exist for Porthole containers. This and other economic considerations make it seem likely that in the event of new-buildings the preference will be for Integrated container vessels fitted with electrical plugs to power machinery units for all containers on deck and in the holds.

THE MODERN REEFER

Vessel size trends

Over the past few years the average size of reefer ship new-buildings has increased appreciably. In the mid-1980s a typical reefer vessel would have had a capacity of 200,000-300,000 eft and would have had room for few, if any, containers on deck.
By contrast, many of the reefers that have been built over the last two years are in excess of 450,000 eft in size, and a significant number have over 600,000 eft of capacity.

While the below deck hold space has been increased, so too has the room for containers on the weather deck. Many of the recently built reefer ships can accommodate in excess of 100 loaded containers, in addition to their conventional cargoes. This has increased the operational flexibility of the reefer ship type.
The higher capacity of reefer ships has been achieved in a number of ways. Of course, one option has always been a simple increase in overall dimensions. In addition, though, more decks, more rational hold arrangements and the positioning of the engine room to the aft of the ship have all helped to create greater cargo carryingcapacity.

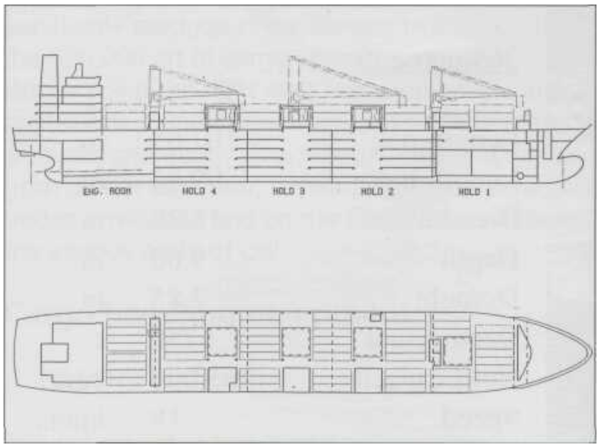


Fig. 7

Table 1 and Fig. 1 show a comparison between a typical older generation reefer and a more modern one. The contrast is evident.

Table 1:

	"Old" reefer	"New" reefer (Fig. 1)
Cubic in holds	250,000 cft	650,000 cft
Length	125m	145m
Breadth	18m	24.4m
Depth to upper deck	11 m	15.7m
Number of decks	3	5
Number of 40 ft loaded/ empty containers on upper deck	0	110-150
Number of 40ft containers in holds	0	70

Another trend that is increasingly apparent with regard to recently delivered reefer ships relates to their speed. Today, a service speed of around 23 knots is frequently specified by the owner so as to allow the vessel to maintain reliable sailing schedules. Only a few years ago a typical speed would have been around 18-19 knots.

Cargo handling methods

Almost all reefer ships built in the past few years have been 'pallet friendly'. This means that factors such as the hold size and deck height have been determined by the need to carry palletised produce in an optimum fashion.
Palletisation is one of the most important trends in the reefer shipping business and will continue to be a major influence on ship design for the foreseeable future. Many trades have recently been converted from break-bulk - where produce is packed in boxes and stowed by hand or slides in the holds - to palletisation, and others will follow over the next few years.

The use of pallets is considered to be more efficient in terms of manpower, and faster in terms of the average time the vessel spends in port. Damage to the cargo is also said to be less.

Typically, 48 boxes are placed on a wooden pallet, with dimensions of 1 m x 1.2 m and a total weight of around 1 tonne. The pallets are loaded onto the ship by cranes and distributed within the holds by forklift truck.
One fairly recent development is the use of a pallet cage. The cage, which can hold 6 pallets weighing up to approximately 8 tonnes, is lifted by crane into the hold, achieving even faster loading/unloading times.
Some ports in Europe and America have invested in automated pallet handling cranes, which incorporate conveyor belt systems and weather protection devices. Extremely fast productivity levels are claimed for this type of crane, although the capital cost can only be justified if throughput levels are high.

Green Arctic

The use of refrigerated containers is also increasing in many trades. Generally 40 ft or 43 ft long insulated boxes are used, fitted with integral machinery units, and each box can carry around 26-28 tonnes of fruit. Most of today's reefer ships have sufficient power points on board to provide an electrical supply for over 100 refrigerated containers.
One vessel recently delivered by Danyard had a power supply for around 150 reefer boxes. As a result, the ship could carry over 300,000 eft of perishable produce in containers, in addition to the 625,000 eft of.cargo space below deck.
Determining the right ratio between pallets and containers is one of the main tasks of the reefer ship designer today. The mix will clearly differ from owner to owner, depending on the particular trades envisaged and on the facilities available in the various ports of call.

Cargo handling equipment

A. Hatches and cranes

The typical hatch size found on contemporary reefer ships is considerably larger than in earlier generation vessels. Some hatches are large enough for pallets to be placed directly in the holds, using lift trucks.
Normally, the hatches will be of sufficient size to allow 40 ft containers to be placed in the holds in a single row, four units across. A clear opening of 13.7 m x 10.5 m is required for this operation.
However, one fairly new development is to restrict the holds to pallets, leaving containers to be stowed on the upper deck only. This means that smaller pallet hatches, around 3.8 m x 6 m in size, one for each hold, can be specified (see Fig. 2). One of the advantages of this design is greater protection of the cargo against the weather.

The special pallet hatches are normally served by a 10 tonnes capacity pallet handling crane, or by a gantry-type crane operating transversely along the vessel. The pallet cranes can lift the cage into the holds, allowing the forklift trucks to empty it and distribute the pallets inside the holds. The trucks are moved with the cage from deck to deck.

Pallet hatches can even be built into the big hatches on the upper deck. The existence of these smaller hatches means that, in cases where only pallet handling is required, the big

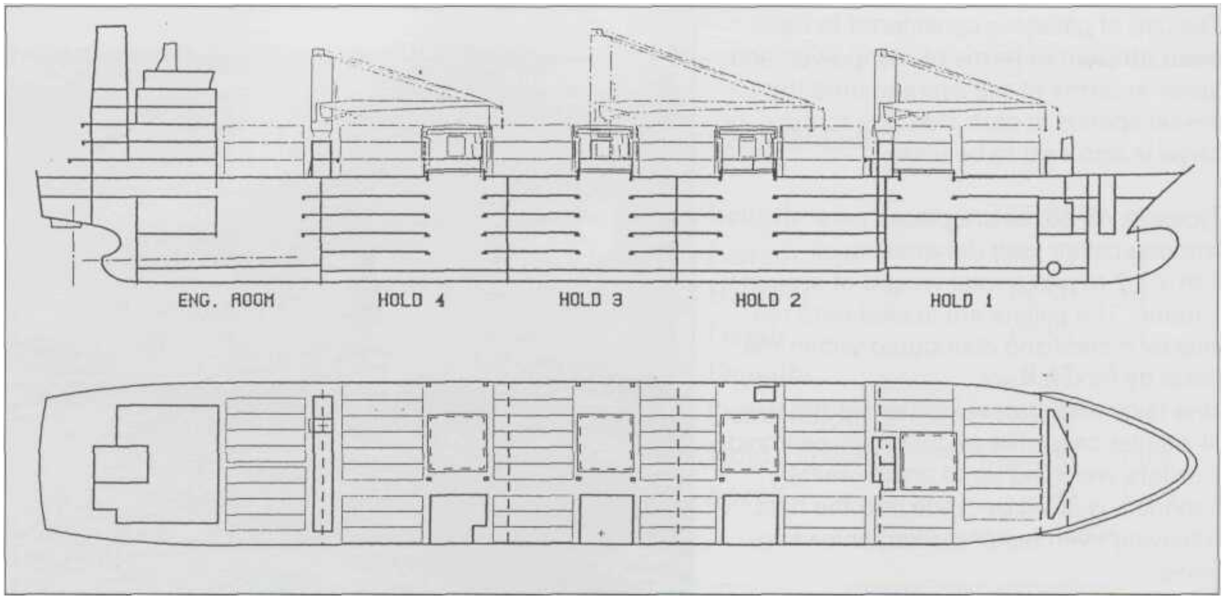


Fig. 2

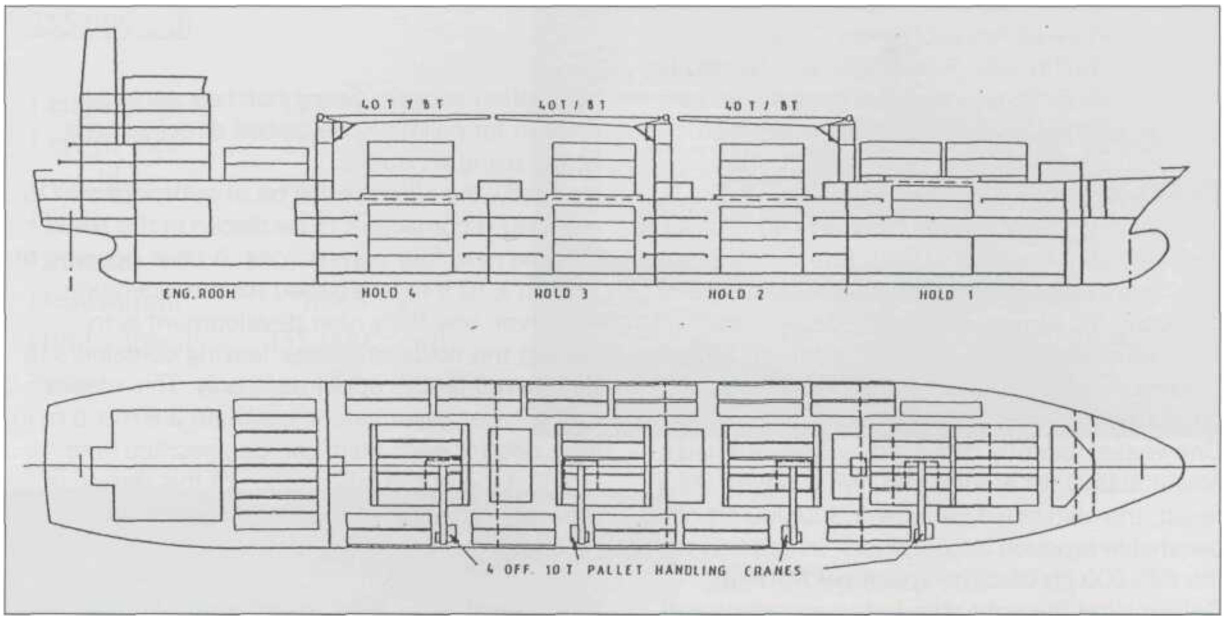


Fig. 3

hatches do not have to be opened or closed (Fig. 3).

In a typical stowage arrangement where the containers are placed on deck between the palle' handling cranes, pallets and containers can be handled at the same time and independently of each other. Containers are generally handled by 40 tonnes capacity deck cranes designed specifically for container operations.

B. Cargo lifts - side loaders

On particular trade routes, a side loader system may be more suitable. This comprises a large side door which is hinged at the bottom and serves as a ramp between the ship and the quayside. Behind the side door is a cargo lift which can operate between tank top and upper deck, serving all the 'tweendecks. This lift can

usually transport two pallets at a time, and can also move forklift trucks between decks as required (Figs. 4a and 4b|.
In this type of operation a forklift truck brings pallets from the warehouse and drives over the ramp into the ship. The truck then places the pallets on the lift, which takes them to the required deck, where trucks lift them out and move them inside the hold to the desired stowage place.
The lifts used within this arrangement can be technically quite sophisticated. They can, for example, be fully automatic with computer-operated roller systems.

C. *Side doors*

Where side doors are fitted, their dimensions are about 9 m wide and 10 m high. In such cases the vessel is also equipped with two top hatches (approx. 9 m x 3 m). The hinged flaps between the pallet lifts and the deck are each dimensioned to take the weight of an 8 tonne forklift truck.

During loading/unloading operations the side doors rest on the quayside and automatically adjust themselves to the draught of the vessel and tide variations. The dimensions of the side doors should be big enough to accommodate three 8 tonne forklift trucks. The doors can also be used for loading cars and other vehicles. To ensure a satisfactory arrangement of the operations, a separate platform extension is required (see Fig. 4b). The extreme angle for loading cars is fixed at 10° on the side doors. As can be seen from the General Arrangement Plan, an extra aluminium platform is used to extend the combined ramp by 14.5 m from the ship's side.

The side doors are opened/closed and raised/lowered by two hydraulic jigger winches. The doors will serve quay heights in top level, fully loaded at departure, to level with weather deck. In ballast condition the minimum height is 0.8 m below deck No. 4.
The side doors, which in a loaded position will extend below the fully loaded water line, are fitted with "false" ship's sides as a hydraulically operated leadline threshold. They are also fitted with the necessary drains and alarms and with hydraulically operated 1 m finger flaps. Two hydraulic pump units serve to operate the side doors, the top hatch, hinged flaps and cleating arrangement. Under normal operation one of these pump units can be kept in reserve.

D. *Pallet lifts*

Two pallet lifts, each of 4 tonnes lifting capacity, are fitted at each side door opening. One of the pallet lifts at each side door is dimensioned to lift a forklift truck. The approximate lifting speed is 24 in/minute.
The pallet lifts are designed as cantilevered units and are guided by at least 4 rollers in a vertical and inclined operating track. The top hatches should be designed to allow full withdrawal of the pallet lifts, trucks and lifting machinery.
The electrically operated pallet lifts are remote-controlled from a portable pushbutton tableau attached to a flexible cable. The pallet lifts can operate over the complete range from tank top to weather deck. Arrangements are made to ensure synchronous operation. There is a selective automatic stop on all decks as well as at the flexible level of the side doors. The pallet lifts are fitted with alarm lights and automatic obstruction stops to meet safety requirements.

Air distribution

Air coolers and blowers are usually arranged at one end of the hold. Air is pressed through the air coolers in a longitudinal direction, and is forced out under the gratings, upwards through the cargo. It then returns longitudinally under the deck, back to the coolers.

The air circulation can also be based on the "Robson system". In this case, air coolers are also positioned at one end of the hold and air is delivered from these coolers into longitudinal air ducts. Air is then pressed transversely out through the floor gratings, upwards through the cargo and longitudinally under the ceiling, before returning back to the coolers. One of the advantages of the Robson system is that it allows the holds to be made longer.

Gratings

Most gratings on board today's reefer ships are manufactured from aluminium. This material

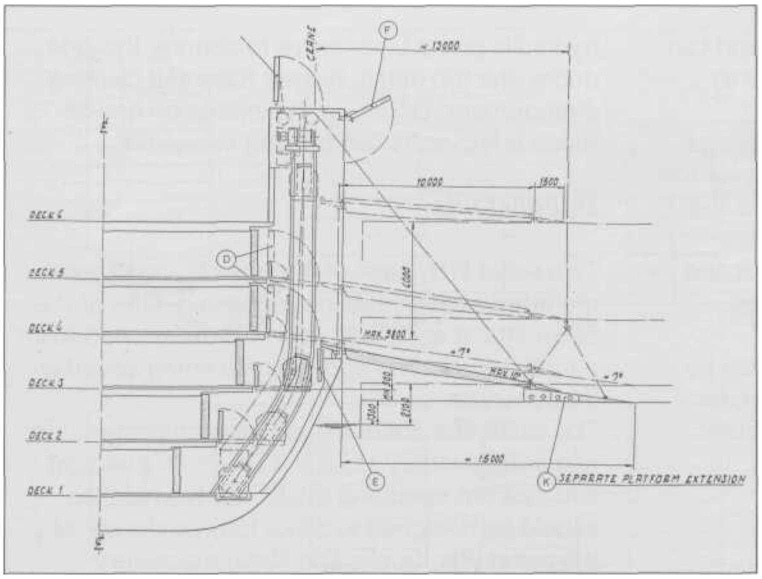


Fig. 4a

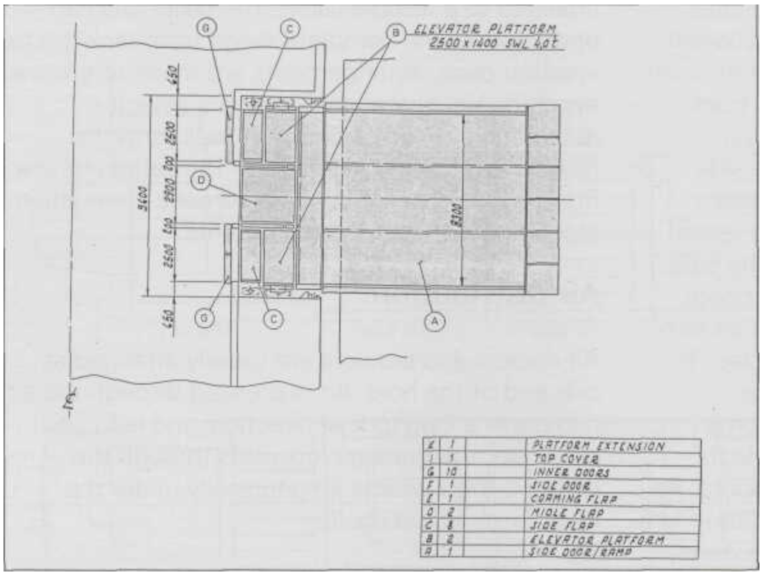


Fig. 4b

provides a high level of strength combined with a relatively low weight and, compared to wood, it is easier to keep clean and hygienic.
A new philosophy, however, is to omit the gratings altogether and to use the pallets themselves to provide the necessary grating. In this case the pallets have to be arranged in the same direction so that the air can pass through them. The advantage of this approach is clear. It is much easier to clean the deck itself than to clean below the gratings. The latter is an arduous, time consuming and manpower intensive task, even when using high-pressure washing equipment.

Future developments

Looking to the future, a number of new types of reefer ship can be expected to appear in the years ahead.
There will, for instance, be ships designed to carry only refrigerated containers on the upper deck and in the holds, all of which will have plugs to power machinery units. The holds will not be insulated and will have an inspection gangway only at one end of the container where the cooling machinery is situated. Such ships will be able to carry conventional containers on return voyages (see Fig. 5).

Another likely development will be reefer ships which have the accommodation quarters and navigation bridge forward, but the engine room aft, as normal. This will allow the ship to carry more containers on the upper deck, which would have a pallet handling gantry crane and small pallet hatches. Figure 6 gives an artist's impression of DANYARD reefer 2000 with side doors.

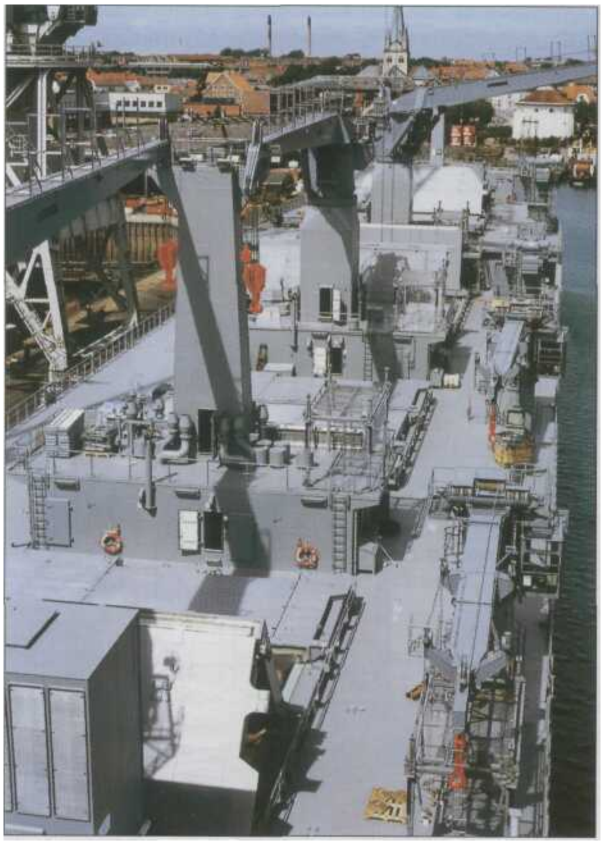
Another development concerns the automation systems on board, which will become increasingly sophisticated. Computerised systems will allow all onboard machinery to be controlled from the bridge, thereby reducing the number of crew required.

The new generation of "green" reefers

To conclude this chapter, we will discuss in more detail the delivery of a series of reefers whose design can rightly be described as "truly pioneering". This relates to the 'Albemarle Island' class, a series of 5 ships built at Danyard in 1993 and 1994 for the Ecuadorian banana exporting group Noboa.

'Albemarle Island'

'Albemarle Island' the bridge



"Albemarle Island" view over deck

"Barrington Island'

The principal features which make these unique "green" reefers different from other contemporary reefers are:

1) They are the largest combined container/reefer carriers yet built.
2) They utilise ammonia as the primary refrigerant with brine as the secondary coolant.
3) They are equipped with a highly distinctive cargo handling arrangement which allows containers and pallets to be offloaded simultaneously yet independently.
4) They have a substantially higher container capacity than is usually found on board reefer ships.
5) The Noboa reefers are double bottomed from fore to aft, without any fuel tanks in these spaces - all tanks are located at higher levels.
6) They are the first reefers to be built in accordance with Lloyd's Register's new Controlled Atmosphere Guidance Notes.

Main engine:
MAN B&W 8S60MC two-stroke design with an output of 13,320 kW MCR at 105 rev/min. Main engine fuel consumption: 65 tonnes daily.

Principal particulars

Length, oa	179.90m
Length, bp	165.00m
Breadth	25.20 m
Depth	13.20 m
Draught	9.20 m
Deadweight	14,160 dwt
Speed	23 knots
Hold capacity	627,683 eft
Pallet deck area	7,314m^2
Container capacity on deck	156 FEU
Container capacity in holds	56 FEU

Classification:
Lloyd's Register
100 A 1, + LMS, UMS, + RMC(CA), SDS(LR).

Cargo handling arrangements

Loading and unloading times in ports can be considerably shortened thanks to the vessel's unique system for parallel pallet/container handling. The system comprises three Liebherr electro-hydraulic single jib cranes for container handling, with a maximum lifting capacity of

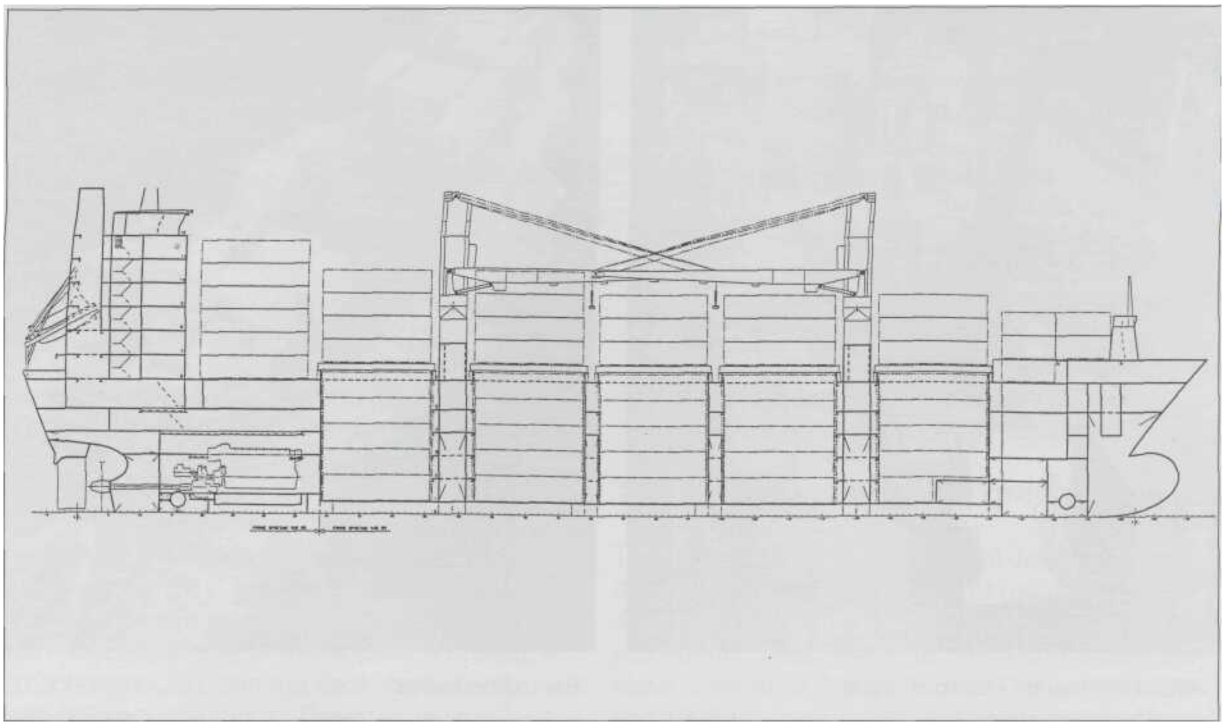


Fig. 5 Container ship with electrical plugs for all containers on deck and in holds

40 tonnes. These cranes, located at the centre of the ship, can also operate in pallet handling mode, with a capacity of 8 tonnes under a hook. The 40 tonne main container cranes are supplemented by four electro-hydraulic pallet handling cranes which are offset to the starboard side of each of the holds and have a maximum capacity of 10 tonnes. Each hatch cover is fitted with a banana hatch. Grouping the cranes in this way makes it possible for containers and pallets to be unloaded simultaneously and independently of each other. So there is no need for the containers to be moved around first so that the pallets can then be unloaded.

Another special feature is the shape of the holds. These have vertical sides throughout. This means that loading and unloading of pallets can take place more easily and, above all, more quickly.

The hatch covers

The ships have hydraulically operated hatch covers supplied by McGregor-Navire. The hatch covers provide clear openings of 13.7 m by 10.5 m in all of the holds. Each insulated weather deck hatch cover of the Rack-Back type consists of three panels in a 2 + 1 arrangement. The single panels on each hatch cover have a smaller hydraulically operated hatch inserted (banana hatch), with dimensions of 3.5 m by 5.5 m, to allow the passage of the pallet cages. On board are a number of pallet cages, each of which can take six pallets at a time. The insulated hatch covers for the weather deck and for the 'tweendecks are constructed to maintain an average heat leakage of less than 0.4 kcal/m^2 h/°C. The insulated covers for the weather deck and the insulated and non-insulated hatch covers in the 'tweendeck are designed for a uniform loading of 1.8 tonnes/m^2, or a 7 tonne forklift truck.

Hold and container capacity

The vessel's cargo space is divided into eight insulated sections in four holds, thus offering the possibility of eight distinct temperature zones. The below deck cargo spaces are subdivided into 15 refrigerated compartments. The biggest hold is number 3 hold, which contributes 180,300 eft to the total of 628,000 eft. The four holds can carry palletised and/or break-bulk frozen and chilled cargoes within a temperature range of -29°Cto+15°C.

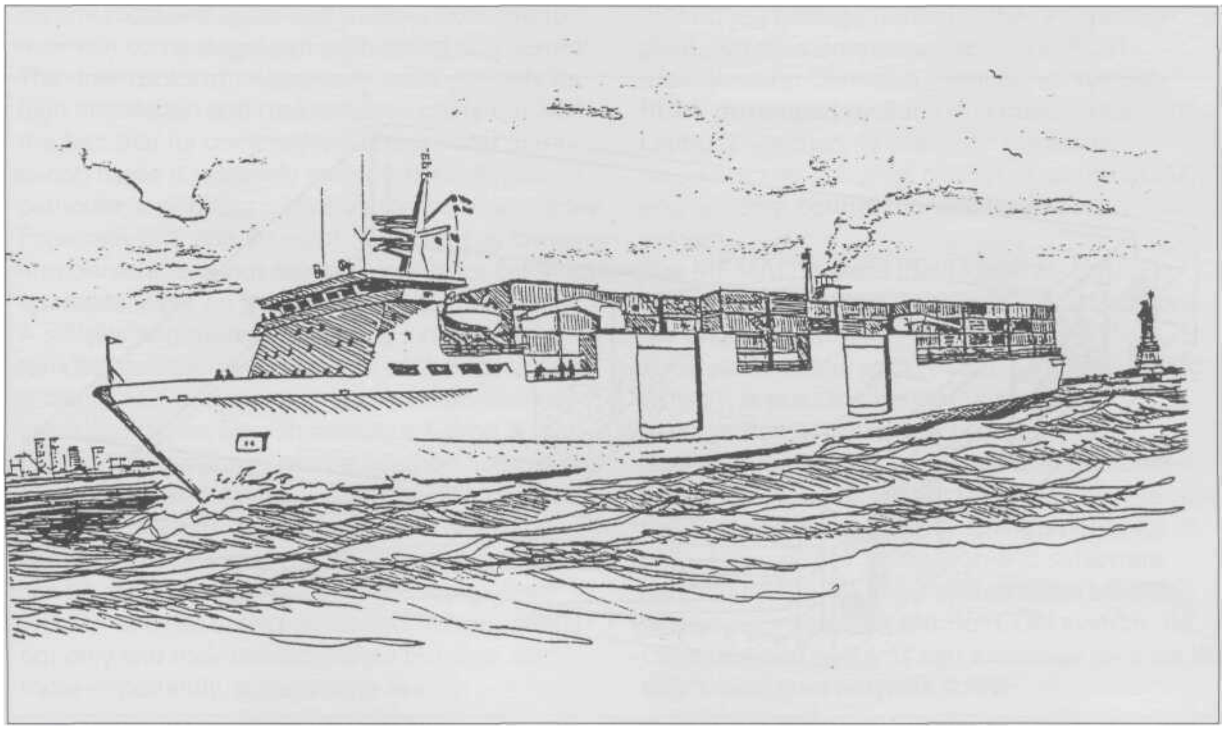


Fig. 6 Artist's impression of the reefer of the future Danyard "Reefer 2000"

The total container intake is 434 TEU, of which a total of 322 TEU or 156 FEU are provided for on deck where there are sockets for 148 reefer 40 ft units. The special advantage of the Noboa reefers is that, besides their big hold capacity, these ships can accommodate an additional 156 loaded 40 ft containers in three tiers on the weather deck. This gives the vessels in the Albemarle Island class a potential extra capacity above deck of some 310,000 eft. Those 156 containers also include 148 refrigerated boxes which require a power supply.

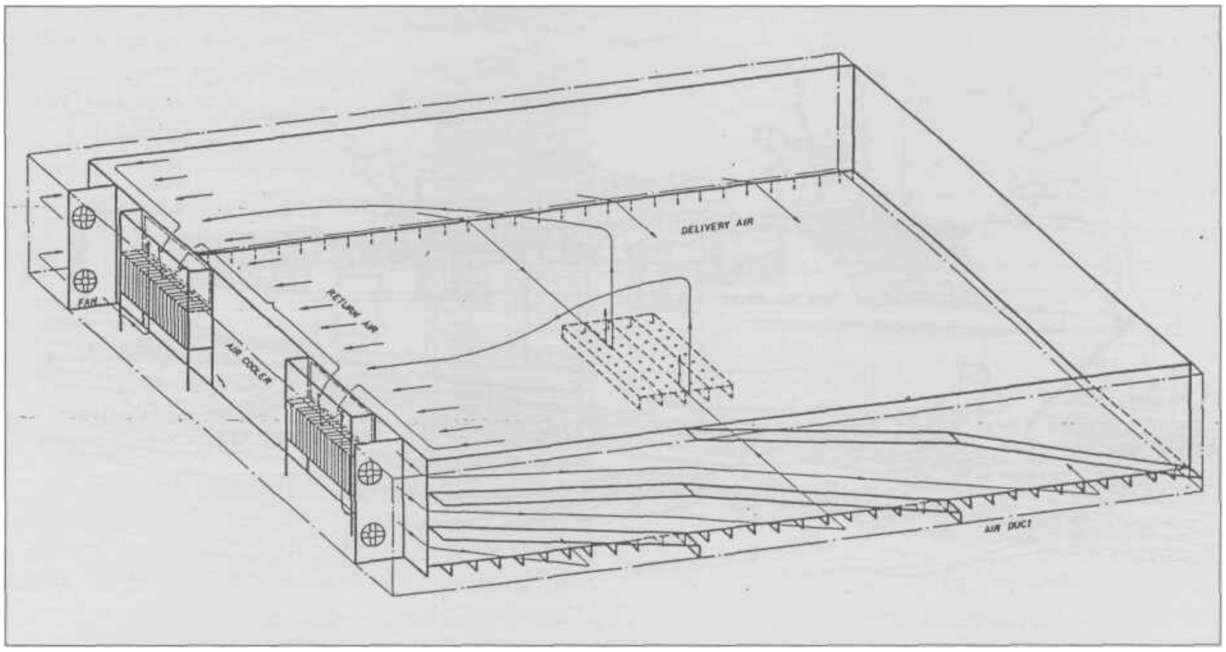
Danyard's previous new-buildings, e.g. for the Geest Line and Chiquita, have 5 decks and can only carry around 108 40 ft containers on deck. By contrast, the reefers in the Albemarle Island class have 4 decks. Because of this construction it has proved possible to carry a big number of containers on deck, thus giving the ship a high degree of flexibility.

The Robson system

Each of the 15 compartments is served by two separate air coolers located along the bulkhead and by fans incorporated in Robson ducts for circulating the air.

The big length of the holds (34.6, 29.7 and 26.4 m respectively) means that the Robson air distribution system was chosen for use on these vessels. In brief, this system works as follows:

The air coolers are placed along the insulated transverse bulkhead in the cooler room. Insulated air ducts slanting downwards have been fitted behind the insulated side walls. Fans are mounted on the sides of the cooler room. The fans deliver the cold air from the cooler through the longitudinal air ducts to outlet openings which force the air transversely along and underneath the aluminium floor gratings. After this, the cold air is forced through the openings in the gratings into the hold and thus passes upwards through the cargo stow and longitudinally under the deck, back to the air coolers.
The return openings are fitted in the cross-partition (cooler room bulkhead) between the cooler room and the hold. The fans mounted on the side walls of the cooler room can then extract the air out of the cargo space for recycling. The dimensions of an air duct depend on the volume of the hold section it has to serve and, of course, also on the length of the duct and the air resistance that occurs in it.



Robson system

Controlled atmosphere storage

The 'Albemarle Island' is the first vessel to have the LR (CA) notation. (For a complete overview of the CA Provisional Rules as prescribed by Lloyd's Register of Shipping (LRS) in London, see Chapter 11).
The ship complies with all the requirements relating to the piping, hatches, seals, safety and warning systems, etc. prescribed in the Rules.
If CA cargoes are supplied for shipment, then the only step that still needs to be taken is to install a controlled atmosphere plant on the ship. However, it would also be sufficient to install an ISO container module with the necessary equipment inside (see Chapter 11) and to link this up to the facilities that have been installed on board.

The REFCON system

In the early years of remote monitoring four-pole 24V systems were used. This 24V system required special communications cables drawn from each container to establish a simple surveillance function and provide an alarm. Later on, a data logger was added to the four-pole system. This, too, required a special communications cable and made it possible to maintain some degree of monitoring and control. The drawbacks of this system were not only its high installation and maintenance costs but also the fact that its complexity of cables and extra wiring made it relatively too complicated and, in particular, too labour intensive for the ship's crew. Especially in these times of reductions in crewing numbers there is not much time left for carrying out repair work on the cables or the monitor.
A simpler and more time-saving system for remote monitoring and control of the containers is the REFCON system, first marketed several years ago by the Danish company Lanng & Stelman. The system can be used on board ships or at container terminals. The advantage of the REFCON system is that the link between the central computer and the individual containers can be made via a single power line. In other words, no extra wiring is needed, which means not only low maintenance costs but also, and more importantly, a great time saving.
The central computer collects the data from all the containers via the communications system. The data can then be displayed to the user on a number of work terminals. It is also possible to interface to other ship management functions such as Loadmaster or Satcoms. The communications system is a network within the REFCON system, which is based on the IP300 processor and RMU masters manufactured by Lanng & Stelman,
The REFCON system offers two-way communication between the ship's personnel and the container so that parameters can be changed. Obviously, the data transmission speed within the system depends on the number of containers that are to be monitored but never takes more than a few minutes, Not surprisingly, this modern system has also been installed on the vessels in the Albemarle Island class. The system has also been installed on the other ships delivered by Danyard, e.g. those built for Chiquita and Geest. It is also in use on many other vessels, e.g. on those of Evergreen and Maersk.

State-of-the-art technology

A "state-of-the-art" monitoring and control system has been applied in the control and monitoring arrangements for the refrigeration plant, which is connected up to the RCM (Refrigeration Control Si Monitoring) system. RCM, developed by Sabroe in cooperation with Lanng & Stelrnan, is based on the same hardware and software principles as the MEMAC engine room control monitoring and alarm system.
The MEMAC system (developed by Lanng & Stelman) is operated via two PC based stations in the engine control room.
The system features 30 mimic diagrams through which it is possible to control power managements, pumps and valves.
State-of-the-art technology has also been used for each of the four auxiliary engines. In this case the control and monitoring arrangements for propulsion, power generation and safety are handled by the MEMAC system. The MEMAC system is linked with the REFCON system. All computerised systems can exchange data via the ship's local area network (LAN).

The refrigeration plant

Another special aspect of the Albemarle Island class of reefers is that they incorporate an onboard ammonia-based refrigeration plant. This class of vessel is therefore the first reefer in recent times to use R 717 as a primary refrigerant.
The refrigeration machinery room is located between No. 4 hold and the accommodation Structure. The refrigeration plant was designed and constructed by Sabroe Marine (Aarhus, Denmark) in accordance with Lloyd's Register (LR) Rules and Guidance Notes for Marine Ammonia Refrigerating Plant. In order to comply with LR's Rules and to contain all ammonia in one gas-tight compartment, an indirect system was chosen in which ammonia (NH_3) is used as a primary and brine ($CaCl_2$) as a secondary refrigerant.

The refrigeration plant consists of four prefabricated, factory-assembled package units ready for immediate installation on board ship. Each package unit incorporates either one large (SAB 128 F) or two smaller screw compressors (SAB 163 F), oil separator and cooler, electric motors, condenser, liquid receiver, economiser (subcooler) and brine cooler complete with all piping, temperature sensors and controls.

The tubes of the seawater cooled shell and tube type condensers are made of a special stainless stee which is suitable for seawater and compatible with ammonia refrigerant.
The shell and tube flooded type evaporators are of a new compact design with an extended surface area and small diameter steel tubes. In this way the refrigerant charge is reduced to a minimum, in this case to 250 kg per unit. If we take into account the ammonia that is required on board for air conditioning and domestic refrigeration, then the total quantity of ammonia on board amounts to approx. 1,100 kg.

To comply with LR's Rules, the total charge of ammonia is kept in a sealed section and is not circulated through the vessel. All other general requirements of Lloyd's Register's Guidance Notes have also been complied with. As examples we would mention an ammonia leak-detection system, 3 dump tank with a capacity of some 32 kg of water for each kg of ammonia, a scrubber system to protect human life, the ship and the environment.

The scrubbing system

The system comprises an ammonia scrubber, emergency fan, seawater supply, sulphuric acid storage tank and dump tanks. The function of the scrubber is to remove ammonia vapour from the air exhaust before it is discharged to the atmosphere.

The outflow from the scrubber passes through the water-ammonia liquid mixer to the dump tanks. If a major leak occurs whilst the vessel is in port, the contaminated water can be stored in a big storage tank with a capacity of 130 m^3, which means that the scrubber can continue to operate for at least about 14 hours.
To prevent calcium and magnesium hydroxides forming and blocking the packing, the water is dosed with concentrated sulphuric acid.

The vapour detection system comprises five detectors: three with dual sensors set for concentrations of 500 ppm and 25 ppm located in the refrigeration machinery compartment, and two with sensors set for a concentration of 25 ppm located in the scrubber exhaust duct and in the pressure relief valve discharge line.
The 25 ppm sensors are arranged to activate audible and visual alarms, alerting the crew of minor leaks. The 500 ppm sensors are arranged to alert the engineers in the event of a serious leak, in which case the sensors stop the refrigeration plant and machinery room ventilation fans and start the scrubbing system.

As we described earlier, the operation of the plant is fully automatic and is operated via a computerised control system. Whilst the ship is sailing in tropical waters, an empty cargo compartment can be cooled from 30^PC to 13^SC in 6 hours with two refrigeration units in operation and with the air cooler fans at slow speed. If the hold is loaded with bananas and the fans are at maximum speed, then the difference between the delivery air and the return air can be reduced to within 2°C in about 24 hours.

Ammonia-based refrigeration plant

In an earlier chapter we gave a detailed discussion of the development of environmentally friendly refrigerants.
As will be known, ICI and Du Pont have been testing new products (Klea Blend 66 and SUVA AC9000 respectively) as replacements for R 22 and expect to make these products commercially available by 1996. If these new-style refrigerants become available at an acceptable price level, it will be simple to use them in existing refrigeration installations without any technical changes being required in the plant. Though the lubricating oil will have to be changed and some minor adjustments made, the plant will still have approximately the same capacity as before.

In this context it is interesting to note that the Swedish-based ABB Stal Marine recently introduced two new types of indirect brine-based refrigeration systems for reefer ships. The VSB 20 unit is described as a compact brine chiller designed to operate on a very low R 22 charge. The manufacturer claims that for a reefer of 500,000 eft, this system will require a charge of only 1,200 kg of R 22, as compared to the 3,200 kg needed for a conventional brine system and the 5,000 kg of R 22 which is needed if the direct-expansion system is applied on a vessel of this size.

The VSB chillers are designed to allow future conversion to environmentally friendly alternatives to R 22 and also permit simplified cleaning of the refrigerant circuit prior to replacement
As we have seen in this chapter, another environmentally acceptable alternative to R 22 is to use ammonia (R 717) as a refrigerant. The drawback here is that the plant has to be designed as an indirect expansion (brine! system with special arrangements for exhaust systems in the machinery room.
Against this, however, we must bear in mind that an ammonia-based refrigeration plant is more compact and more efficient and will eventually work out cheaper than an R 22 plant of the same capacity.

To many people's surprise, the results of heat balance tests have shown that the marine ammonia plant onboard the 'Albemarle Island' is more efficient than a comparable R 22 direct-expansion (DX) system.

We would remark here that Stal Marine has also developed a compact ammonia-based brine chiller, the VSX 126, which is designed to operate with very low refrigerant charges. According to Stal, only 280 kg of ammonia will be required for a complete cooling installation on board a 500,000 eft reefer ship.

CHAPTER 24

CHARTERING PRACTICE

The first known attempt to reach an agreement on the transportation of goods, or what we now know as a Contract of Carriage, dates back to pre-Roman times.

Many books have been written on the subject of chartering from many different angles.
Over the past twenty years, however, we have often found that Charterers lacked or had only a limited knowledge of chartering. This is possibly due to the seasonal pattern of their trade. In this chapter, therefore, we felt it would be useful to describe the most important aspects of day-to-day chartering practice in the reefer trade.

First we will describe some of the more important technical terms that are used, after which we will go through the various stages involved in the actual negotiations.

The reefer market

Since the consumer market is described in the beginning of this book we will restrict ourselves to the subject of the reefer (shipping) market.

As one of the 'youngest' of the freight shipping markets, refrigerated transportation only started during the last century,
Bulk transportation of perishables by sea became more significant around the middle of this century. From that moment on, there was a clear development of a market.
The most important influencing factors are the seasons in the two hemispheres. In simple terms: during wintertime, when no fruit or vegetables are grown because of low temperatures in the Northern Hemisphere, fruit in the Southern Hemisphere is ripening and becoming ready for harvesting.

This is the main factor responsible for the increased demand for the transportation of perishables during the period between January and May, a period we will refer to below as the 'Season'.

A more limited demand for transportation exists during the remaining period between June and November, known as the 'Off-season'.

Season

Following the almost constant increase demand for fruit and vegetables in wintertime in the Northern Hemisphere, and the related volume requirements, the demand for sea-borne transportation of these products increases rapidly in a relatively short period towards harvest-time in the Southern Hemisphere.

As described in previous chapters, the transportation of perishable produce requires the maintenance of certain temperature conditions on board the vessel to ensure keeping qualities and freshness. Consequently, the demand for refrigerated shipping capacity (reefers) rises rather quickly during the months of November, December and January.

In its turn the freight market responds to this demand and prices for dedicated shipping capacity (reefers! also rise rapidly during this period, with a peak during the months of February, March and April.

In May and June the pressure of the Season generally fades away. Once harvest-time has come to an end in the Southern Hemisphere, the demand for sea-borne transportation from the Southern Hemisphere dwindles rapidly.
The Off-season starts.

Off season

During the Off-season the demand for sea-borne bulk transportation is relatively low in comparison with the demand during the Season.

Traditionally, the reefer market's reaction is to lay up a significant proportion of the older, larger reefer ships that are not obliged to sail for cash-flow purposes.

For all the other ships, owners generally try to find different employment such as transportation of cars, or they carry out carefully planned overhauls in dry dock and have the required surveys performed during this period.

During the Off-season the freight income is relatively low and, in combination with longer ballasting distances, this means that reefer ship Owners find it hard to generate the required income to meet their financial obligations.

Charters

Just like other shipping markets, the reefer market generally uses two methods of chartering:

- Time Charter (t/c!
- Voyage Charter (v/c)

For clarity's sake we will briefly describe both of these chartering methods below.

Time Charter

In the case of a Time Charter (T/C), a Shipowner rents out his ship to another party, the Charterer, or more specifically to the Time Charterer, at a mutually agreed rate, the Time Charter Hire. Additional details such as delivery/redelivery time and place, taking over of remaining bunkers on board fr.o.b.), hire payment and many other items are negotiated and recorded on an internationally recognised form, the Time Charterparty.
One example of such a form is the Baltime Charterpartyform.

This Charterparty makes very specific provisions for both the Owners' and the Charterers' obligations and rights and their legal liabilities.

The Charterer may use the ship, within the agreed limits as laid down in the Charterparty, for the carriage of his cargo during an agreed period of time. The Charterer who opts for this type of charter (Time Charter! is himself responsible for the operations of the chartered ship. This includes bunkering, instructing the Master, arranging Port Agents, etc.

Quite some work is involved in a Time Charter, but under certain circumstances it can be more practical, will provide greater flexibility and/or can be more economical to a Charterer.

Sometimes a Charterer charters out the ship to a third party.
This is called a 'Sublet'. Charterers should therefore not forget to include the right of sublet whilst negotiating the Charterparty details.

Voyage Charter

In the case of a Voyage Charter, the successful completion of negotiations is followed by an agreement between the Charterer and the Owners to transport a certain cargo from one place to another for a certain fee, known as the Freight.
The results of the negotiations are recorded on an internationally recognised document: the Charterparty, e.g. the Gencon Charterparty form.

Under a Voyage Charter the Charterer rents "the ship's space for a specified trip. The Owners undertake to arrange for the operational affairs during the voyage. Obviously, if disputes are to be avoided, very clear agreements must be made prior to commencement of the voyage.

The items negotiated include the arrival and cancelling date of the vessel in the port of loading, the time allowed for loading and discharging, the stowage of the cargo, the specified time for payment of the freight, the loading and discharging ports and berths, etc.

Brokers

Brokers have existed for as long as chartering has existed. Since the world reefer fleet is limited to about 2,500 ships, only a handful of specialised reefer brokers are active in this field. They work the market daily and know what ship and/or which shipowner would be most suitable for a certain type of cargo or contract. In other words, via their worldwide network of business friends and associates. Brokers provide the best

marketing for both Owners and Charterers.
Of course Charterers can and do work the major shipowners directly without using a broker. However, working via an independent intermediary has proven to be very helpful, especially because Brokers are paid their commission by the Shipowner.

Both Owners and Charterers have different interests and could therefore easily become involved in disputes, momentarily losing sight of the mutual interest they share: the transportation of valuable cargo.

Where a Shipbroker acts as an intermediary, he can provide a 'buffer' and can help to "take the heat off" certain matters. Quite often problems can thus be solved much faster and in a more practical manner. Obviously a broker will always try to eliminate as many problems as possible in advance during the negotiations of both main and charterpartydetails.

Marketing

Cargoes are generally marketed in a very practical way, mainly by phone or by telex. It is therefore important to have some significant cargo details at hand.

Important cargo details for marketing are:

- the approximate cargo quantity plus some essential details of how the cargo is packed, i.e. in bags, in cartons, on pallets, etc., together with the weight per bag, per carton or per pallet and the stowage factor (the volume-to-weight ratio of the cargo) and the pallet dimensions specified by length x breadth x height/weight;
- the ports of loading and discharging;
- the preferred date of loading ('layday') and the last date of loading (cancelling day), the so-called 'laycan' period;
- the type of loading and discharging terms, like full liner terms (fit), free in/liner out (filol or free in out stowed and tallied (fiost);
- the time required for loading and discharging; this may be specified in, for instance, hours or days;
- the preferred Charterparty;
- the address for commission and/or broker's commission.

As an example: a cargo of 2,500 tonnes of frozen fish for shipment from Holland to Egypt will be marketed as follows:

"abt. 2500 mt frozen fish in cartons
abt. 65 cbfVmt {65')
ijmuiden/alexandria
5/10 March
fios/6 ttl days
gencon 3.75 including 1.25 pet adcom"

It is therefore very important for the Charterer to provide as many of the above details as possible to ensure the best marketing for his cargo.

Charterer

As the Charterer is the legal party who carries out the contract, he thus bears the legal responsibility to pay the Shipowner. Sometimes it is the Seller of the cargo who offers his Buyers a price for the cargo including the cost of sea transportation. This is referred to as 'Cost and Freight' (abbreviated as C&F).

The Recipient of the cargo may also act as Charterer in the case where he bought his cargo only 'delivered Free On Board', better known as FOB.

Other parties can also act as Charterers.

Owner

The Owner is generally referred to as the party chartering out the ship.

Owners may be the legal owners. However, other types of ownership are more frequently found in the market.

Sometimes Shipowners join forces in what is termed a Pool. The Pool is appointed by contract to carry out the commercial management of the group. The combination gives the Pool more flexibility to take, say, contracts of affreightment out of the market, which an individual Owner would never be able to do. It also gives the Pool more flexibility for rescheduling and thus less ballasting, which undoubtedly restricts expenses. This is what a Pool is all about: how to operate ships more economically.

As we mentioned above, another possibility is that an Owner time-charters his vessel out to a Charterer, who in turn charters the ship out again to another party, the Sublet. In this case the second Owner is called the Disponent Owner.

Indication

Prior to selling the cargo, the Charterer should know the expenses of sea transportation, and additional expenses such as stevedoring, insurances etc., as they form a significant part of his expenses.

If a cargo is still under negotiation, each negotiating party - whether or not he is going to be the Charterer - should at least check the market for a reliable 'indication' of the expected freight. Such an 'indication' will enable him to evaluate the tota price for cargo and transportation and help him to secure his business deal.

Firm offer

Cargoes can be placed on the market with the request to either indicate or offer firm. The first situation was explained above.
Making a firm offer means that the Charterer has finalised his business deal and is ready in every respect to negotiate on a firm basis with the Shipowner. His cargo is ready and confirmed and the financing and/or his letter of credit (l/c! is in place. He therefore requires firm offers from the market.

To avoid frustration during the negotiations, it is important that the Charterer has properly arranged all his affairs prior to the start of firm negotiations. Too often it happens that Charterers have to stop halfway through the negotiations or, what is even worse, they cannot declare a final subject after having carried out the negotiations. This sometimes happens a couple of times in succession and the the result then is that a potential Charterer is very quickly classed as being 'unreliable' and will no longer be served by the Shipowners.
Remember that the reefer market is a market with a very limited number of players and that rumours tend to spread very rapidly, especially when they relate to an unreliable reputation.

Negotiations

After having received a specific firm offer from the Shipowner, which should contain the main terms of the business, the Charterers should reply to such an offer on an 'accept/except' basis. This has proved to be a very clear way of negotiating in that it avoids problems and frustration as much as possible.

The 'accept/except' principle works in a very simple way: the offer is partly acceptable to the Charterers and the items that are not acceptable are directed back by him to the Owners in his Counter Offer.

As a simple example, the items that are stated in an offer might include:

- a cargo of abt. 2500mt frozen fish in cartons abt 65'
- laycan 5/12 March

The Charterer's Counter Offer reads as follows:

accept/except (a/e):
- laycan 5/10 March

This actually means that the Charterer has accepted the item of:

- a cargo of abt. 2500mt frozen fish in cartons stowing abt. 65'

but he wants the Owners to accept a different 'laycan'.

Once the negotiations have been completed and the parties have reached agreement on the main details, a recapitulation, or 'recap', must be drawn up. This should be done by the Owners or their brokers, for approval by the Charterers.
In their turn the Charterers or their broker must draw up the Charterparty after they have successfully negotiated the Charterparty details.
After agreement has been reached on the main details, the Charterer should submit his proforma Charterparty to the Owners for their consideration. The Charterparty details must then be negotiated on the same accept/except basis, after which a recap of Charterparty details must also be drawn up.

Then, finally, the original Charterparty must be drawn up in line with both the recap of the main terms and the recap of the charterparty details. Subsequently, the completed Charterparty must be mailed to both business partners for their respective signatures.

MAIN TERMS

Ship's details

An accurate and as complete a description as possible of the ship must be supplied by the Shipowners, so that the Charterer and/or his Broker can evaluate whether the vessel is suitable for the intended cargo. Sometimes Owners are not yet sure which ship they will nominate for the cargo and in such cases we see a certain ship mentioned, plus the words 'or nominee'. This means that a brief or general description can be given by the Owners, or Owners can give a description of all the vessels that they could nominate for this business. Charterers must then make sure that all the ships that can be nominated by the Owners are more or less of comparable specification.

Charterers

The Charterers should be named including their full style, i.e. full address and phone/fax/telex numbers, together with their background, such as ships fixed recently. This information enables the Owners to satisfy themselves as much as possible that the party they are going to liaise with is a party with a good track record and proven performance.

Here we often see in practice the term 'A1' or 'First Class', a classification that is given to a certain Charterer after a period of excellent performance. All too often these terms are misused. A prudent Owner must therefore always satisfy himself by sufficient investigation. Brokers, too, have the same responsibility.

In the case of unknown Charterers it would therefore be prudent to negotiate on the basis of 'Subject to Owners' approval of Charterers'. The Charterers will be asked to supply the required background information to substantiate their reputation.

Cargo/Stowage factor

An accurate description of the cargo is essential. Charterparty and Bills of Lading must contain the same cargo specification. The following chapter on the Bill of Lading gives further details about this item.

To avoid disputes about the actual intake of the vessel, the cargo description must also be as clear as possible. For instance, if the cargo is packed in bags, or in cartons, or on pallets, then the dimensions and the gross and net weight of this packaging must always be mentioned.

Since reefer cargo is rarely a very heavy-weight cargo, an important factor to know is the cubic capacity of the cargo; in other words: how much space does the cargo require?

A very practical and good indicator unit is the 'stowage factor', which expresses the relation between cubic capacity and weight of the cargo in cbft per metric ton.
The stowage factor enables the estimated intake of a ship to be calculated very quickly. For instance, if a ship's cubic capacity of 250,000 cbft is divided by the cargo's stowage factor of 125 cbft/mt, then the estimated intake is 2,000 mt.

Port of loading

The port(s) or place of loading must be described, together with the number of berths that the Charterer needs for loading the ship. Generally speaking, the Shipowner will also want to know whether the intended berth is accessible at all times and whether his ship can lay there safely afloat.
Sometimes, due to the tide, certain berths are not accessible for a certain time so it must be determined who will pay for the extra time required.

In the so-called "tide ports" a ship cannot always lay safely afloat as the tide difference means that it will touch bottom during low water. If the bottom of the port only consists of soft material, such as mud, then it is possible that the ship can lay safely aground despite the fact that she touches bottom during low tide. Such a port is called a NAABSA port (Not Always Afloat But Safely Aground)

It is necessary to know if there is more than one port and/or more than one berth. Several ports or berths will definitely cause an increase in expenses, whilst extra time will also be required for steaming/shifting. It is then very important to make clear agreements on who will pay for these extra expenses and for whose account the extra waiting time is

Port of discharging

Here, the same comments are applicable as for the Port of loading. Often the term "I gsbaaaa bends' is seen. It stands for One Good Safe Berth Always Accessible Always Afloat Both Ends.
Of course more ports can be appointed as discharging ports. In that case it is handy to agree on the rotation of calling in the Charterparty.

Laydays/Caneelling days/Laycan

As mentioned earlier, the preferred date of loading must be specified in combination with the last possible date of loading, the cancelling date, or 'laycan'. If the vesse is delayed for some reason or another, i.e. if she enters the port of loading after the cancelling day, then the Charterers could, under some circumstances and subject to certain restrictions, have the option of cancelling the vessel. This also depends on what provisions have been made in this respect in the Charterparty.

Freight

The freight can be stipulated in various ways, such as: per cargo unit (pallet) or per metric ton or in one total amount, known as the 'lumpsum'.

A Shipowner would generally prefer a 'lumpsum' freight and leave the actual intake to the Charterer. In such a case the Owner knows exactly what the earnings of his ship are.

The Charterer in turn would prefer a freight per unit because only then will he know exactly what he is paying for the transportation of his cargo. Moreover he will not be paying for any ship space that he does not use. These are always items to be negotiated, obviously in close relationship with the stowage factor and the intake.

Freight payment

It must be specified/negotiated when the freight is payable and into which account.

Generally speaking, the Shipowner would like to receive his freight in full, as soon as possible, "discountless, non-returnable, whether ship and/or cargo lost or not lost". The somewhat cryptical abbreviation for this is: 'dnrsaoclonl'.

The freight may be payable in various ways such as:
Before Breaking Bulk (BBS), i.e. before the actual discharging takes place, or for instance 3 banking days after signing and prior to releasing of the Bills of Lading.

Other variants of freight payment are also used.

Terms and conditions

In order to establish who will pay for the actual stowing, loading and/or discharging expenses, it is important to agree the terms and conditions specifying this.

Shipowners would generally prefer to have these expenses paid by the Charterers and they will therefore ask for the cargo to be stowed and discharged free of expenses to the vessel 'FIOS' (an abbreviation for Free In Out Stowed).

Alternatives could be:
- Free In/Liner Out (filo), in which case Charterers pay for the loading expenses and Owners pay for the discharging expenses.
- Full Liner Terms (fit), where the Owners pay all expenses.

Time for loading and discharging

When agreeing 'fios' terms, the total time allowed for loading and discharging must be specified/negotiated in days or hours.

In addition more specific situations are often negotiated, such as:

- the possible weather delay - wp (weather permitting) or weather working days: wwd ;
- sometimes it is agreed that only working time counts or days of 24 hours are agreed;
- Saturdays, Sundays and/or holidays excluded: sshex;
  or the same days included: shine ;
- time between Friday 5 pm and Monday 8 am not to count as laytime unless used (uu);
- time to count:
  Whether vessel In Berth Or Not (WIBON);
  Whether vesse In Free Pratique Or Not (WIFPON);
  Whether vesse awaiting berth in or out the official confines of the port;
  Whether In Customs Clearance Or Not;
- Waiting time in or out of berth to count as laytime.

Demurrage

If the mutually agreed time for loading/discharging is exceeded, it is fair that the Charterers should pay the Owners an agreed amount per day to contribute towards the extra time used which was not calculated for.

Demurrage is quite often considered by Charterers as a sort of 'penalty' and in practice, therefore, it is almost always negotiated again after discharging.

This is obviously not correct.

The Shipowner calculates his voyage on the basis of the specifications as given by the Charterers. The calculation allows for a certain amount of time to be used for loading and discharging. If more time is used, the Owner must be compensated, as this is extra time used for the voyage.

Otherwise the Shipowners would have allowed for more time for loading and discharging prior to commencing the negotiations. The extra time used by the Charterers could easily create problems with the 'laycan' for the next employment of the vessel. Owners could also run the risk of having to ballast the vessel for quite a long distance. The vessel might easily run past the cancelling days for the next agreed Charter, and this would mean a loss of extra time and money to find the following employment for the vessel. And all of this would stem solely from the fact that the present Charterer is using more time than agreed or anticipated. It is therefore no more than normal for Owners to be compensated by the Charterers for the extra time used.

In respect of demurrage, too, it is always helpful to set a limit on payment of demurrage, as very often Charterers exercise all of their options to delay payment of demurrage as much as they can.

Taxes, tolls and/or dues

A specification must also be made of who is liable for taxes, tolls and/or dues.
Quite often it is negotiated that any taxes, tolls and/or dues on the vessel and/or the freight, if any, are for Owner's account and that taxes, tolls and/or dues on the cargo, if any, are for Charterer's account.

Certain countries sometimes apply taxes or dues or fees on, say, freight or vessel or cargo.
In order to avoid extra expenses, both Owners and Charterers have the obligation to check such matters prior to fixing.
A collection of descriptions of taxes of this type can be found in a BIMCO booklet.
BIMCO stands for Baltirne International Maritime Conference and refers to an organisation which has its base in Denmark and was founded by people from the shipping industry. BIMCO provides general services to its members in the shipping world.

Agents

Negotiations must also be held to agree on whose agents will be used for the voyage, either Owners' Agents or Charterers' agents, and in which port (loading or discharging}. If Charterers' agents have been agreed in both loading and discharging port we often see this abbreviated as: CHABE, i.e. Charterers Agents Both Ends.

Charterparty form

Also during the negotiation of main terms, the parties must agree on the Charterparty form to be used. On many occasions this is a Gencon Charterparty, supplied and filled in by the Charterer or by the broker on Charterer's behalf. This form is then amended according to the result of the negotiations, often called 'Logical amendments'. In addition further details and terms still have to be negotiated. However, these will be described later on in this Chapter under the heading 'Charterparty details, terms and conditions'. After the main details have been fixed as per recap, very often the well known phrase of 'fixed sub details' is seen. This means that the contract has been fixed "subject to details".

Commission

The Owners are liable for payment of the commission to the Brokers and/or the extra commission to the Charterers, if any; this is referred to as the address commission ('adcorn'i.

After agreement has been reached on all the above items, there is a 'fixture subject to Charterparty details' (sub details). In other words, these sub details still have to be negotiated. As explained above, the fixture recap must be drawn up and the Charterers' proforma Charterparty must be faxed to the Owners, after which the negotiations can start on the terms and conditions of the Charterparty.

Subs

Once all items have been agreed, we have what is termed a 'fixture', i.e. a legally binding contract between parties.
As stated earlier, it quite often occurs that all details have been negotiated, except that either the Owners still have to declare certain subs, like for instance 'sub schedule' (whether the vessel is indeed available) and/or Charterers still have to declare their sub(s), e.g. 'sub stem', or 'sub receivers' approval', etc.

Needless to say, such 'subs' should be avoided as much as possible, although they have proven to be very helpful in practice. If subs are used, they should always be attached to a certain time limitation, e.g. 'sub to be declared at latest within 24 hours after fixing main terms'.
Incidentally, we would add here that quite often in practice, parties erroneously use the expression 'lifting the sub' instead of 'declaring the sub'.

Bill of lading

After all subs have been declared the business is fixed and the contract is legally binding: the goods can be shipped. Once the ship has arrived in the agreed port of loading, within the agreed 'laycan', Charterers hand over their cargo to the Shipowner in return for a receipt: the Bill(s) of Lading(Bs/L).
Since the Bill of Lading has various functions and involves numerous legal consequences it is described separately in Chapter 25.
At this point, however, we would like to mention that the type of Bill of Lading to be used for the voyage should be agreed in advance.
Parties must assure themselves that the agreed Bill of Lading is not in contradiction with the terms and conditions of the Letter of Credit, as in practice this quite often proves to be the case.

Practice

The Charterer has the obligation to deliver the goods duly packed and in a good condition to the Shipowner's representative, the Captain and/or his crew. The captain always has the right to refuse cargo if he considers it not fit for transportation or if he feels that it is not the cargo as agreed upon in the Charterparty.

To detect possible problems at an early stage, it is recommended that arrangements be made for a surveyor to attend during the loading operation. Both Owners and Charterers could appoint their own independent surveyors. The surveyors can then determine the quality status of the cargo and/or its packaging, as described in an earlier chapter in this book.

The surveyors could attend again at the discharging. On the basis of the loading report they should then be able to determine what damages have occurred during the voyage. It should be noted, however, that palletisation has resulted in a significant decrease in cases of damage.

Especially where perishable cargoes are concerned, special attention must be given to whether the vessel is fitted with sufficient equipment to 'measure' the status of the cargo. A relatively small investment may well save the Shipowner a cargo claim, whilst this would also make it much easier for the Charterer to file claim against his cargo owners.

In practice many surveyors do not seem to have the right background knowledge of the complicated subject of the various diseases encountered in perishables. Both Owners and Charterers should make sure that their surveyor has proven experience with perishables.

It will be clear that facilities like a 'Pallet Tracking and Tracing system', as used by modern port terminals, make it much easier to determine problems in an initial stage, whereas liability can also be declared at an early stage.

Prudence should be exercised with regard to the insured value of older ships and whether these are insured under a Protection and Indemnity insurance cover, the so-called P&I clubs. Usually Charterers' own cargo Underwriters require a vessel to be sufficiently insured under a P&I cover.
If a ship is not properly covered, the possibility exists that in the event of damage to the cargo, no indemnification will be paid by the cargo Underwriters.

CHARTERPARTY DETAILS, TERMS AND CONDITIONS

Charterparty form

Various standard Charterparty forms are used. Two important forms that are often used are:

- Gencon Charterparty (for voyage charters)
- Baltime Charterparty (for time charters)

Again we will restrict ourselves to some terms and conditions that are often negotiated and/or used in Voyage Charterparties. For practical Time Charter terms and conditions we would recommend that Charterers should gain expertise with voyage chartering prior to venturing into time chartering and experiencing its pitfalls for themselves.

Notice of readiness

The master and/or the Owners should give the Charterers and/or the Agents the so-called: 'Notice of Readiness' - NOR. By means of this message the master notifies parties of the arrival of the vessel at her destination and he confirms that she is in all respects ready to load or discharge the intended cargo.

in an additional clause it should be agreed that upon arrival at the loading port, the vessel's holds and cargo spaces should be clean, dry, and free of smell and odours. Failing this, the Owners should rectify this in their own time and at their own expense.

Notice can be given in various ways and by various means. Often NOR is given during office hours on working days in the port, after which the time for loading or discharging will start to be counted as from an agreed time.

Very often we see that if Notice is given during office hours before noon, the time will start counting on the same day at 13:00 or 14:00 hours. If Notice is given during working hours in the afternoon, the time starts counting only from the next day at 06:00 hrs or 07:00 hrs or 08:00 hrs, depending on the agreement.

If 'Even If Used' (EIU) for loading/discharging was agreed upon during negotiations of main terms, the time used for loading and/or discharging will not be counted.

If 'Unless Used' (UU) was agreed, time used for loading and discharging will count. Additionally 'actual time used to count' can be agreed, in which case only the time that was actually used will be counted.

Arbitration

In the event of disputes under the Charterparty it is helpful if a mutually agreed Arbitration Clause is included in the Charterparty.

A well-known and frequently used arbitration clause could be:

'Should any dispute arise under this Charterparty, the matter in dispute shall be referred to three persons in London, one to be appointed by each of the parties hereto and the third by the two so chosen.
The decision of any of two Arbitrators shall be final. For the purpose of enforcing any award, this agreement must be made rule of the court according to English Law. Arbitrators shall have discretion to award the winning party its cost of the Arbitration, including wholly or partly the fees and disbursement of its attorneys and/or agents.'

Damages to the ship

Generally speaking, most Charters are fixed FIOS, in which case the Charterers appoint the Stevedores to stow the cargo. Since they have no control over the stevedores in such cases, Owners would always like to protect themselves against damage to the vessel.

Cargo instructions

The Charterers must issue the master with his temperature instructions prior to commencement of loading.
This should be done in writing as there have on many occasions been disputes about whether the vessel had maintained the required temperatures throughout the voyage. We would therefore advise parties to agree a cargo temperature/instruction clause under the Charterparty. It avoids lots of problems during discharging.

In addition, the vessel should be equipped with temperature recorders which keep an automatic log of the temperatures throughout the voyage.

Stowage materials

Extra expenses frequently occur because stevedores use stowage materials such as dunnage, air-bags, etc. to stow the cargo.
It should be agreed in advance who is liable for these expenses.

Notice

The master should keep interested parties advised of the vessel's position and estimated time of arrival (eta). On many occasions it will be agreed that these Notices are given 10/5/3/2 days plus 24 and 12 hours prior to the vessel's arrival.

Sealing of Hatches

To avoid disputes about the amount of cargo loaded and discharged, a hatch sealing clause is very useful.
If the vessel's hatches are sealed after loading by an official surveyor and provided that the seals are intact at the discharge port, neither the vessel or the Owners can be held liable for any shortages.

Use of ship's gear

The Charterers should have free use of the vessel's winches/derricks and/or other cargo gear. In many charterparties it is agreed that any shortfall in cargo gear can be substituted pro rata by shore cranes at Owners'/Vessel's expense.

Additional clauses

Possible additional clauses such as: 'Both to Blame Collision Clause', Bunker clause. General Average clause, etc. should be stipulated as forming an integral part of the Charterparty.

In this Chapter we have tried to highlight some of the basic procedures of reefer chartering practice. To gain a more in-depth knowledge of Chartering in general, we would recommend that the reader consult specialised books such as:

Scrutton on Charterparties - Sir Alan A. Mocatta
MichaelJ. Mustill
Stewart C. Boyd

Shipbroking and Chartering Practice
- R. Ihre
L. Gorton
A. Sandevarn

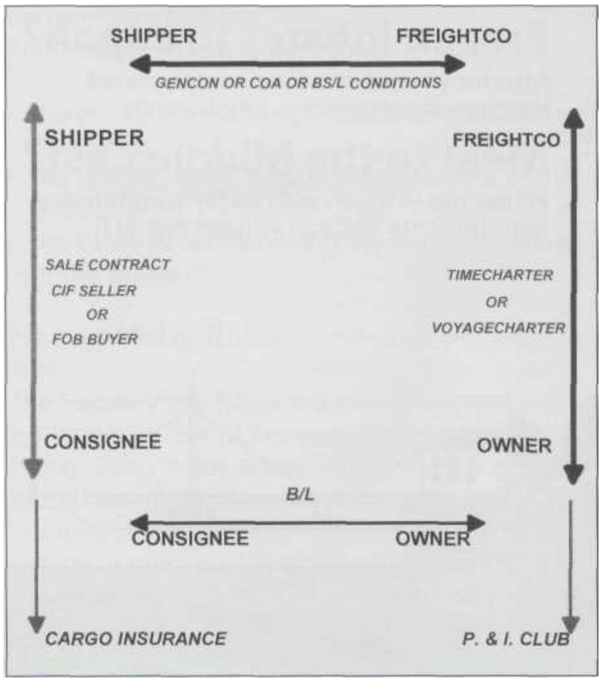
Alternatively we would suggest that parties consult a good shipbroker.

THE BILL OF LADING

Contract of Carriage

When goods are shipped contractual relationships are laid down in transport agreements (contracts of carriage) and, after the goods have been loaded, these contractual arrangements are set out in the bill of lading. The unusual feature of a bill of lading (B/L) is that it can represent a contract between parties who become each other's contractual partners by signing the agreement without this being based on any previous transport agreement between them. Obviously, a prior agreement has been concluded, but that was between other parties, e.g. between a shipper and a time-charterer of a vessel. Because of this construction we can say that the bill of lading is not the transport agreement itself but gives form to an agreement concluded at an earlier moment. It is important to bear this difference in interpretation in mind.

String of contracts



We can distinguish between two sorts of agreements:
During transport of general cargo by a scheduled service the bill of lading is the only transport contract, i.e. the transport agreement between the scheduled shipping line as carrier and the shipper is not laid down straight away in an official document but is limited to a telephone memorandum, a telex message or a booking confirmation form. These bookings are usually made by the carrier's agent. It is agreed between carrier and shipper that the transport conditions are the same as the conditions on the bill of lading.

Other agreements are charter agreements and these are set out in an official document. The contract for this type of transport is almost always concluded in the form of a document known as a "charter party", of which there are many types. Sometimes a "booking note" is used. These documents may contain provisions which are applicable to the bill of lading. This is why we see bills of lading which refer to a particular "charter party". We will not go into this subject matter in greater depth but will restrict ourselves to the bill of lading, since this is an important document in all cases.

The front and back of a bill of lading

Some confusion exists in this respect because the front, on which the printed conditions of the bill of lading are printed, is regarded in practice as the back of the form. Whichever way you look at it, however, the details about the shipment are mentioned on the other side.

Main types of charter parties

A. Time charter party

For the carriage of refrigerated cargoes the Baltime and the NYPE (New York Produce

Exchange) form of Charter Party are commonly used. The difference between these two forms is that the **Baltime** is more in favour of the Shipowner, whereas the **NYPE** is more advantageous for the Charterer.

In short the main characteristics of a Time Charter Party are as follows:

- The shipowner takes care for a seaworthy ship with valid classification and employs the Captain and the Crew, enabling the ship to safely sail between the ports as ordered by the Charterer.

- The Charterer takes care for the loading, stowage, lashing/securing and discharge of the cargoes and gives the Captain orders and instructions as to the cargoes to be shipped to and from various ports.

- The Charterer takes care and pays for the vessel's bunkers.

8. *Voyage Charter Party*

The form commonly used is the Gencon Charter Party. The principle is that the type of cargoes and the ports between which the cargoes are being carried are known beforehand. On Liner Terms the Shipowner takes care for loading, stowage and discharge, whereas on FIOS terms (Free In Out Stowed) the Charterer takes care for it. In both cases it is not the Charterer who gives instructions to the Captain, but always the Shipowner. Consequently the liabilities for a Voyage Charterer are slightly less than for a Time Charterer.

Bills of lading formats

There is no standard form of Bill of Lading that will be used in all trades within the refrigerated market. The most commonly used forms are the BIMCO approved forms, named Congen and Conline Bill of Lading. The Congen form is used when a voyage charter party between the shippers/consignees and the carrier exists and the Conline form is used when cargoes are directly booked on Bills of Lading conditions. Further it is quite common that particular trades are performed by socalled "parcel services". In such cases the ship-owning or ship-operating company has designed it's own Bill of Lading format.

Bill of lading

The definition of the bill of lading is as follows:

> *"The bill of lading is a dated document in which the carrier declares that he has taken receipt of certain goods in order to transport them to a designated place of destination and to deliver them at that place to a designated person, and also the conditions under which such delivery will take place."*

The bill of lading has three functions:

- it is a proof that the cargo has been received on board on a certain date, i.e. a receipt;
- it is a transport agreement between the carrier and the holder of the bill of lading;
- and it gives the holder of the bill of lading the right to the cargo.

This important document has to comply with certain requirements.
For instance, it has to mention:

- the principal marks required for identification of the goods;
- the weight, quantity or number of units of the goods;
- the external condition and the external nature of the goods.

Hague-Visby Rules

The Hague-Visby Rules are mandatory and are applicable by law to transport under a bill of lading. This means that it is not possible to depart from these rules. As a result, if the carrier includes certain clauses in his bill of lading which reduce or preclude his obligations under the mandatory provisions of the Hague-Visby Rules, such clauses will be null and void. They can be regarded as never having been written.

What are the Hague-Visby Rules? To find out, we have to go back more than one hundred years in history, to a time when it was very common practice for carriers to exonerate themselves in writing for all liabilities, even for the fault of the carrier.

This of course was an untenable situation and it led to a meeting between the parties interested in the cargo on the one side with representatives of the shipowners on the other. This meeting, attended by delegates from various countries, was held in The Hague in 1921. The outcome was the establishment of a treaty which was signed in Brussels in 1924. In addition to the name Hague Rules, this is sometimes also known as the Brussels Bill of Lading Treaty. Its official name is "Treaty to determine some Uniform Rules relating to the Bill of Lading".
In 1963 a conference was held to amend the Hague Rules. The proposals for the amendments were signed by the delegates in the old Hanseatic port of Visby. These Visby proposals were adopted in their entirety at a diplomatic conference in Brussels in 1968. The name of the treaty then became the Hague-Visby Rules or Amended Bill of Lading Treaty.

What do the Hague-Visby Rules actually regulate? In brief, we can say that the rules regulate the carrier's obligations as well as the exemptions he can appeal to in respect of the goods accepted for carriage. They also lay down the period during which the carrier has the obligation to deliver the cargo in the same condition as when it was loaded on board. This period extends from the moment of taking receipt until the moment of delivery of the goods. However, the carrier is free to exclude his liability for the period preceding the loading of the goods into and out of the ship,

A clause to this effect is included in many bills of lading. We shall return to the significance of these provisions later.

The Hague-Visby Rules are important because the treaty is recognised ail over the world, which means that the Rules are applicable to many bills of lading.

The scope of applicability is also laid down in the treaty as follows:

(a) The bill of lading must have been issued in a treaty state.
or
(b) The transport must take place from a treaty state.
or
(c) The bill of lading must contain a clause relating to the choice of law, known as the "paramount clause", which declares that the Hague-Visby Rules are applicable or, alternatively, a national law which has incorporated the Hague-Visby rules.

If the Hague-Visby Rules are applicable, the nationality of ship, carrier, shipper, consignee or anyone else involved in the transport agreement is immaterial.

Hamburg Rules

In 1978 a conference of the United Nations took place in Hamburg, the outcome being a new treaty on seagoing transport. The treaty was given the name Hamburg Rules. In October 1991 Zambia ratified the 1978 UN Treaty on Seagoing Transport. That meant that the treaty officially entered into effect on 1 November 1992. There are now twenty countries which have ratified the Hamburg Rules. Although the signatories are less important maritime nations, the Hamburg Rules cannot be ignored and it is even possible that the Hamburg Rules will be recognised by more countries in the years ahead.
The Hamburg Rules impose a heavier liability on the carrier. They imply that the carrier is responsible for damage unless he can prove that he has taken all measures which can be reasonably expected of him to prevent the damage and its consequences. In principle this means that the carrier has to prove "force majeure" (circumstances beyond his control), which is a very difficult onus of proof.

Types of bills of lading

There are two types of bills of lading (Bs/U:

- straight bills of lading;
- *bills of lading to order.*

Straight bills of lading

Also known as "recta" Bs/L. These are made out to the "consignee", the recipient, who is mentioned by name, This type of B/L cannot be transferred to third parties by means of an endorsement but only via a "deed/act of transfer", something which seldom occurs in practice.

Bills of lading to order

Bs/L can also be transferred by means of an endorsement, which means that the B/L can very easily be traded as a negotiable instrument conferring title of ownership on its holder. This is the most frequently found form of the bill of lading.

Endorsing

The act of endorsing (endorsement! implies that the holder of the B/L, e.g. the shipper in the case of a B/L to order, transfers ownership of this document to another party by writing the name of his company on the back of the document together with the name of someone who is authorised to sign for his company.

"Shipped on board"
The printed text on most Bs/L contains the following passage:
"Shipped in apparent good order and condition" or "Shipped on board in apparent good order and condition".
Both phrases basically have the same meaning. Bs/L of this type are described as "shipped on board" Bs/L. Obviously, these Bs/L can only be issued after the goods have been loaded.

"Received for shipment"
Bs/L can also be issued before the goods have been loaded on board. In such cases they do not carry the date on which the goods are loaded. Bs/L of this type are known as "received for shipment" Bs/L. However, they do show the date of receipt. Subsequently, i.e. after the goods have been loaded, the following annotations can be made on these Bs/L:
"Actually on board ... [followed by the date and the signature of the stevedore],
This document then carries two dates, i.e. *the*

B/L date and the date on which the goods were actually loaded on board-

"Clean bills of lading"

Bs/L which contain no clauses or annotations stating that something is wrong with the goods and/or the packaging are referred to as "clean" Bs/L.

Loading on board

The liability of the ship's owner or operator commences even before the start of loading. This is one of the aspects in respect of which the carrier has to comply with stringent obligations under the terms of the Hague-Visby Rules. The carrier is obliged to take all reasonable care to ensure a seaworthy vessel prior to and upon commencement of the voyage and the onus of proof in this respect lies on the carrier.
The relevant words in the Hague-Visby Rules are short, but very much to the point;

(a) The ship must be made seaworthy.
(b) The ship must be sufficiently crewed, equipped and provisioned.
(c) The holds, refrigerated cells and cool rooms and all other areas in which cargo can be transported must be made suitable and in good condition to receive and transport the cargo and keep it in a good condition.

In practice these obligations mean that the following requirements have to be met:
The ship must have valid (class) certificates; it must be possible for the holds to be properly closed; the hatch covers, pontoons, tarpaulins or patent hatches and fittings must be in good working order and able to function effectively; the same applies to every point affording access to the holds, such as manhole covers, doors, tank covers, air shafts or fans. In addition, the holds themselves must be thoroughly clean, whilst all measures must be taken that are required by the nature of the goods to be transported.

If the holds are checked prior to loading by an inspector representing the shipper, it is advisable for the ship's officers to have a written declaration drawn up, e.g. in the following words:

Date

To the Owners and the Master of the m.v.................

*** Bill of Lading dated...........................**

*** Charter Party dated............................**

Pott of Loading................................

On behalf of *Shippers/*Charterers I/we confirm that I/we have examined the cargo spaces in the above vessel and have found them in every way fit for the reception and carriage of..............[type of cargo].

Signed on behalf of
*** Shippers/* Charterers**

*** Delete what is not applicable.**

Obviously, a good beginning is half the battle. This is specifically true where the reasonable duty of care is concerned.

Measures to be taken during loading

We are now approaching the actual start of loading. This is the moment when the carrier is confronted with a following duty of care, viz. ensuring proper and careful loading, handling and stowage of the goods to be transported. As we have already said, the carrier's liability starts at least upon commencement of loading. But, at what exact moment? Often, it is assumed that this is the moment when the hoist passes over the ship's railing. But this is incorrect. The sole moment when loading actually commences is when the hooks are attached to the goods on the quayside. Consequently, if the cargo is being handled roughly on the quayside, this is the moment when the ship's officers can intervene to prevent any damage to the goods.
In view of the B/L a check should also be made of the number of units of the goods and this can only be done in one way: by making a tally. It is true that almost every B/L contains a clause relating to "unknown" factors: "weight, measurement, marks, numbers, quantity, contents and value unknown" or words to similar effect, but this proviso offers less of an escape clause than we would expect.
Even additional provisos which are regularly seen in practice, such as "said to weigh" or "said to contain", are terms which should be treated with caution, ex,cept in cases where the information specified by the shipper cannot reasonably be

checked. In these cases the cargo has not been counted, weighed or measured before being transferred to the care of the ship's officers, or the carrier cannot be deemed to be familiar with the nature or condition of the cargo.
If the cargo has been counted both by the ship's crew and by the quayside personnel and if the situation arises in which the shipboard tally is lower than the quayside tally, then it is advisable to make an annotation on the B/L with the following text:

> ".... packages less in dispute, if on board to be delivered".

During loading an accurate check must also be made of the external appearance and condition of the goods and, if they are supplied in an obviously damaged condition, a remark to such effect must be made on the B/L.
No standard texts can be given for this, as each cargo will require different remarks. If possible, it is always better if damaged goods can be replaced prior to loading by undamaged goods of the same type.
In addition to the carrier's responsibilities there are a number of matters in respect of which the carrier can exclude his liability. Several examples are given below.

Inadequate packaging

If the packaging is found to be inadequate upon loading, 3 remark will have to be made on the B/L The text might read as follows:

> *"All the carrier's rights and immunities in the event of loss of or damage to the goods arising by reason of the nature or quality of the packing and/or its insufficiency are hereby expressly reserved".*

Unpacked goods

The provisos in relation to insufficiently packed goods will certainly also have to be made in respect of goods which are not packed at all. Again, however, this will have to be noted down on the B/L. The remark might be worded as follows:

> *"The goods hereby acknowledged are unprotected and all the rights and immunities in the event of loss of or damage to the goods by reason of that fact are expressly reserved".*

Mate's receipts

The B/L is always drawn up after completion of loading. Usually this is done by the shipping agent. The information that has to be written on the B/L is provided by the shippers. In other words: the B/L has been filled in according to the wishes of the shippers. An effective check must therefore be made of the contents of the B/L before it is signed by or on behalf of the Master and before the signed B/L is released via the shipping agent to the shippers.

Apart from checking the general information, such as name of ship, port of loading and unloading, specification of the cargo, the quantity, and the date, the most important check involves making sure that the contents of the B/L are in agreement with the remarks made on the mate's receipts. When the goods are supplied for loading, it is customary for a mate's receipt for each (part) batch to be handed over to the first mate who can then inspect the supplied goods as to their external appearance and condition, i.e. the packaging, the temperature, the quality (if this is visible) and the number of units. Any remarks are noted down on the mate's receipt, after which this document is signed. The first mate retains a copy, so that the contents of the mate's receipts can be checked against the contents of the B/L which is presented at the end of the loading operation.

It is always in the interests of the shipper not to make any remarks on the B/L, as this means that he will be notifying his buyer that the goods have some defects or shortcomings. In most cases "clean" bills of lading have to be submitted in order to obtain the Letter of Credit. We can therefore more or less take it for granted that the remarks made on the mate's receipts will not in the first instance be included on the B/L. It is therefore essential that the shipping line and the Master should check everything very carefully and, in cases where the B/L is signed by the shipping agent on behalf of the Master, the authorisation to sign must be accompanied by a clear written instruction that all remarks on the mate's receipts must also be shown on the B/L.
In cases where no mate's receipts are supplied and where the goods show defects, the Master must write a protest letter setting out the

relevant remarks and declaring that, when the goods are loaded, these remarks will be written on the B/L

Cooled and refrigerated cargoes

In addition to the general obligations, cooled and refrigerated cargoes have to comply with several special requirements. The cargo can only be carried properly if the goods are supplied at the right temperature. The goods supplied must therefore be subjected to accurate checks to make sure that the temperatures are in accordance with the loading and carrying instructions of the shippers or charterers. If the temperatures deviate from the requirements, the goods must in principle be refused, as it will then be obvious in advance that the goods will not reach the port of unloading in a sound condition.

Deck cargo

The Hague-Visby Rules contain a provision which excludes deck cargo from the scope of the Treaty. From this it follows that the carrier must write down a remark on the B/L to exclude his liability for goods transported on deck. This remark should preferably be worded as follows:

"Carried on deck without liability for loss or damage howsoever caused".

Practical experience has shown that shippers sometimes tend to object to this remark. In such cases a solution might be to phrase the remark as:

"Shipped on deck at shipper's risk ".

This latter remark is, however, a minimum requirement, as the goods must be deemed to have been transported in the ship's holds. Obviously, the risk of loss of or damage to goods carried on deck is higher than in the case of stowage in the holds, Failure to make a remark about this will have far-reaching legal consequences for the carrier. He will in fact be strictly liable for any loss of or damage to the goods and he will have absolutely no excuse if he has failed to register his remarks. Lastly, it should be noted that the actual making of such a remark does not give the carrier the freedom to devote little or no attention to the cargo being carried on deck. In the final analysis his primary task is, after all, to watch over, protect and take good care of the goods entrusted to him.

Containers on deck

It is very common for containers to be carried on deck without the B/L incorporating any clauses relating to the containers loaded on deck. It is in fact a "custom of the trade" for containers also to be carried on deck, provided that the ship is adequately equipped for such purpose and meets the "container-fitted" requirement at least. To ensure that the carrier has a free hand, the containers are booked for carriage subject to the condition that the carrier has the option as to whether the containers should be carried on deck or below deck. This provision is regulated in the B/L by what is known as the "optional stowage" clause. Where a contract of this type is concluded, all containers are covered by the Hague-Visby Rules.

Letter of Indemnity

This now brings us to an area which unfortunately causes problems in seagoing shipping, i.e. the deliberate omission of remarks from the B/L, even where such remarks are essential so as to provide an accurate picture of the goods being transported on the ship, Basically, the problem is as follows. The international trade, in cooperation with the banks, provides a possibility for offering the consignee a guarantee of the goods he has bought and the shipper a guarantee of payment for the goods he has sold by means of a credit document (Letter of Credit).
In brief, this means that the consignee's and the shipper's bank will complete the transaction once all the conditions of the Letter of Credit have been met. Almost invariably, one of these conditions is that a "clean" bill of lading must be presented, i.e. one with no remarks. This is meant to provide the consignee with certainty that the goods have been loaded into the ship "in apparent good order and condition". But there is also another party involved, i.e. the carrier who is using the ship and who has to perform the purchase contract between the shipper and the consignee by transporting the goods from the port of loading to the port of unloading. The carrier in turn will make this transport subject to

his contract of carnage and will of course be very careful to ensure compliance with the terms of the B/L in which it is stipulated that the goods should be shipped "in apparent good order and condition". If the goods have been loaded in a partly damaged condition or if all or some of them have not been loaded on board, then the carrier will have to make remarks to such effect on the B/L so as to prevent himself from being held liable in the port of unloading for damage or loss which is basically the shipper's responsibility.

Where, then, does the crux of the problem lie? The shipper has two different contracts. The B/L is his contract with the carrier. The purchase contract represents only a contractual tie with his purchaser, in our case the consignee. This implies that both the shipper and the carrier have certain obligations to fulfil. As regards the B/L the most important obligation for the shipper is being to present a clean bill of lading to his bank so as to collect the purchase price. However, if it proves necessary for the carrier to make certain remarks on the B/L, then the shipper will do everything in his power to induce the carrier to issue a clean bill of lading after all.

In many cases the shipper will then offer a Letter of Indemnity (also known as a Back Letter), which states that the carrier is exonerated with regard to any possible damage which may result from the issue of a clean B/L despite the fact that the goods were already damaged when shipped or some of the goods were not shipped at all. Enormous pressure is often brought to bear on the carrier to accept such a letter.
Aside from possible commercial considerations or the belief that the shipper will provide the money or will abide by his promises, every offer of a Letter of Indemnity must definitely be refused, as such an action is regarded as tantamount to fraud. In this case the recipient of the goods is in fact being deliberately misled and deceived. Under Dutch legislation, for example, such fraud is classed as an offence under the shipping regulations and is punishable by a maximum fine of ten thousand guilders. Besides, the carrier also retains full liability as against the recipient of the goods for any damage and/or shortfall. And there is yet another risk: the carrier may also lose the cover of his P&I Club with which he has insured his liability, since the insurance policy does not provide cover for the consequences of accepting Letters of Indemnity as compared to the issue of a clean B/L. A second form of fraud which regularly occurs is the issue of a B/L with the wrong date, again aimed at providing a "service" to the shipper in connection with his obligations under the Letter of Credit.

The voyage

During the voyage the carrier is obliged, under the terms of the Hague-Visby Rules, to ensure the proper and careful transport, protection and care of the goods. This implies that the rules of good seamanship must be obeyed so as to prevent damage to or loss of the cargo.
Depending on the type of cargo, the ship's refrigerated and cooled cargo compartments should be properly operated and the holds should, where necessary, be ventilated.
In the case of cooled and refrigerated cargoes the shipper's instructions should be followed to the letter and temperature lists must be kept during the entire voyage so as to demonstrate that the carrier has taken proper care of the cargo and also to provide proof that the cooling/freezing installations on board the vessel have functioned effectively.

Perils of the sea

The Hague-Visby Rules contain an exemption provision to the effect that the carrier cannot be held liable for damage caused by unavoidable bad weather. The official words used in the Rules to describe this situation are: "perils of the sea or other navigable waters".
In the event of "perils of the sea" the carrier can appeal to the exemption clauses contained in the Hague-Visby Rules.
If the other party to the contract takes the view that the damage is not attributable to "perils of the sea" but believes that the rea cause of the damage is inadequate care on the part of the carrier, then such other party must be able to prove such breach of the duty of care.

Unloading

We are now approaching the end of the period of liability. According to the Hague-Visby Rules the carrier must ensure the proper unloading of the cargo so that the goods can be delivered in an undamaged condition. Here again, the carrier's liability does not end when the hoist passes the ship's railing but when unloading is actually completed. If the goods are handled roughly on the quayside and if such handling may give rise to damage, then this situation must be brought to an end immediately. Proper unloading also means that everything must be delivered in the same condition as it was supplied in the port of loading. If a shipboard tally was conducted in the port of loading, a tally will have to be held again during the unloading operation. In the case of certain loose bulk cargoes it is necessary for the cargo to be topped off with goods in sacks so as to guarantee the safety of the stow. During unloading these sacks are usually cut open but it is often forgotten to count the empty sacks. The result is that a claim is made against the ship for a shortfall in delivery of a number of sacks plus contents. It is therefore advisable to collect and count the empty sacks before they are delivered, after which the consignee or stevedore can sign for receipt. The delivery of goods is of course not limited to this one example. All empty packs should be counted and delivered in the same way.

Exemption provisions

In the foregoing we have dealt with the cases in which the carrier is or is not liable for loss of or damage to the goods being transported.

We have deliberately concentrated on those situations which occur most frequently in day-to-day shipping operations. However, there are a number of further matters which are regulated by the Hague-Visby Rules and in which the carrier is not held liable if loss of or damage to the goods is caused by:

- an act or omission by the Master or a subordinate in the navigation or handling of the ship; (explicitly, therefore, this does not refer to the handling or care of the cargo);
- fire;
- unavoidable natural events;
- acts of war;
- acts by enemies of the state;
- government measures;
- quarantine measures;
- an act or omission by the shipper of the goods;
- work stoppages/strikes;
- rebellion or not;
- the saving of human lives or goods at sea;
- a hidden defect or inherent vice in the goods themselves;
- insufficient or incorrect marks;
- hidden defects of the ship;
- some other cause, not being due to the personal negligence of the carrier or his subordinates.

Furthermore, the carrier is not liable for the consequences of a reasonable deviation (from the ship's course) where this is required for urgent reasons, e.g. for an essential repair or to take a sick person to shore on medical advice. Obviously, there can be no question of a course deviation being regarded as "reasonable" in cases where the carrier changes the ship's course solely for the purpose of securing a commercial advantage. If loss of or damage to the goods arises as a result of an unreasonable deviation from the course, then the carrier is liable in full. It should be clear that the carrier or the owner of the ship has a heavy responsibility towards those who have an entitlement to the cargo and that it will not always be easy to keep a cool head in the face of this responsibility.

Insurance

in respect of cargo loss or damage the Bill of Lading conditions usually determine the liability between the parties in the first instance. Thereafter recoveries and other liabilities, such as damage to the vessel, are determined by the clauses laid down in the Charter Parties.

Due to the high values of both cargoes and ships it is quite common that parties who are involved in a marine adventure seek insurance protection, which means that in the handling of claims insurance companies are usually involved on both sides. This being the case it is recommended to select a specialist marine insurance broker, as it will not only warrant that the financial risks are secured, but additional advice can be obtained to develop loss prevention programmes and logistics control systems.

TABLE 1

Table for converting degrees Celsius into degrees Fahrenheit

C	F	C	F	C	F	C	F
-40	-40.0						
-38	-36.4	11	51.8	41	105.8	71	159.8
-36	-32.8	12	53.6	42	107.6	72	161.6
-34	-29.2	13	55.5	43	109.4	73	163.4
-32	-25.6	14	57.2	44	111.2	74	165.2
-30	-22.0	15	59.0	45	113.0	75	167.0
-28	-18.4	16	60.8	46	114.8	76	168.8
-26	-14.8	17	62.6	47	116.6	77	170.6
-24	-11.2	18	64.4	48	118.4	78	172.4
-22	- 7.6	19	66.2	49	120.2	79	174.2
-20	- 4.0	20	68.0	50	122.0	80	176.0
-18	- 0.4	21	69.8	51	123.8	81	177.8
-16	+ 3.2	22	71 .6	52	125.6	82	179.6
-14	6.8	23	73.4	53	127.4	83	181.4
-12	10.4	24	75.2	54	129.2	84	183.2
-10	14.0	25	77.0	55	131.0	85	185.0
- 8	17.6	26	78.8	56	132.8	86	186.8
- 6	21.2	27	80.6	57	134.6	87	188.6
- 4	24.8	28	82.4	58	136.4	88	190.4
- 2	28.4	29	84.2	59	138.2	89	192.2
0	32.0	30	86.0	60	140.0	90	194.0
+ 1	33.8	31	87.8	61	141.8	91	195.8
2	35.6	32	89.6	62	143.6	92	197.6
3	37.4	33	91 .4	63	145.4	93	199.4
4	39.2	34	93.2	64	147.2	94	201.2
5	41.0	35	95.0	65	149.0	95	203.0
6	42.8	36	96.8	66	150.8	96	204.8
7	44.6	37	98.6	67	152.6	97	206.6
8	46.4	38	100.4	68	154.4	98	208.0
9	48.2	39	102.2	69	156.2	99	210.2
10	50.0	40	104.0	70	158.0	100	212.0

TABLE 2

Heat of respiration of fruits and vegetables (kj/kg. 24 h)

Product	0°C	5°C	15°C
apples (fast ripening)	0.8- 1.5	1.3- 2.7	4.6 - 8.0
apples (slowly ripening)	0.5 - 0.9	1.2- 1.8	3.2 - 5.0
oranges	0.4 - 0.9	0.9- 1.6	3.1 - 4.8
apricots	1.3- 1.5	2.8 - 4.8	7.5'- 13.4
bananas, green	—	1.9- 4.4	5.2 - 11,3
bananas, ripe	—	3.4 - 5.0	7.5- 14.2
pears (slowly ripening)	0.7 - 0.9	1.5- 3.6	7.1 - 10.9
pears (fast ripening)	0.7- 1.3	1.9- 4.0	8.8 - 13.8
strawberries	2.9 - 4.0	3.8 - 8.0	11.3 -20.9
cherries	1.3- 2.1	1.9- 3.1	7.1 - 15.1
melons "	2.7 - 3.3	3.6 - 4.4	9.4 - 16.3
peaches	1.1 - 1.6	2.2 - 3.5	7.5 - 11.3
plums	1.2- 1.8	2.5 - 5.7	6.3 - 15.9
plums yellow	1.6- 1.7	3.1 - 5.4	6.7 - 15.1
grapes	0.4 - 0.8	0.9- 1.7	2.1 - 4.1
lemons	0.5 - 0.8	0.9- 1.7	2.1 - 4.1
cauliflower	2.1 - 5.4	4.6 - 6.7	16.7 - 22.4
beans	4.9 - 6.1	9.0 - 10.5	22.8 - 35.6
peas	7.5 - 9.0	13.4 - 16.3	31.4 - 39.8
mushrooms	9.8 - 10.4	12.8 - 13.8	40.2 - 41.9
cucumber	1.6- 1.8	2.1 - 2.9	8.2 - 10.5
carrots	0.8 - 2.4	2.4 - 3.3	6.3 - 8.4
carrots with foliage	4.4	5.4	13.1
potatoes	0.9 - 2.3	1.0- 1.7	1.7- 3.1
rhubarb	2.9 - 3.3	4.0 - 4.6	9.4 - 10.9
spinach	5.2 - 7.1	11.1 - 17.2	36.6 - 45.2
tomatoes	1.2- 1.5	1.7- 2.3	4.6 - 7.5
asparagus	5.0 - 5.7	6.7 - 7.3	17.8 - 24.1

TABLE 3

CO_2-development of fruits (g/ton. 24 h)

Product	0°C	5°C	15°C
apples	75 - 100	120 - 200	500 - 750
bananas	—	—	360 (12°C)
pears	75 - 100	120 - 250	1000 - 1500
oranges	60- 80	100 - 200	200 - 350

TABLE 4

Specific heat and freezing point

	percentage of water %	specific heat		heat of solidification kJ/kg	freezing point °C
		before freezing kJ/(kg K)	after freezing kJ/(kg K)		
Vegetables					
- beans	89	3.85	1.97	297	-1.25
- peas	82 - 76	3.35	1.76	251	-1.09
- carrots	90- 83	3.64	1.88	276	-1.35
- potatoes	77	3.35	1.76	243	-1.71
- cabbage	92 - 86	3.89	2.01	306	-0.42
- asparagus	94	3.89	1.97	314	-1.22
- tomatoes	95	3.89	2.05	314	-0.90
- onions	89-50	3.81	1.93	268 - 297	- 1 .66/ -1.95
Fruits					
- apples	87 - 83	3.85	1.76	281	-2.0
- oranges	86	3.85	1.84	285	-2.23
- bananas	75	3.35	—	251	-1.2
- pears	85	3.85	1.76	281	-2.2
- strawberries	91	3.85	1.97	300	-1.16
- cherries	86	3.64	1.84	276	-2.35
- melons	94	3.85	1.93	297	—
- peaches	88	3.85	1.72	293	-1.45
- grapes	82	3.68	1.88	264	-2.15
- lemons	91	3.85	1.93	276 - 297	-2.16
Meat					
- beef, lean	74	3.22	1.76	234	-1.0
- beef, fat	58	2.55	1.49	172	
- veal, fattened	73	3.05	1.67	216	
- mutton, lean	57	3.15	1.72	228	
- mutton, fat	46	2.82	1.47	187	
- pork, lean	67	3.40	1.40	240	
- pork, fat	50	2.54	1.34	154 - 182	
Sea Fish					
- fresh, lean	79- 73	3.43	1.80	255	-1.0
- fresh, fat	65 - 60	2.84	1.59	209	
- smoked	65 - 55	3.18	—	—	
- dried	25 -20	2.26	1.42	151	
Dairy Products					
- milk	88	3.94	2.51	293	-0.55
- butter	14 - 15	2.51 - 2.68	1.26	197	
- margarine	15	2.72 - 2.93	1.47	126	
- quark	81 - 75	2.93	1.88	268	
- cheese, lean	55- 50	2.85	1.67	176	
- cheese, full cream	50 -41	1.88-2.51	1.26	109- 155	
Miscellaneous					
- chocolate	1.6	3.18	—	84 - 126	
- ice cream	74-60	3.43	1.88	218	

TABLE 7

Hold temperature and storage time of perishable commodities

Commodity	Storage temperature °C	Highest freezing point °C	Relative humidity %	Ethylene production (1)	Ethylene-. sensitive (2)	number of air changes (3)	Approximate storage time in days
FRESH FRUITS:							
Apple							
non-chilling sensitive	-1 to 1	-1.5	90 - 95	vh	h	h	90 - 240
chilling sensitive	4.5	-1.5	90 - 95	vh	h	h	40 - 45
Avocado	5 to 10	-0.3	85 - 90	h	h	h	14- 28
Banana	11 to 15	-0.8	85-95	m	h	h	7- 28
Berries							
Blueberry	- 0.5 to 0	-1.3	90-95	l	l	vl	10 - 20
Cranberry	0 to 2	-0.9	90 - 95	l	l	vl	28 - 60
Gooseberry	-0.5	-1.1	90 - 95	l	l	vl	14 - 28
Coconuts	0 to 1	-0.9	80-85	l	l	n	30 - 60
Grapefruit	10 to 16	-1.1	85-90	vl	m	m	28- 42
Grapes (Am.)	- 0.5 to 0	-1.3	85 - 90	vl	l	vl	14 - 56
Grapes (Europe)	- 1 to - 0.5	-2.2	90 - 95	vl	l	vl	70 - 150
Kiwifruit	0	-0.9	90-95	l	h	h	28 - 84
Lemon	10 to 14	-1.4	85 - 90	vl	m	m	30 - 180
Mango	13	-0.9	85 - 90	m	h	m	14- 25
Nectarine	-0.5	-0.9	90-95	h	h	m	14- 28
Oranges	0 to 8	-0.8	85-90	vl	m	m	20- 85
Peaches	- 0.5 to 0	-0.9	90-95	h	h	h	10 - 28
Pear	- 1 toO	-1.6	90 - 95	h	h	m	60 - 180
Pineapple	10 to 12	-1.0	85 - 90	l	l	vl	14- 30
Plums	- 0.5 to 0	-0.8	90 - 95	m	h	m	14 - 28
Tangerines & Mandarines	7	-1.1	85 - 90	vl	m	m	14 - 28
Melons							
Cantaloupes	4	-1.2	85-90	h	m	m	8- 14
Honeydew	7 to 10	-1.0	85-90	m	h	m	21 - 28
FRESH VEGETABLES:							
Artichoke, globe	0	-1.2	90 - 95	vl	l	l	10 - 16
Artichoke, Jerusalem	0	-2.5	90 - 95	vl	l	vl	80 - 150
Asparagus	Oto2	-0.6	90-95	vl	m	m	14 - 21
Beans	5 to 7	-0.7	90 - 95	l	m	m	7- 12
Broccoli	0	-0.6	90 - 95	vl	h	h	10 - 14
Brussel sprouts	0	-0.8	90 - 95	vl	h	h	21 - 35
Cabbage, Chinese	0 to 1	-0.9	95	vl	h	m	30 - 60
Carrots, topped	0	-1.4	95	vl	l	vl	30 - 180
Cauliflower	0 to 1	-0.8	90 - 95	vl	h	h	20 - 30
Celery	0	-0.5	90 - 95	vl	m	m	14- 28
Chicory	0 to 1	-1.2	95	vl	h	h	14- 28
Cucumbers	10 to 13	-0.5	90-95	l	h	m	7 - 14
Garlic	0	-0.8	65 - 70	vl	l	vl	150 - 200
Kohlrabi	0	-1.0	95	vl	l	vl	15 - 30
Leeks, green	0	-0.7	95	vl	m	l	30- 90
Lettuce, head	Oto 1	-0.2	95	vl	h	h	14 - 20
Onions, dry	0	-0.8	65 - 75	vl	l	l	30 - 200
Peppers	7 to 10	-0.7	90 - 95	l	l	l	7- 18
Potatoes, processing (chips)	10	-0.8	90 - 95	vl	m	l	60 - 1 70
Potatoes, table quality	4 to 6	-0.8	90-95	vl	m	l	60- 160
Radishes, (topped)	0	-0.7	95	vl	l	vl	14 - 21
Rhubarb	0 to 1	-0.9	95	vl	l	vl	14 - 21
Spinach	0	-0.3	95	vl	h	m	10 - 24
Tomatoes, green	8 to 13	-0.5	90-95	vl	h	m	20 - 30
Tomatoes, ripe	Oto 1	-0.5	80 - 90	m	h	m	10 - 14

;1) vh = very high
h = high
m = moderate
l = low
vl = very low

(2) v = very
m = moderately
l = low

(3) n = none
l = low
v = very low
m = medium
h = high

TABLE 8

Hold temperature and storage time of frozen cargoes

Commodity	Storage temperature (°C)	Freezing point (average)	Relative humidity %	Approximate storage time in days
Butter	- 1 to 4	-2.2	75-85	18 - 40
Butter (frozen)	- 23 to - 10		80 - 85	150 - 360
Cheese	0 to 4.5	- 10 to - 3	65 - 70	180 - 360
Eggs	- 1.5 to 0.5	-1.7	85 - 90	150 - 200
Eggs, frozen	- 18			360
Fish, fresh	- 0.5 to 1	- 1.5	90-95	5 - 15
Fish, frozen	- 23 to - 18	—	90- 95	180 - 360
Ice cream	- 26 •	- 6		90 - 360
Meat				
Beef, lamb, pork, veal (fresh)	- 1 to 1	_ 2	85- 90	7- 28
Beef, lamb, pork, veal- (frozen)	- 23 to - 18		90 - 95	150 - 300
Poultry, fresh	- 1 to 0.5	-2.5	85-90	8
Poultry, frozen	- 23 to - 18		90 - 95	200 - 300

TABLE *9*

Storage recommendations for bulbs, corms, and tubers

Commodity	temperature (°C)	Approximate storage life in days	Highest freezing point (°C)
Amaryllis	5 to 10	180	- 0.6
Anemone	20 to 25	60 - 90	—
Crocus	10 to 18	60 - 90	—
Dahlia	5 to 9	180 - 210	- 2
Freesia	25 to 30	120 - 150	—
Hyacinth	12 to 20	90- 180	- 1.5
Iris	15 to 25	120 - 360	
Lily	O to 1.5	120 - 240	- 1.7
Narcissus	10 to 17	120 - 180	- 1.7
Tulip (for forcing)	8 to 15	120 - 180	-2.5

Desirable relative humidity for storage of most bulbs and related materials is 70% to 75%.

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A list of the relevant literature consulted in compiling this book can be found on page 343.
Despite every care taken in this book's preparation, an illustration or passage may have been inadvertently included without consultation or source reference. In such case I would not only give my acknowledgment but also my apologies.

Capt. A.W.C. Alders