Refrigerants

by
C. Maheshwar

In this article, we examine the various aspects of Refrigerants. In particular, we have a look at the various changes that a Refrigerant undergoes as it passes through the various components of a Refrigeration System. We also look at the history timeline of the evolution of refrigerants, various types of refrigerants, nomenclature of refrigerants, environmental impact of refrigerants, compatibility of refrigerants with lub oil and effects of moisture on refrigerant and oil quality and the importance of personnel safety when handling refrigerants and working in refrigerated spaces. We consider the various aspects regarding the refrigerant charge required for a Container Refrigeration Machinery, procedure of recovery of refrigerants and change over of refrigerant from CFC to HFC.

1. REFRIGERANT

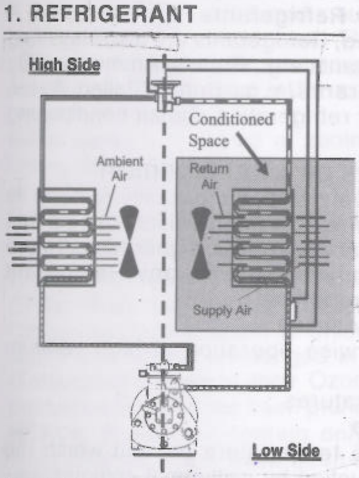


Fig. 1 Flow of Refrigerant through the Refrigeration System

A Refrigerant is a medium to move heat. It is the substance which flows inside the coils or tubes and through the various components of the Refrigeration equipment.

A **Refrigerant** is a substance which evaporates at low temperature and pressure by absorbing heat from surroundings which are at a higher temperature and condenses at high temperature and pressure by giving away heat to the surroundings which is at a lower temperature. It is a substance that **gives up Heat** by **Condensing** at High Temperatures and Pressures and **absorbs Heat** by **Evaporating** at Low Temperatures and Pressures.

2. FLOW OF REFRIGERANT THROUGH THE REFRIGERATION CIRCUIT

2.1 Evaporator

If the temperature of the cargo space is required to be maintained at a temperature of -15ºC, the refrigerant entering the evaporator should be at a temperature less than the required temperature. Only then, can it absorb heat from the chamber. It enters the **Evaporator** as Saturated Mixture (80% liquid and 20% Vapour, in the form of Flash Gas)) at low pressure. In the Evaporator, as the Refrigerant absorbs heat from the chamber, it gets converted into 100% vapour. (That is why it is called an evaporator). Temperature goes a little more than the Saturated Temperature at that Pressure making it slightly superheated. This is to ensure that only vapour goes into the Compressor in all circumstances. The degree of superheat is maintained within a specific range by the Expansion Valve whose sensing bulb, situated at the end of Evaporator, gives a pressure signal to the Expansion Valve to open or throttle the refrigerant flow through the Expansion Valve.

2.2 Compressor

In the **Compressor** the low pressure, low temperature refrigerant in the form of Superheated Vapour, gets compressed into High Pressure, High Temperature Superheated Vapour. The pressure of the refrigerant gets raised, heat is induced into the refrigerant, external work is done on the refrigerant, raising its energy level. Compression is done using power from an electric motor, the compressor being coupled to the motor. The motor needs electric power for its running. After the compression, the refrigerant leaves the compressor in the form of high pressure, high temperature superheated vapour and enters the condenser.

2.3 Condenser

Condenser is a heat exchanger using atmospheric air (air cooled condenser) or water (water cooled condenser) as the cooling medium.

Since the temperature of the atmospheric air or water is much lower than the temperature of the refrigerant which is in the form of superheated vapour after it exits from the compressor, it gives away the heat to the air or water. First, it loses the superheat which is a form of sensible heat and becomes a Saturated Mixture. As it progresses through the Condenser Coil, it loses further heat till all the latent heat is lost and it becomes completely liquid. Before it finally exits the Condenser Coil, it loses further heat giving up sensible heat and becomes Subcooled to a certain degree. Thus, when it exits from the Condenser coil, it is in the form of Subcooled Liquid. The efficiency of heat transfer in the condenser from the refrigerant to the ambient air or water, is dependent upon the temperature difference between the two and cleanliness of the heat transfer surfaces of the condenser. A condenser coil with choked or dirty fins will impede the air flow and sufficient amount of heat transfer does not take place across the condenser coil causing a drop in efficiency. For an air cooled condenser, there must be a free flow of air across the condenser coils. For a water cooled condenser, there must be sufficient amount of water flow across the condenser.

The efficiency of heat transfer across a condenser coil is enhanced by providing one or more electric driven fans which suck in ambient air through the condenser coil and throw the hot air back into the atmosphere. Thus, as we pass alongside a running reefer container machinery, and we get a blast of hot air with good air throw, we can presume that heat transfer across the condenser is satisfactory. Similarly, if the difference in the temperatures of inlet and outlet water of a water cooled condenser is substantial, it means that the heat transfer across the condenser is satisfactory.

2.4 Expansion Valve

An **Expansion Valve** is an orifice through which the refrigerant is allowed to pass and expand. When the refrigerant expands, the pressure falls substantially and the Saturation Temperature also falls. Part of the refrigerant absorbs heat from the remaining refrigerant and converts itself into vapour, known as Flash Gas, causing formation of Saturation Mixture at low Pressure. Thus what comes out of the Expansion Valve is a low pressure Saturated Mixture, which is at Saturation Temperature and at low pressure.

This Low Pressure Saturated Mixture from the Expansion Valve enters the **Evaporator** and the cycle continues further.

3. HISTORY TIME-LINE OF REFRIGERANTS

- 3000 BC- an Assyrian merchant had the walls and floor of a room below his courtyard sprayed with water in hot weather.
- 775 AD- Caliph Madhi of Baghdad had a summer residence built with double walls between which imported snow was packed.
- Industrial Revolution of 1700s and the machinery age intensified the heat problem due to increased number of machines in enclosed areas of factories.
- 1748 - Dr. William Cullen did research on creating cold by evaporating a liquid.
- 1851 - First Ice Making Machine was patented by Dr. John Gorrie
- 1902 - Sir Willis Carrier succeeded in reducing air humidity and controlling moisture content. First scientific air conditioning system was created.
- 1903 - Ammonia and CO2 machines were made. Calcium Chloride also being used, Carbon Tetra Chloride was tried out but was discarded as it attacked metals.
- 1920 - Sir Willis Carrier was looking for a liquid with Boiling Point of around 110 deg F and high molecular weight. He found dielene (C2H2Cl2), the first CFC to be used as a Refrigerant.
- 1930s - Freons came into existence. CH2Cl2 Methiliene Chloride was created. Freon was the brand name of DuPont. R-11, R-12, R-113, R-114 and R-22 were created.
- 1940s - World War II extensively utilized refrigeration technology for transport of frozen food and blood plasma for troops and other medical applications. R-13 created.
- 1950s - R Numbering system introduced. R-14 created.
- 1960s - R-502 introduced. Ultra low temperature applications of refrigeration introduced to maintain temperatures below – 100°F.
- 1970s -Ozone Depletion Theory propounded. R-134a introduced as non-ozone depleting refrigerant, HFC.
- 1980s - Montreal Protocol of 1987 imposes severe sanctions on ozone depleting CFCs. R-134a replaces R-12 in most of the applications.
- 1990s - HCFCs-R-407C, 408A, 409A, 410A introduced. 1996-CFCs phased out in US.
- 2000s - Ammonia and Hydrocarbons like Propane and Butane make a comeback as Refrigerants due to their environment friendly characteristics.

4. CLASSIFICATION OF REFRIGERANTS

4.1 Halocarbon and Non-Halocarbon Refrigerants

Halocarbon Refrigerants are predominantly from a group of compounds called **halocarbons,** consisting of an element from the Halogen Group of elements (Fluorine, Chlorine, Bromine and Iodine) **combined** with a Hydrocarbon Compound. These may be either **Methane Derived** like R-11, R-12, R-22 etc., or **Ethane Derived Refrigerants** like R 113, R 114, R 115 etc., **Non-Halocarbon Refrigerants** do not contain any Halogen element nor hydrocarbon content e.g., Water, Ammonia, CO_2, Dry ice, etc.

4.2 CFCs, HCFCs and HFCs

Based on **Number of Chlorine atoms** present and consequent **Impact on the Environment, Halocarbon based** Refrigerants can also be further classified into 3 types: **CFCs** - R-11, R-12, **HCFCs** - R-22, R-404a and **HFCs** - R-134a.

4.3 Pure and Blended Refrigerants

Based on **Composition,** Refrigerants can be classified into 2 types: **Pure Refrigerants** which are made by modification of a single base Hydrocarbon molecule e.g., R-11, R-12, R-22, R-113, R-114, R-123, R-124, R-125, R-134a etc. and **Blended Refrigerants** made by a mixing of 2 or more pure refrigerants e.g., R-404a, R-407c, R-500, R-502, R-503, R-507, R-410a etc.

4.3.1 Azeotropic, Near Azeotropic and Zeotropic Refrigerants.

Blended Refrigerants are classified further based on Evaporation and Condensation Point into 3 types: Azeotropic, Near Azeotropic and Zeotropic.

Azeotropic

Blends of multiple refrigerants that condense and evaporate at a constant pressure e.g., R-500, R-502, R-503, R-507 etc.

Near Azeotropic

Blends of multiple refrigerants that have a very small difference in glide temperature i.e., the different constituents boil off at varying rates, producing a temperature glide e.g., R-410a etc.

Zeotropic

Blends of multiple refrigerants that condense and evaporate over a range (glide) at a constant pressure e.g., R-404a, R-407c etc.

4.3.2 Temperature Glide Effects

In systems using **zeotropic** refrigerant blends with a relatively high temperature glide, the more volatile components will escape first if there is a leak while the system is shutdown. This process is called *fractionation*. However, while the unit is operating, the action of the compressor and expansion device tend to keep the refrigerant blended and a leak is less likely to result in fractionation. Furthermore, fractionation complicates the refrigerant charging process.

In systems utilizing **azeotropic** refrigerant blends, there will be no fractionation since all components will tend to escape at similar rates, if there is a leak in the system.

4.4 Primary and Secondary Refrigerants

Based on **Application Method,** Refrigerants are also classified into 2 types: Primary Refrigerants e.g., Freons, Ammonia, CO_2 etc and **Secondary Refrigerants,** e.g., Brine, Chilled Water, etc., which are used in larger refrigeration and air conditioning installations.

5. DESIRABLE PROPERTIES OF A REFRIGERANT

In order to efficiently, effectively and economically perform its function of removing heat from a place and discharging it into a place which is unobjectionable and at a higher temperature against the natural thermodynamic flow, any Refrigerant should have the following properties:

1 High Latent Heat of Vaporisation
2 Low Boiling Point, otherwise operation at high vacuum becomes necessary.
3 Low Condensing Temperatures
4 High Critical Temperature

Critical Temperature is the temperature beyond which the refrigerant gas cannot be liquefied by isothermal compression.

5 Non Corrosive
6 Stable under all operating conditions
7 Non flammable and non-explosive
8 Non toxic
9 Compatible with material being used
10 Easy leak Detection
11 Eco friendly
12 Cheap, easily available and easily stored

6. R NUMBERING SYSTEM

All **Fluorocarbon-halocarbon** based Refrigerants are referred to by their **R–number**. They are made by replacing one or more Carbon atoms in the base Hydrocarbon, with Flourine and Chlorine. Based on the number of Chlorine atoms present, Refrigerants may be classified into 3 types:

6.1. CFCs (Chlorofluoro Carbons)

Which contain more than one Chlorine atom, i.e., more than one Hydrogen atom in the base Hydrocarbon (Methane or Ethane) has been replaced with a Chlorine atom e.g., R-11., R-12 etc. All Refrigerants have one Carbon atom as their origin is from Methane

(CH_4) or Ethane (C_2H_6) where one or more Hydrogen atoms have been replaced with Chlorine, Fluorine or Bromine.

6.1.1 Methane (CH_4) Derived Refrigerants: R number consists of two figures, e.g., R-11, R-12, R-13, R-14, R-21, R-22, R-23 etc. First figure shows the number of Hydrogen atoms plus one. Second figure shows the number of Fluorine atoms. The number of Chlorine atoms is not shown in the R number. The sum total of Hydrogen and/or other replacement atoms should be equal to 4.

R-11: CCl_3F

R-12:CCl_2F_2 DichlorodifluoroMethane

6.1.2 Ethane (C_2H_6) Derived Refrigerants

R number consists of three figures, e.g., R-113, R-114, R-115 etc. First figure shows number of C atoms minus 1, Second figure indicates the number of H atoms plus 1, The third figure indicates the number of F atoms. If the number of Cl atoms is not mentioned, the sum total of all the replacement atoms should be equal to 6.

R-113- $CCl_2F/CClF_2$ 1,1,2 Trichloro1,2,2 Trifluoro ethane

R-114- $C_2Cl_2F_4$ 1,2 Dichloro 1,1,2,2 Tetrafluoroethane

The numbering system is similar to Halons.

6.2 HCFCs (Hydrochloro Fluoro Carbons) which contain one chlorine atom. They could be either Mehane derived e.g., R-22, ($CHClF_2$), or Ethane derived e.g., R-124 $CHClFCF_3$, R-404a, etc., which is a mixture of 3 ethane derived refrigerants.

6.3 HFCs (Hydro Fluoro Carbons) which do not contain any Chlorine atom. e.g., R-134a (CF_3CH_2F), etc.

6.4 Summary of R-numbering system

Rightmost digit - Number of fluorine atoms per molecule.

Tens digit - One plus the number of hydrogen atoms per molecule.

Hundreds digit - The number of carbon atoms minus one. Omitted for methyl halides, which have only one carbon atom.

A suffix with a capital B and a number, indicates the number of bromine atoms, when present. This is rarely used. Remaining bonds not accounted for are occupied by chlorine atoms.

A suffix of a lower-case letter a, b, or c, indicates increasingly unbalanced isomers.

R-400 series is made up of zeotropic blends (those where the boiling point of constituent compounds differs enough to lead to changes in relative concentration due to fractional distillation).

R-500 series is made up of azeotropic blends.

7. IMPACT OF REFRIGERANTS ON ENVIRONMENT

7.1 Chlorine Based Refrigerants

CFCs: When they are released into the Atmosphere destroy the Ozone layer by the action of Chlorine. They are chemically very stable and remain unchanged in the lower atmospheric layer (Troposphere). Due to their Ozone Depleting nature, use and production of CFCs has been prohibited by the Montreal Protocol.

HCFCs: Since they contain only one Chlorine atom, as the other chlorine atoms have been replaced by Hydrogen atoms, they are considered to be more environmentally friendly, compared to CFCs. Use and production of HCFCs has been permitted till 2020, but it is likely that the phase out time of HCFCs will be advanced to 2010.

HFCs: They do not contain any Chlorine atom, as all the Chlorine atoms had been replaced by Hydrogen atoms. These are considered to be most environmentally friendly and are widely promoted to be the accepted refrigerants for the future.

7.2 Process of Ozone Depletion

- Upon reaching the Stratosphere, CFCs and HCFCs encounter high energy Ultra Violet light which breaks them, releasing Chlorine atoms. One Chlorine Atom can destroy upto 100,000 ozone molecules before the chemical processes remove the Chlorine from the Atmosphere. Further, it can remain in the atmosphere for over a 100 years.
- Chlorine in the Stratosphere gets trapped in so called reservoir compounds such as Hydrogen Chloride and Chlorine Nitrate, which themselves do not destroy Ozone.
- Once the Stratosphere becomes cold enough to freeze closed particles, ice crystals provide surfaces on which reactions can occur. Chlorine Nitrate reacts with Hydrochloric Acid present on the ice surface, producing molecular chlorine and Nitric Acid.
- Nitric Acid remains bonded to the ice and molecular Chlorine is quickly broken down into Atomic Chlorine which reacts with Ozone, destroying it through the production of chlorine Monoxide and Molecular Oxygen.
- Chlorine Monoxide undergoes further reactions that reform a chlorine atom which is free to destroy another Ozone molecule.
- The Ozone depletion process is accelerated in the presence of sunlight and low temperatures

7.3 Chlorine Levels in the Stratosphere

- 1970 - 1.2 parts per billion
- 1985 - 3.0 parts per billion
- 2050 projected - 8.2 parts per billion

7.4 What happens if the Atmospheric Ozone Layer gets depleted?

- Ultra Violet rays from sunlight can reach the Earth and can damage the human immune system, cause cataracts, and increase incidence of skin cancer.
- Every 1% depletion of the Stratospheric Ozone, results in 2% rise in skin cancer.
- In the USA, about 3,000,000 to 4,000,000 new cases of skin cancer are reported every year.
- Effects on Plants: Reduced leaf size, stunted growth, poor seed quality, susceptibility to weeds, disease and pests.
- Marine Food Chain can be killed with significant UV Radiation.
- Lesser amounts of UV Radiation causes slowdown of Photosynthesis.

7.5 Key Refrigerant Characteristics Affecting Environment

7.5.1 Ozone Depletion Potential (ODP): R-134a and R-404a have Zero ODP, R-12 has ODP of 1, R-22 of 0.05, R-502 of 0.33.

7.5.2 Global Warming Potential (GWP): This calculation considers only the direct effect of the refrigerant as a greenhouse gas when it escapes into the atmosphere. It is referenced against CO_2 where CO_2 is equal to 1. R-404a has a much higher GWP, representing upto 5% of TEWI compared to R-134a. R-12 has a GWP of 4500; R-152a has 120 and R-134a has 420; R-22 has 510 and R-502 has 4000.

7.5.3 Atmospheric Life (years)

R-11 has an atmospheric life of about 50 years, R-12 of 130 years, R-134a of 16 years, R-22 of 15 years, R-502 greater than 200 years, R-115 of 1,700 years and so on.

7.5.4 Total Equivalent Warming Impact (TEWI)

This is a measure of a refrigeration system's atmospheric impact that combines the effects of the refrigerant's direct effects on global warming with the indirect effects associated with the production of electricity for the reefer unit, through the combustion of fossil fuels or otherwise. TEWI integrates the global warming impacts of an equipment's energy consumption and refrigerant emissions into a single number, usually expressed in terms of CO_2 mass equivalents. The calculated TEWI for any given piece of air conditioning and refrigeration equipment is based on estimates for: (1) the quantity of energy consumed by the equipment over its lifetime, (2) the mass of carbon dioxide produced per unit of energy consumed, (3) the quantity of refrigerant released from the equipment over its lifetime, and (4) the global warming potential of that refrigerant expressed in terms of CO_2 mass equivalent per unit mass of refrigerant.

7.5.5 Threshold Limit Value (TLV)

This is a measure of supporting life and suitability of a working atmosphere. R-12, R-152a and R-134a have a TLV value of 1000.

7.5.6 Montreal Protocol

7.5.6.1 Genesis

This issue of ozone first discussed by the Governing Council of the United Nations Environment Programme (UNEP) in 1976. A meeting of experts on the ozone layer was convened in 1977, after which UNEP and the World Meteorological Organisation (WMO) set up the Coordinating Committee of the Ozone Layer

(CCOL) to periodically assess ozone depletion. Inter governmental negotiations for an international agreement to phase out ozone depleting substances started in 1981 and concluded with the adoption of the Vienna Convention for the Protection of the Ozone Layer in March 1985. The Vienna Convention encourages intergovernmental co-operation on research, systematic observation of the ozone layer, monitoring of CFC production, and the exchange of information. The Convention commits its Parties to take general measures to protect human health and the environment against human activities that modify the ozone layer. The Vienna Convention, however, is a framework agreement and does not contain legally binding controls or targets.

Following the discovery of Antarctic ozone hole in late 1985, governments recognized the need for stronger measures to reduce the production and consumption of a number of CFCs and several Halons. Consequently, the Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in September 1987 and came into effect in 1990.

7.5.6.2 The Legislation

- The Montreal Protocol was signed under the auspices of IMO on 16th September, 1987 and later ratified by 36 nations, including the United States.
- It seeks to inhibit production, consumption and trade of ozone depleting compounds.
- Also distinguishes between developed countries with higher consumption and developing countries with lower countries.
- It established guidelines for alternate refrigerants and set appropriate time-tables for phasing out chlorine based refrigerants.
- It was designed so that the phase out schedules could be revised on the basis of scientific evidence and technological assessments.
- It seeks to establish a financial mechanism in the form of a Multilateral Fund for paying agreed incremental costs incurred by developing countries in phasing out their consumption and production of ODS.

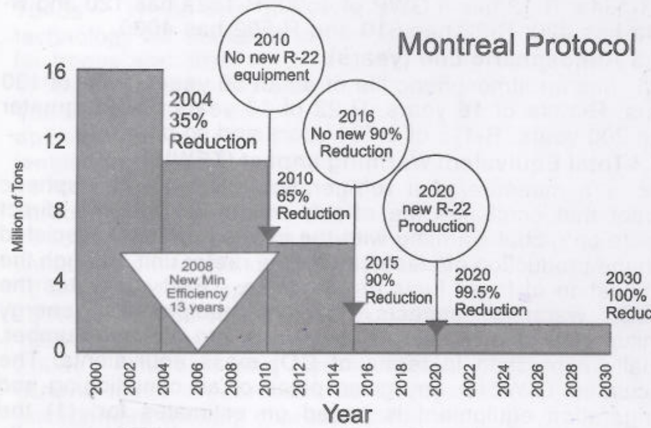


Fig. 2 HCFC Phase Out Timeline Schedule. *Source: Carrier Corporation*

The Montreal Protocol seeks to control 96 chemicals which include the following:

- Halocarbons, notably Chlorofluorocarbons (CFCs) and Halons
- Carbon tetrachloride
- Methyl chloroform
- Hydrobromofluourocarbons (HBFCs)
- Methyl Bromide
- Bromochloromethane (BCM)

The phase out schedules for **developed countries** are as follows:

- Phase out Halons by 1994.
- Phase out CFCs carbon tetrachloride, methyl chloroform and HBFCs by 1996.
- Reduce Methyl Bromide by 25% by 1999, 50% by 2001, 70% by 2003 and phase out by 2005.
- Reduce HCFCs by 35% by 2004, 65% by 2010, 90% by 2015, and 99.5% by 2020, with 0.5% permitted for maintenance purposes only until 2030.
- Phase out HBFCs by 1996 and phase out BCM immediately.

The phase out schedules for **Developing Countries** are as follows:

- Phase out HBFCs and BCM immediately.
- Freeze CFCs, Halons and Carbon tetrachloride at average 1995-97 levels by 1 July, 1999, reduce by 50% by 2005, 85% by 2007, and phase out by 2015.
- Freeze methyl chloroform by 2003 at average 1998-2000 levels, reduce by 30% by 2005, 70% by 2010, and phase out by 2015.
- Freeze methyl bromide by 2002 at average 1995-98 levels, reduce by 20% by 2005, and phase out by 2015.
- Freeze HCFCs by 2016 at 2015 levels and phase out by 2040.

The phase out schedules cover both the production and consumption of the target substances. However, even after phase out, both developing and developed countries are permitted to produce limited quantities in order to meet the essential uses for which no alternatives have been identified, eg, the use of CFCs in metered dose inhalers for asthma. production is defined as total production minus amounts destroyed or used as chemical feedstock. Consumption is defined as production plus imports minus exports. Trade in recycled and used chemicals is not included in the calculation of consumption in order to encourage recovery, reclamation and recycling.

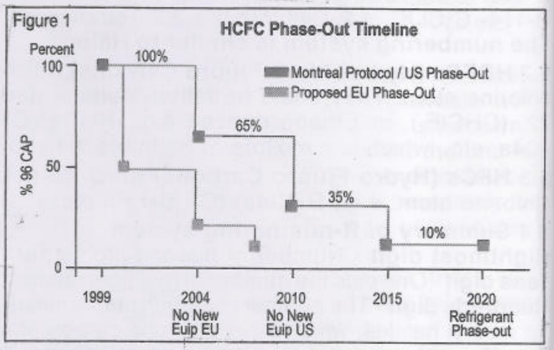


Fig. 3 HCFC Phase Out – Montreal Protocol vs EU Schedules. *Source: Copeland Corporation*

7.5.6.3 International Compliance

Although all the signatories of the Montreal Protocol are guided by the Protocol itself, in the EU and in ma198ny individual countries, the legislation exceeds these requirements, imposing far stringent requirements.

Developing countries, however, are not obliged to halt the production of CFCs until 2010 which has given rise to anomalies. Supply of R-12 in US has reduced considerably with substantial increase in prices. But, in neighbouring countries like Guatemala, R 12 is available very cheap. Eleven countries have not yet ratified the Protocol and the subsequent amendments. Some countries with economies in transition are having difficulty complying with Montreal Protocol.

Inspite of its implementational hurdles, Montreal Protocol has been hailed as a remarkable example of international co-operation. Scientific evidence has indeed indicated substantial reduction of ODSs in the atmosphere.

7.5.6.4 Amendments to Montreal Protocol

Following the periodic scientific and technological assessments, The Montreal Protocol was adjusted subsequently, either to accelerate the phase out schedules, to include additional substances or to introduce other kinds of control measures.

- 1990 – London Amendment included additional CFCs and two solvents.
- 1992 – Copenhagen Amendment added methyl bromide, HBFCs and HCFCs.
- 1997 – Montreal Amendment finalized schedules for methyl bromide phase out.
- 1999 – Beijing Amendment included bromochloromethane for immediate phase out and introduced production controls on HCFCs as well as controls on trade with non-Parties.

8. REFRIGERANT COLOUR CODE SYSTEM

Refrigerant	Cylinder Colour	Expansion Valve Colour
R-12	White	Yellow
R-22	Green	Green
R-134a	Light Blue	Blue
R-404a	Orange	Orange
R-500	Yellow	Orange
R-502	Purple	Purple

Recovered Appropriate Colour with yellow shoulder or Grey with yellow shoulder

9. R NUMBER NOMENCLATURE FOR SOME COMMON CFC/HFC BASED REFRIGERANTS

TABLE 3. ***R Number nomenclature for some common CFC/HFC based Refrigerants***

Refrigerant	Chemical Name	Chemical formula	Normal Boiling Point (°C)
R-11	Trichlorofluoromethane	CCl_3F	28.82°C
R-12	Dichlorodifluoromethane	CCl_2F_2	-29.79°C
R-13		$CClF_3$	
R-22	Chlorofluoromethane	$CHClF_2$	-40.76°C
R-23		CHF3	
R-32		CH2F2	
R-113	Trichlorofluoroethane	CCl_2FCClF_2	47.6°C
R-114	Dichlorotetrafluoroethane	$CClF_2CClF_2$	3.6°C
R-115	Chloropentafluoroethane		
R-123	Dichlorotrifluoroethane	$CHCl_2CF_3$	28.2°C
R-124	Chlorotetrafluoroethane	$CHClFCF_3$	-12.°C
R-125	Pentafluoroethane	CHF_2CF_3	-50°C
R-134a	Tetrafluoroethane	CF_3CH_2F	-26.6°C
R-152a		CH_3CHF_2	-25.0°C
R-404a	Zeotropic	R-125/R-143a/R-134a (44:52:4%)	-46°C
R-407c	Zeotropic	R-32/R-125/R-134a (23:25:52%)	-40.24°C (based on mean temp)
R-410a	Near Azeotrope	R-32/R-124 (50:50%)	-51.53°C
R-500	Azeotrope	R-12/R-152a	-33°C
R-502	Azeotrope	R-22/R-115	-45.5°C
R-503	Azeotrope	R-23/R-13	-88°C
R-507	Azeotrope	R-125/R-134a (50:50%)	-47°C

10. Basic Characteristics of Some Commonly used Refrigerants

TABLE 4. ***Basic Characteristics of Refrigerants*** *Source: Fleet Management Limited*

Refrigerant ASHRAE No.	ODP	GWP	Repl. For	Chemical Name or Composition	Group	Oils*	Boiling Point °C	Remarks
R-11	1	4000	-	Trichlorofuromethane	CFC	Min, AB	23.7	Production and trade ended
R-12	0.82	8500	-	Dichlorodifluoromethane	CFC	Min, AB	-28.8	Production and trade ended
R-502	0.224	5590	-	Mix R-22/115 (48.8/51.2)	CFC	Min, AB	-45.3	Production and trade ended
R-22	0.049	1700	-	Chlorodifluoromethane	HCFC	Min, AB, PAO	-40.8	Production and trade limited phase out 2030
R-401A	0.031	970	R-12	Mix R-22/152a/124 (53/13/34)	HCFC	Min, AB, PAO	-34.4	Interim replacement. Zeitrop, Glide 4.9K
R-13B1	12	5600	-	Bromitrifluoromethane	Halon	Min, AB,	-57.7	Mostly used for fire fighting systems, Production and trade ended
R-134a	0	1300	R-12	Tetrafluoromethane	HFC	POE	-26.1	Single refrigerant. No Glide
R-404A	0	3260	R-502	Mix R-125/143a/134a(44/52/4)	HFC	POE	-46.6	Near-Azeotrop with Glide 0.7K
R-407C	0	1525	R-22	Mix R-32/125/134a(23/25/52)	HFC	POE	-43.8	Zeotrop Glide 7.4K
R-409A	0.048	1290		Mix R-22/R124/R142b(60/25/15)	HCFC	Min, AB,POE	-35.4	Zeotrop Glide 6K
R-410A	0	1725	R-22	Mix R-32/125 (50/50)	HFC	POE	-51.6	Near-Azeotrop with Glide<0.2K. Pressure approz 60% higher than R-22
R-413A	0	1770		Mix R-218/R134a/R600a(9.0/88.0/3.0)	HFC/FC	Min, AB,PAO, POE	-35	Zeotrop Glide 5K
R-507	0	3300	R-502	Mix R-125/143a (50/50)	HFC	POE	-47.1	Azeotrop
R-417A	0	1950	R-22	Mix R-125/143a/600 (46.5/50/3.5)	HFC	Min, AB,PAO, POE	-42	Zeotrop Glide 5.6K
R-717	0	-	-	Ammonia	-	Min, PAO	-33.3	Flammable / Toxic
R-744	0	1	-	Carbon dioxide	-	Min, AB,PAO, POE	-78.4	Low Crit. Temp. / High pressure
R-290	0	10	-	Propane	HC	Min, AB,PAO, OE	-42.1	Very Inflammable

Oils Min = Mineral Oil, AB = Alkyl Benzene, PAO = Polyolphaolefins, POE = Polyolester Oil.

11. REFRIGERANTS AND OIL

The oil type being used depends upon and, should be compatible with the refrigerant in use. CFCs and HCFCs use Mineral Oil. However R-134a (HFC) is immiscible with mineral lubricating oil, causing improper oil return and posing reliability problems. Therefore special Synthetic Oils, viz., Poly olester oils (Castrol Icematic SW20) have been developed ensuring good miscibility with the refrigerant at all working conditions. However, both the Refrigerant (R-134a) and the synthetic oils are much more hygroscopic in nature compared to R-12 and mineral oils. They must not be exposed to atmospheric humidity. Opened Oil tins must be used immediately. It is generally available in only small quantities (960 ml).

Fig. 4 Poly olester Oil (Synthetic) for R 134a Castrol Icematic SW20 in 960 ml tins
Source: Carrier Transicold

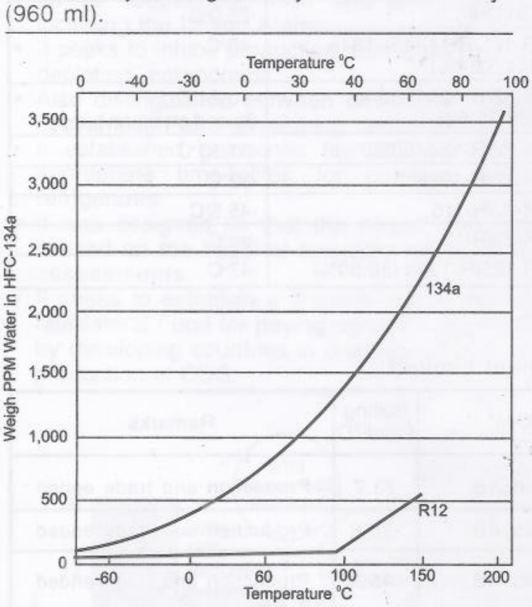


Fig. 5 Solubility of water in R-134a and R-12.
Source: Air Conditioning and Refrigeration Journal

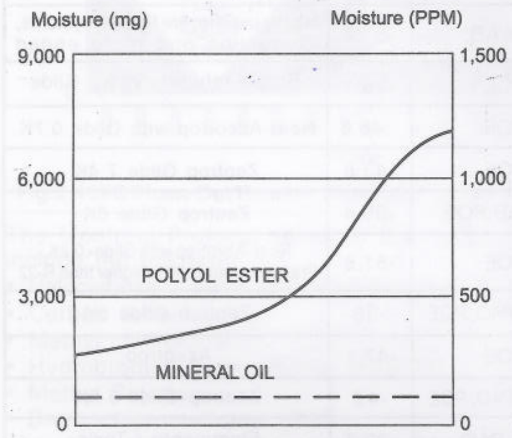


Fig. 6 Hygroscopicity Comparison
Source: Air Conditioning and Refrigeration Journal

The solubility of water in R-134a rises steeply with temperature. Similarly, the hygroscopicity of Poly olester oil increases rapidly with the time of exposure to the atmosphere. Additionally, reaction of poly olester oil with water, leads to acid and sludge formation which could lead to other functional problems like capillary blockages etc. If the moisture content of POE oil rises above 100 ppm, corrosion of metallic parts can result. Additionally, moisture in a Refrigeration system contributes to ice formation in capillaries, expansion valves, damage to motor windings, etc. Hence, it is imperative to keep moisture out of the refrigerant and the synthetic lubricating oil used.

12. MIGRATION OF REFRIGERANT

A Refrigerant vapour can migrate into the compressor when it is not running and condense in the oil. This migration is a natural process which occurs whenever a refrigerant and oil are in contact and the compressor is not in operation due to the difference in their vapour pressures. It is harmless when occurring in small quantities and becomes a matter of concern and alarm only when occurring in large quantities, especially when the compressor is not running for a long time or when the oil temperature is too low. Due to the migration, the compressor sight glass shows a high level. This liquid refrigerant dilutes the lubricating oil and reduces the lubricating properties causing insufficient lubrication of the bearings. When the compressor starts, sudden reduction in pressure inside the crankcase causes a violent reaction, the refrigerant literally explodes out of the oil looking like a white foam which actually consists of liquid refrigerant and oil droplets. Damage occurs when the refrigerant foam washes the oil away from the bearing surfaces. Migration increases with greater refrigerant charge to oil ratio and lower compressor ambient temperatures. Manufacturers provide crank case oil heaters on compressors to enable working at low ambient temperatures. The maintenance of correct refrigerant charge and oil level is of paramount importance.

13. LEAKAGE OF REFRIGERANTS

Generally leakage of refrigerant can occur through valve spindles, pipeline brazed or coupling joints, expansion valve capillary, compressor cylinder head connection and through evaporator coil and condenser coils. It is important to regularly perform refrigerant leak checking using an electronic gas detector. Using soap solution is satisfactory for small leakages. When using halide lamp for refrigerant leak checking, care should be taken to prevent contact of naked flame to any metal parts or electric components and cables. When in normal operation, all the line valves should be fully backseated (fully open) to prevent any possible leakage through the service port connection.

The correct type of refrigerant should only be used to top up any system. A CFC refrigerant should never be mixed with HCFC or HFC refrigerant. Head Office should be consulted before replacing a refrigerant. If desired, the entire refrigerant should be changed along with the lub oil. PART CHANGING OF REFRIGERANT IS NOT PERMITTED. Since the machinery operates with different set of pressures for different refrigerants, close watch should be kept on the pressures.

Refrigerant should be charged in liquid form only, as far as possible. If the pressure in the refrigerant bottle is low, it may be required to run the compressor.

There are generally 3 places from where refrigerant can be charged into the system.

1. Through Receiver outlet valve (also known as King valve or Liquid line shut off valve). This is the most preferred point because refrigerant passes through the filter drier and any moisture present in the refrigerant gets trapped in the filter drier.
2. Through Compressor Suction Service valve
3. Through Suction Modulation Valve.

Do not attempt to charge refrigerant through the discharge service valve. The back pressure will be too high to allow any refrigerant to flow into the system.

14. SPARE REFRIGERANTS

It is always prudent to stock sufficient quantity of spare refrigerant to avoid prolonged non-functioning of the refrigeration machinery resulting in damage to the food stuffs kept inside the chamber. At least one full charge of refrigerant should be kept as a reserve stock and stock should be replenished as it gets used up. The room in which spare refrigerants are kept should be cool, shaded and well ventilated. It should be provided with an exhaust fan which should be always running before personnel entry. It should be dedicated only for the storage of refrigerants. No combustible substances like paints should be stored along with refrigerants.

16. REFRIGERANT CHARGE

16.1 Refrigerant Charge Quantity

The refrigerant charge required for a particular unit is mentioned in the specifications of the machinery. It can be found on the specifications plate fitted near the compressor of the unit and also in the instruction manual. Refrigerant charge varies depending upon factors like refrigerant being used, the type of compressor - whether scroll or semi-hermetic reciprocating, whether water cooled condenser or receiver, whether a 2-row or a 4-row condenser coil, etc. To ensure proper refrigerating capacity, a refrigeration system must have the proper charge. An **undercharged system** may display low suction and discharge pressures. A semi-hermetic compressor may overheat as cool refrigerant returning from the evaporator is used to cool the compressor motor. An under charged system will have a low refrigerating capacity. An overcharged system may have extremely high discharge pressures, which may become high enough to cause severe system damage. The compressor discharge temperature may cause oil to breakdown. Acids and sludge formed by the oil break down may damage the compressor. An overcharged system may also have a low refrigerating capacity.

16.2 Refrigerant Charge Testing Procedure

a. Connect the gauge manifold to the compressor discharge and suction service valves. For units operating on a water cooled condenser, change over to an air cooled operation.

b. Bring the container temperature to approximately 1.7°C (35°F) or —17.8°C (0°F). Then set the controller set point to —25°C (—13°F) to ensure that the suction modulation valve is at maximum permitted open position.

c. Partially block the condenser coil inlet air. Increase the area blocked until the compressor discharge pressure is raised to approximately 12 kg/cm^2 (175 psig).

d. On units equipped with a receiver, the level should be between the glasses. On units equipped with a water cooled condenser, the level should be at the center of the glass. If the refrigerant level is not correct, continue with the following paragraphs, adding or removing refrigerant as required.

e. Do not add refrigerant just because bubbles are seen in the sight glass. The only sure way to tell how much charge is in a unit is to remove the refrigerant and weigh it.

16.3.1 Adding Refrigerant to System (Full Charge)

a Evacuate unit and leave in deep vacuum.

b Place the refrigerant cylinder on a scale and connect charging line from cylinder to liquid line valve. Purge charging line at liquid line valve and then note weight of cylinder and refrigerant.

c Open liquid valve on cylinder. Open liquid line valve half-way and allow the liquid refrigerant to flow into the unit until the correct weight of refrigerant has been added as indicated by the scale. It may be necessary to finish charging unit through suction service valve in gas form, due to pressure rise in high side of the system.

d Backseat manual liquid line valve (to close off gauge port). Close liquid valve on cylinder.

e Start unit in cooling mode.

f Run approximately 10 minutes and check the refrigerant charge.

16.3.2 Adding Refrigerant to System (Partial Charge)

a Examine the unit refrigerant system for any evidence of leaks. Repair as necessary.

b Maintain the conditions outlined for checking the Refrigerant Charge.

c Fully backseat the suction service valve and remove the service port cap.

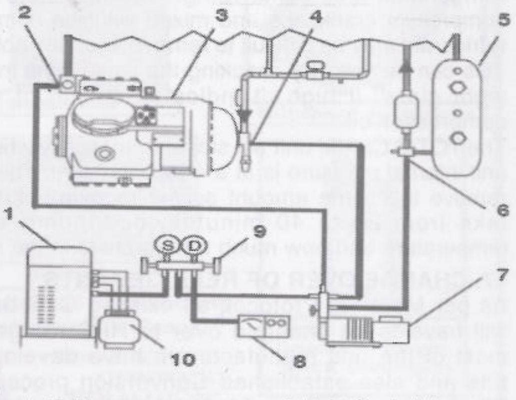
d Connect charging line between suction service valve port and cylinder of refrigerant R-134a. Open VAPOUR valve.

e Partially frontseat (turn clockwise) the suction service valve and slowly add charge until the refrigerant appears at the proper level.

16.3.3 Refrigerant Recovery

As per Montreal Protocol, deliberate discharge of CFCs into the atmosphere is a cognizable offence and punishable by law. Refrigerants are expected to be recovered and landed ashore to reception facilities. Therefore, much importance has been given to the Recovery equipment and Recovery Procedures. Carrier has developed a Recovery Unit called TOTALCLAIM which can be operated irrespective of the working condition of the Refrigeration unit.

Method: Connect a manifold gauge set between the refrigeration unit and the TOTALCLAIM unit. Connect the high side hose from the manifold gauge set to the unit king valve (receiver outlet valve) and the low side hose from the manifold gauge set to the compressor suction service valve. The centre hose from the manifold gauge set should have an inline sight glass and be connected to the TOTALCLAIM unit at the bottom hose connection that is designated as the "black" connection. The king valve and the suction service valve must be midseated and the manifold gauge set hand valves must be front seated, isolating the centre hose from the low side and high side connections.



1. Reclaimer
2. Discharge Service Valve
3. Compressor
4. Suction Service Valve
5. Receiver or Water Cooled Condenser
6. Liquid Service Valve
7. Vaccum Pump
8. Electronic Vaccum Gauge
9. Maifold Gauge Set
10. Refrigerant Cylinder

Fig. 7 Refrigerant Recovery Procedure
Source: Carrier Transicold

Manifold Gauge Set Valve Operation:
Front Seat = Fully Close
Back Seat = Fully Open
Mid Seat = Half Open

16.3.3.1 If the unit is operable

Set the TOTALCLAIM recovery unit to **liquid** and **recovery** modes (NOT RECOVERY PLUS), then press the start button. Midseat only the high side hand valve on the manifold gauge set to allow liquid refrigerant to flow from the king valve of the refrigerant unit through the manifold gauge set to the TOTALCLAIM unit. Running the refrigeration unit in a cool mode while blocking the condenser airflow will raise pressure at the king valve and reduce the recovery time considerably. You may run the unit the entire time you are extracting liquid refrigerant, taking care that the compressor does not overheat. When there is no more liquid being extracted (WATCH THE SIGHT GLASS IN THE CENTRE HOSE), turn the TOTALCLAIM unit off and then back on and select **vapour** and **recovery** modes. When the high and low side gauges read the same pressure, open the low side hand valve to allow the TOTALCLAIM to draw from both hoses connected to the unit. The TOTALCLAIM unit will stop automatically when the refrigerant has been recovered and the refrigeration unit internal pressure is at a 4-inch vacuum. This method will not remove the same amount as the "recovery-plus" mode and can take from 10 to 20 minutes, depending upon pressure, temperature and how much refrigerant is in the refrigeration unit.

In high ambient temperature (>85°F), you may not be able to get the TOTALCLAIM unit to complete the recovery procedure until the TOTALCLAIM unit completes a bottle cooling procedure. This may be caused by high bottle storage pressure. In this case, there will be no way to circumvent bottle cooling mode as this protects the internal compressor from damage. This will happen more often with R-22 and R-502 as they have higher saturation temperatures.

16.3.3.2 If the Unit is Inoperable

In this situation if the unit has not been running for the last 24 hours, the refrigerant would have dispersed evenly throughout the unit and will be mostly in vapour form at the king and suction service valves. In this case set the TOTALCLAIM unit to **vapour** and **recovery** modes (NOT RECOVERY PLUS) and open both the low and high sides of the manifold gauge set. In an inoperable refrigeration unit, some refrigerant may have migrated to the compressor crankcase and mixed with the compressor oil. This refrigerant may be difficult to remove and may not all be extracted. This can be seen by checking the liquid level in the compressor sight glass. If high, it indicates mixing of refrigerant with compressor oil.

The TOTALCLAIM unit will stop automatically when the refrigerant unit internal pressure is at a 4-inch vacuum. This method will not remove the same amount as the recovery-plus mode and can take from 20 to 40 minutes, depending upon pressure, temperature and how much refrigerant is in the refrigeration unit.

17. CHANGE OVER OF REFRIGERANTS

As per Montreal Protocol, all existing CFC based machinery will have to be changed over to HFC refrigerants. For this, most of the unit manufacturers have developed Conversion Kits and also established Conversion procedures.

When changing the refrigerant, the old refrigerant must be totally removed from the system, collected in a receiver, disposed off to an authorized reception facility and receipt obtained. The system should be fully vacuumized and the right quantity of the new refrigerant should be charged. Lub oil should also be changed. Filter Drier and Expansion valve should be changed. Since the system will be operating under changed pressure conditions, the pressure alarms, and cutouts should be readjusted to the new settings.

18. WHAT REFRIGERANT IS SUITABLE FOR MY APPLICATION?

All refrigerants have a certain operating temperature below which they go into vacuum. It is undesirable to run a unit under vacuum conditions due to possible ingress of air and moisture. So this becomes a limiting value for the choice of Refrigerant. e.g., R-134a goes into vacuum at below -26.1°C. This implies that it is unsuitable for temperatures below this temperature. As R-22 goes into vacuum at -40°C, it is suitable for applications only upto this temperature. R- 504a remains under positive pressure even at -45.6°C, so does R-507a.

19. PERSONNEL SAFETY

19.1 Precautions when handling Refrigerants

a Be certain that the Refrigerant Recovery Cylinder being used is the Refillable Type and has the capacity to contain the refrigerant to be added to its contents.

b Never fill any Refrigerant Cylinder more than 80% by volume.

c Never mix two different refrigerants.

d Never mix Refrigerants with air. They may form combustible and explosive mixtures.

e Label the cylinder with the contents using the appropriate colour code.

f Ensure no refrigerant leaks into the atmosphere. Follow local environmental laws when purging hoses of air.

g Beware of leaking refrigerants which can cause frostbite. Keep away from the line of leaking refrigerants.

h Beware of valve spindles and other components which can fly off because of high pressures. Enough fatal accidents have been reported which have occurred because of personnel coming in direct line of loose flying off parts fitted on pressurized equipments.

19.2 Precautions when working in Refrigerated Spaces

a Take all personal safety precautions not to inhale any refrigerant vapourswhich could have possibly leaked out into the chamber which can also cause chemical poisoning of the human system. **Refrigerant Vapour under high temperature ca liberate Phosgene gas, which is highly poisonous.**

b Always vent refrigerated spaces for sufficient duration befor personnel entry.

c When working in refrigerated spaces with frozen cargoes wear sufficiently protective warm clothing.

d When working in refrigerated spaces with chilled cargoes especially fruits, beware of accumulated pockets of carbon-di-oxide and ethylene which could cause an oxygen deficien atmosphere. This is particularly applicable for controlled regulated and modified atmospheres.

e It is better always for at least two persons to enter and wor in refrigerated spaces at a time.

f All personnel should be aware of the push button alarms nearest escape routes and emergency exits from refrigerated spaces.

20. FUTURE OF REFRIGERANTS

Due to their relative higher GWP, HFCs are also included in th basket of Greenhouse Gases along with CO_2, CH_4, NO_2, etc whose emissions are to be controlled under the Kyoto Protocol Denmark recently proposed a resolution to ban HFC refrigerant within 10 years in favour of natural refrigerants like Ammonia CO_2 Nitrogen, Propane, Air etc.

Continuous research is going on to make new refrigerants b blending different percentages of various methane based an ethane based constituents with different properties, to sui various newer applications. Continuous fine tuning is being don to obtain the perfect refrigerant for different applications.

Pure Hydrocarbons are being increasingly used as Refrigerant these days e.g., HC-290 (Propane) with Boiling Point -42.1°C HC-600a (Isobutane) with Boiling Point -11.73°C and the mixtur of these two in varying proportions. Both of them have Zero ODP GWP at 3, and are classed as Simple Asphyxiants for TLV. Th higher COP and low operating noise levels have also contribute to the increasing use of pure Hydrocarbon Refrigerants. Th only consideration against their use is their flammability rang of 1.8-9.5 % in air, which is of great significance, particularly o board the ships. However, this aspect has been taken care of b use of non-sparking and sealed components like thermostat compressor relays, Overload protectors, contactors, doo switches, etc. Today, Hydrocarbon Refrigerants are considere to be worthwhile substitutes to CFCs for appliances with sma charges, i.e. less than 350 grams of refrigerant. It will not be to long before they are used as refrigerants for Marine Refrigeratio and Air Conditioning.

References

1 www.carrier.transicold.com, 2 www.hvacindia.org.in, 3 www.copeland.co
4 www.fleetship.com

ABOUT THE AUTHOR

Mr. Chilukuri Maheshwar is a Marine Engineer, having passed out from Mari Engineering College (DMET), Kolkata, India in 1980. He has sailed with Th Shipping Corporation of India Ltd. from 1980 to 1997, the last 5 years of whi were as Chief Engineer. Ashore, he had worked from 1997 to 1999 as Chi Engineer of Taj Connemara Hotel, Chennai, India, a business Class Five St Hotel belonging to The Taj Group. From 1999 to 2001, he was Customer Servi Manager, for South Asia for Reefer Container Products Group of Carri Transicold and set up the Reefer Container Service Office for South Asia Mumbai (Bombay).

From October 2001 till August 2006, he was a member of Engineering Facul at the Training Ship Chanakya, College of Nautical Sciences, Navi Mumba India, which is a Merchant Navy Training Institute of the Govt. of India a affliated to the University of Mumbai and Indira Gandhi National Op University (IGNOU). He is also involved in training and consultancy in the fie of Reefer Containers. Presently, he is with Fleet Management Training Institut Mumbai, India, as Training Superintendent.

He had completed his MEE, MBA and M Phil. in Management and is current pursuing Ph.D. in Management with BITS, Pilani, India under the Distan Mode. His topic of research is related to "Inland Usage of Reefer Containe for reducing the Post Harvest Losses of Horticultural Products in India".

He is a life member (Fellow) of Institute of Marine Engineers (India) a Institution of Engineers (India). He is also an Insurance Regulatory Developme Authority (IRDA) approved Insurance Surveyor and Loss Assessor, a Charter Engineer, an Approved Valuer and an Institute of International Container Lesso (IICL) certified Container Inspector.

He can be reached at cmaheshwar@hotmail.com.

Ocean Carriage of Refrigerated Cargoes

by
C. Maheshwar

In this article, we examine the evolution of Containerization as a concept and its application with refrigeration for carriage of various types of cargo. We have a look at the global trade in refrigerated products, with particular reference to reefer containers and reefer ships. We also go through the guidelines for loading reefer cargo and its carriage across oceans and the various instances of cargo losses which have occurred in the recent past.

Traditionally, refrigerated cargo has been carried across oceans on ships in refrigerated cargo holds. However, with the advent of Containerization with Refrigeration since 1960 onwards, more and more amount of refrigerated cargo is being carried through refrigerated containers instead of ships with refrigerated cargo holds.

Advantages Of Containerization

1.Faster and reliable delivery
2.Unitization of cargo
3.Greater protect - ion of fragile and easily contamina - ted cargoes
4.Ensures original quality of goods
5.Reduces pilfer- age
6. Enables Physical separation of various types of cargoes
7.Simplification of documentary proc- edures
8.Reduction in cost of cargo handling and ships' stay in ports.
9.Reduction in packing cost to the shipper.

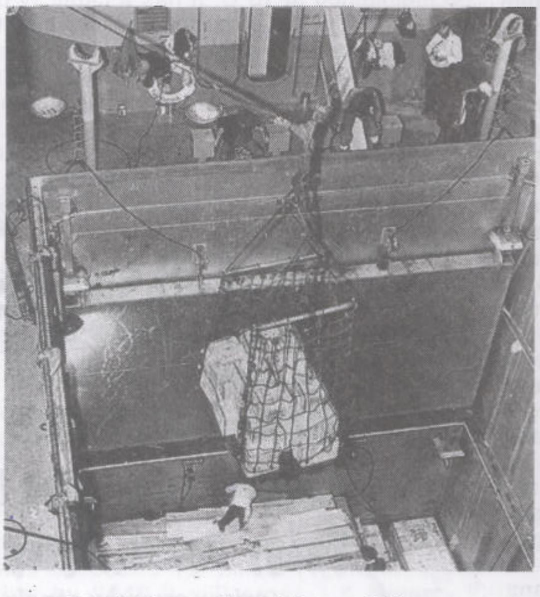


Fig. 1 Conventional Cargo Ships


Fig. 2 Container Ships

Various Stresses on Cargo carried on Ships

Whatever motion the ship is subj - ected to, is also applicable to the Cargo contained inside the ship, whether in a Cargo hold or in a Container.

There are 6 **Degrees of Freedom** or basic motions to which a ship is subjected to while at sea. Degree of Freedom, means ability to move or rotate about a axis.

1.About the ship's axis: Pitching, Rolling, Yawing
2.Bodily Motions: Heaving, Surging, Swaying

In addition to the above stresses, the ship is continuousl subjected to vibrations originating from the various machiner The resultant stresses due to a combination of any two c more of these motions can be extremely complex for analysis All these motions of the Ship can be restricted to a certai extent by suitable changes in Hull Shape. For a Container, th stresses can be restricted by Better Stowing, Lashin Mechanisms, Stuffing Procedures etc.

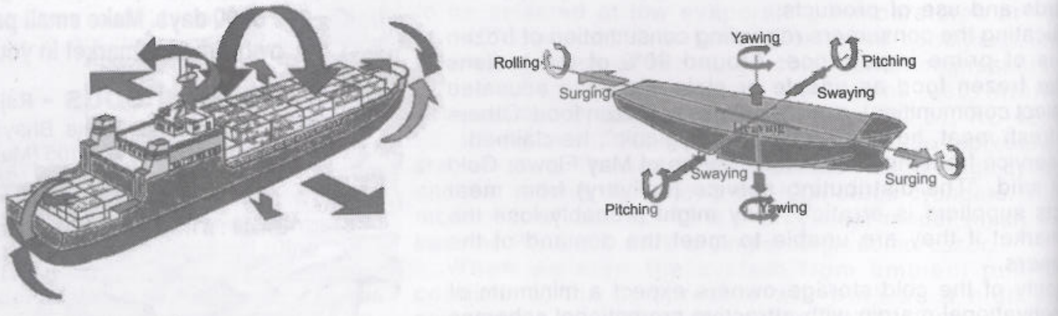


Fig. 3 Ship Movement at Sea —Degrees of Freedom

Refrigerated Containers

A Refrigerated Container (Reefer Container) is a container in which temperature can be maintained within certain limits that correspond to the storage conditions required for certain types of cargoes. It is equipped with refrigeration machinery which is capable of maintaining the temperature inside the container at a specified value.

Currently, Marine Reefer Containers are mostly **Picture Frame Type Containers**. Here, the refrigeration equipment is fitted within the overall standard dimensions of the container, ie, 40 X 8 X 8 ½ ft or 20 x 8 X 8 ½ ft. Some of the cargo carrying space is utilized to accommodate the refrigeration machinery. This is because of the availability of limited space within the ship and the need to carry maximum number of containers, requiring optimization of space. These containers are robust and are designed to withstand the rigours of the sea passage.

Overhanging type of units are those where the refrigeration unit protrudes out of the overall dimensions of the container. They are generally used ashore for transporting perishable products over the road. These units are not so robust and are vulnerable to breakdowns in the long run. Ashore, they are preferred because of their relative inexpensiveness and availability of service and repair facilities.

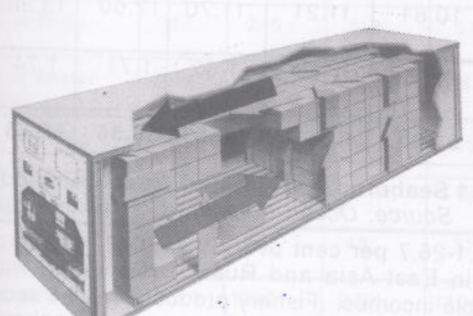


Fig. 4 Refrigerated Containers

Evolution of Container Refrigeration

Refrigerated Containers have been employed on ships for more than 40 years. The earlier versions had only the basic components and a very narrow range of temperature applications. Setpoint could not be changed at will and even if it could be changed, the arrangement was very crude using a potentiometer arrangement. There was little scope for changing the defrost interval. There were no low voltage components, resulting in lot of heat generation and power consumption. There were very few alarms and safeties, thus safety of the cargo, machinery and personnel was not ensured. There was no fool-proof and tamper-proof temperature recording mechanism; the only one which was available was a mechanically moving paper chart powered by a hand wound clock mechanism. There were frequent breakdowns caused by mechanical failures of components. Instances of Cargo damage were many, resulting in huge cargo insurance claims. Reefer Container Machinery has come a long way over the last 40 years and has evolved phenomenally. Each of the components has undergone a metamorphosis. Present systems are power efficient with foolproof and tamperproof

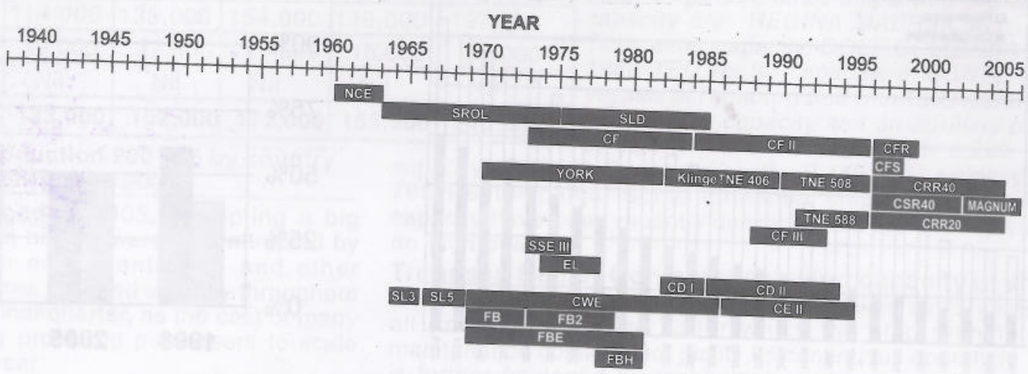


Fig. 5 History Timeline of Thermoking Reefer Container Machinery Models
**Source: www.thermoking.com*

recording; back-ups for all important components; advanced warning systems in the form of alarms and cut-outs; increased reliability of components resulting in enhanced safety of cargo, machinery and personnel. Now, with Remote Monitoring Modems and Radio Frequency Identification Systems, it is possible to monitor the performance of each Reefer Container from a shore office continuously and perform necessary adjustments

Commercial Aspects of Reefer Containers

Today, a 20 feet Dry (general purpose) Container Box, costs about **US$ 2000**. A Reefer Container consists of 2 distinct components - the Refrigeration Machinery and the Box. The Refrigeration Machinery with standard features costs about **US$ 10,000.** A 20ft. Reefer Box costs about **US$ 5,000**. The major Reefer Machinery manufacturers are Carrier, Thermoking, Daikin, Mitsubishi, etc. The major Reefer Box manufacturers are Freuhauf, CIMC, SIMC, MCI, Moon, GE, Transafe, Balmer Lawrie, etc. When a Reefer Container has to be bought, the orders are placed separately to the Box manufacturer and the Machinery manufacturer. The Machinery manufacturer delivers the machinery at the location where the box is manufactured. The machinery is fitted on to the box, tested, and the unit commissioned, and then delivered to the customer's representative by the machinery manufacturer's representative in the presence of the box manufacturer.

Because of shift of manufacturing activities from Europe and USA to Asian countries, especially China, there is a downward trend in the prices of containers and the machinery.

Comparison of Reefer Container Freight and Air Transportation Freight

Cost of Air Transportation of perishable goods is almost five to seven times the cost incurred by transportation through Reefer Containers, depending upon the route. If it costs US$ 20,000 to transport 20 Metric Tonnes of perishable cargo by air @ US$ 1.00 per kilogramme transport costs by a normal marine reefer container would be approximately US$ 3,000 to US$ 4,000. If the product warrants CA transportation, the additional costs would be approx. US$ 1,500. Thus for large scale transportation of perishable goods across long distances over sea and land, reefer containers are very economical.

Trends in Growth of Seaborne Refrigerated Cargo Trade

Seaborne trade of refrigerated commodities increased by 32% over 1995-2002 to 63.5 million tonnes (mt), and there was further growth in 2003 and 2004. Seaborne refrigerated trades are forecast to increase by 54% to 97.5 mt over 2002-10. Further growth of 30 per cent is anticipated to 126.9 mt in 2015.

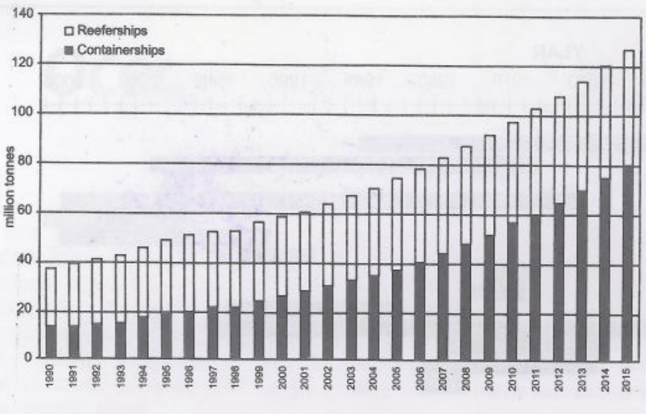


Fig. 6 Trends/Forecast of Refrigerated Cargo Trade
Source: Ocean Shipping Consultants Ltd.

Commodity-wise Trade

Trade has increased in all commodity groups. The most rapidly growing, and largest, sector is meat. which saw a rise in share

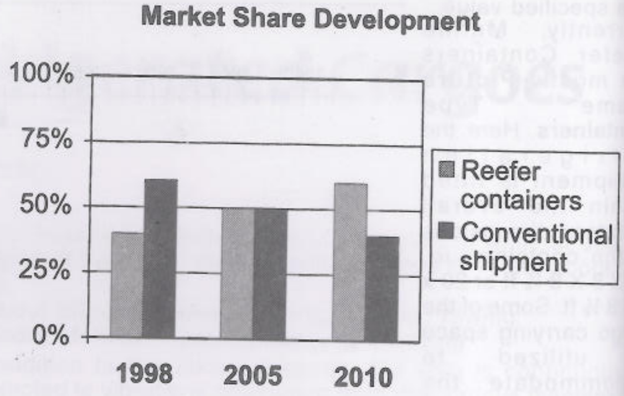


Fig. 7 Reefer Container vs Conventional Shipment
Source: B M De Beer b.v.

Milion tonnes	1990	1995	1996	1997	1998	1999	2000	2001	2002
Bananas	8.77	11.67	12.13	12.22	11.86	12.64	12.99	1246	12.75
Deciduous fruit	4.07	5.62	5.86	6.12	6.07	6.49	6.49	7.04	7.39
Citrus fruit	4.87	6.10	5.96	6.26	6.18	6.07	6.40	6.60	6.91
Tropical fruit	1.47	2.06	2.31	2.50	2.61	2.97	3.08	3.26	3.76
Meat	7.64	11.13	11.45	12.42	12.89	14.04	15.19	15.85	16.93
Fisheries products	8.23	9.98	10.60	10.81	11.21	11.70	12.50	13.38	13.86
Dairy Products	1.54	1.54	1.49	1.62	1.46	1.62	1.71	1.74	1.86
TOTAL	**36.60**	**48.10**	**49.80**	**51.94**	**52.28**	**55.53**	**58.36**	**60.33**	**63.46**

Table 1 Seaborne Refrigerated Trade Commodity-wise
Source: Ocean Shipping Consultants Ltd.

The conventional reefer trade is set to expand by 14-25% to 38.2-41.9 mt over 2002-10, and by a further 6-12% to 40.7-47.0 mt in 2015. This is despite an anticipated fall in their share of the seaborne market from 52.6% in 2002 to 43.0-43.6% in 2010 and 37.0-37.9% in 2015. Refrigerated trade handled in containerships is forecast to rise by 64-85% to 49.4-55.6 mt over 2002-10 and by a further 35-44 per cent to 66.6-79.9mt in 2015. The more rapid growth of the containership trade will stem both from the continued increase in penetration by containers in all sectors, and from the greater pace of expansion anticipated in sectors where containers are already dominant – meat, fish and tropical fruit.

Growth of Reefer Containers over Conventional Shipment

Since 2002, demand has been strong in both the container and conventional reefer sectors, and the shift from reefers to containers appears to have slowed. This has been driven by demand growth in existing commodity sectors, the extension of the market to new sectors previously handled by air (such as tropical fruits, broccoli, asparagus and cut flowers), and the saturation of container shipping capacity caused by the strength of growth in the dry cargo market. Conventional reefer operators have thus benefited from the supply constraints in the container shipping industry.

Market conditions for reefers are likely to remain strong in the next couple of years – given the combination of continuing underlying demand growth for refrigerated products, driven by rising prosperity, notably in Russia and East Asia, and a static supply of reefer fleet capacity due to the dearth of new building activity.

However, the longer-term trend toward containerization will reassert itself, as new and even larger containerships with ample reefer container capacity continue to be added to the containership fleet. The youth and growing reefer capacity of the containership fleet contrasts starkly with the age and static numbers of the conventional reefer ship fleet.

from 23.1-26.7 per cent over 1995-2002, with strong market growth in East Asia and Russia correlating with growing disposable incomes. Fishery products are the second largest category, accounting for 21.8 per cent of seaborne trade in 2002, up from 20.8 per cent in 1995. The share of bananas fell to third place from 24.3-20.1 per cent over 1995-2002. Shares in the other sectors remained static or fell, except that of tropical fruit which advanced from 4.3 per cent to 5.9 per cent, as a result principally of advances in controlled atmosphere technology, which have made it possible to transport more fragile commodities by sea instead of by air (Refer Table 1).

In recent years, some trades and commodity groupings have become increasingly containerised. whilst others (typically high-volume, homogenous and/or highly seasonal) continue to be largely dependent upon conventional reefer tonnage. However, reefer containers have also increased their share in these trades. Reefer containers have a longstanding hold in the frozen food trades for meat and dairy products.

Capacity & Production of Reefer Containers — Region wise

Table 2 shows container production and present production capacity by region. The excess capacity in China is particular noticeable. This excess capacity has led to a dramatic drop in the price of refrigerated containers and a decline in production capacity in other regions. Refrigerated containers are as a result no longer manufactured in the USA, Japan and even South Korea.

Country	2001	2002	2003	2004	2005	2006	Capacity
China	72,800	94,500	114,000	135,000	154,000	139,000	197,000
Denmark	21,000	20,000	19,000	17,000	17,500	16,000	18,000
Other	3,200	500	Nil	Nil	Nil	Nil	Nil
Total:	97,000	115,000	133,000	152,000	172,000	155,000	215,000

Table 2 Reefer Container production 2001-06 by country (TEU) *Source: World Cargo News June 2006*

Reefer trade may have surged in 2005, prompting a big expansion in the fleet size, but buyers were also attracted by the prevailing movement in equipment price and other incentives. Finished reefer prices dropped steadily throughout the year to a low point in the final quarter, as the cost of many materials fell, and this further prompted purchasers to scale up their ordering later in the year.

Trends in Age and Size of Reefer Container Ships

As a thumb rule, we can say that in a typical container ship, the reefer slot capacity is generally 10-12% of the total TEU capacity. However, there are exceptions to this rule. There may be some container ships with much less reefer capacity. There are certain dedicated fruit traders who have custom – built for their use dedicated reefer container ships. A typical 5th generation container ship has a capacity of 600-800 reefer slots. Table 15.3 shows the development in the size and age of the container ship fleet with refrigerated container capacity. In total, there are approximately 2,200 ships available for transporting refrigerated containers. The large ships with a high refrigerated container capacity which were over five years old in 1997, were ships used to transport porthole containers. Recently built ships are exclusively ships used to transport integral containers. *The largest container ship built to date is EMMA MAERSK with 11,000 TEU capacity and a reefer plug capacity of 1000 (2000 TEUs). Among the other large container ships with big reefer capacity are REGINA MAERSK with 1400 TEU reefer capacity, DOLE COLUMBIA with 1980 TEU reefer capacity, 6 MONTE class vessels of Hamburg Sud with 1365 reefer plug (2730 TEU) capacity and an auxiliary power of 15MW, MSC Pamela* with 9,200 TEU capacity, *COSCO Guangzhou* with 9.449 TEU capacity and 700 Reefer plugs. Some container ships of 12,000 TEU capacity have been recently delivered and are already sailing on high seas.

Trends in Reefer Container carrying capacity of ships

Generally, the economic life of a ship is taken as 25 years for all practical purposes, after which the ship running and maintenance costs do not justify its continuous operation. This is further hastened by technological changes in the marine industry and environmental concerns. However, there are exceptions to this generalization. With good management decisions and maintenance techniques, some ships do continue to run even after 25 years. Table 3 indicates the way the number of reefer containers have been carried in ships as a function of time. There are 131 ships older than 25 years which are carrying 22,575 reefer TEUs with an average of about 168 reefer TEUs per ship. Among these, there was a single ship which had a carrying capacity of a largest number of 758 reefer TEUs There are 51 ships of the same age group with a carrying capacity of 3,219 with an average of 64 reefer TEUs. Contrast these figures to the age group of less than 4 years.

Age of ships	Refrigerated Container Capacity TEUs	<100	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	>1000	Total
0-4 years	No. of Ships	117	246	113	51	24	17			4		11	583
	No. of Reefer TEUs	7688	33558	24916	16183	10540	8826			3200		14224	119735
5-9 years	No. of Ships	118	130	60	25	15	16	2	7	7			380
	No. of Reefer TEUs	7527	17355	13220	8108	6530	8072	1276	5140	5972			13208
10-14 years	No. of Ships	212	147	43	32	4	7	3					448
	No. of Reefer TEUs	13520	19564	9771	11042	1782	3730	1841					81240
15-19 years	No. of Ships	247	135	46	11	5	5	5	1	7	3	2	467
	No. of Reefer TEUs	15533	16791	10967	3630	2118	2734	3146	721	6240	2815	2456	668
20-24 years	No. of Ships	84	58	25	9	4	1	1		1	1	4	189
	No. of Reefer TEUs	5475	7848	5752	3074	1732	593	622		692	98	4542	3151
25- years	No. of Ships	51	47	14	7	3	1	1	1				131
	No. of Reefer TEUs	3219	6276	3173	2558	562	4673	768	759				22676
Total	No. of Ships	829	764	301	135	55	47	18	9	19	4	17	2188
	No. of Reefer TEUs	52962	101382	67207	46193	24060	24537	11558	6619	16304	3796	21312	374930

Table 3 : Trends in the size and age of ships with refrigerated container capacity

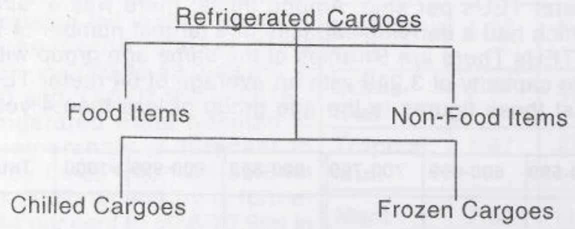
We see that, there are a total of 583 ships with a carrying capacity of 119,735 reefer TEUs, with an average of a about 205 reefer TEUs per ship among these, there are 11 ships of above 1000 TEU capacity with a total carrying capacity of 14,224 with an average of 1340. There are also 117 ships with a less than 100 reefer TEU capacity with a total carrying capacity of 7,688 TEUs with an average of 65 reefer TEUs. Thus we see that carriers do have a good number of smaller (less than 100 reefer TEU) capacity. Generally these (and such lower reefer TEU capacity ships) are reefer ships which also carry reefer containers as part of their cargo. However, there has been a phenomenal growth in ships with high reefer carrying capacity (above 1000 TEUs). This is going to the future trend. More and more ships in future will be built with above 1000 TEU reefer carrying capacity.

The reefer carrying capacity of a container ship is technically determined by sufficient availability of ships' power generation capacity and the design of the cargo holds – their air exchange blower capacity, ability to accommodate water cooled reefers etc. Since commercial concerns take precedence, the most important factor is the long term availability of sufficient quantity of containerized reefer cargo.

Classification of Reefer Cargoes

Refrigerated Cargoes can be classified as Food Items and Non-Food Items. Examples of Food Items are: Fruits, Vegetables, Meat, Fish, Beverages, Dairy Products, Ice Cream, etc. Examples of Non-Food Items are: Chemicals, Explosives, Leather, Photo films, Medicines, Vaccines etc.

More importantly, Refrigerated Cargoes can be classified as Chilled Cargoes and Frozen Cargoes.



Chilled Cargoes are those cargoes which are stored above –10°C. They are live cargoes with chemical reactions and processes going on within the product due to **Respiration**, with continuous liberation of gases and heat. **Chilled cargoes are also known as Perishable Cargoes in refrigeration parlance.**

Chilled cargoes are temperature sensitive cargoes. The heat generated by the chemical reactions has to be led outside the cargo space faster than it is liberated to prevent any accumulation of heat and rise of temperature. Similarly, gases which are liberated as products of the chemical reactions have also to be drawn out of the cargo space if found unsuitable for the cargo. Otherwise the cargo might deteriorate and get damaged. Chilled cargoes are generally, fruits and vegetables, dairy products, chilled meat, beverages etc.

Frozen cargoes are those cargoes which are stored below –10°C. They are dead cargo, with no chemical processes or reactions taking place within the product and no liberation of gases or heat.

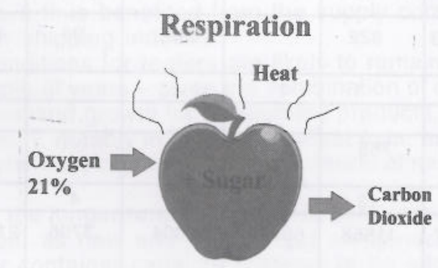


Fig. 8 Respiration

The temperature of chilled cargo needs to be maintained wi a very narrow band of $\pm$ 0.5°C around the set point. Varia of temperature beyond this may increase the chance of ca deterioration.

Myth and Reality Reefer Cargo Temperatures

Myth: For all refrigerated cargoes, the lower the temperat the better it is for the preservation of cargo.

Reality: For chilled cargoes, temperature must be maintai very close to the set point. If temperature is allowed to lower than the set point, cargo damage may occur becaus overcooling of cargo. Frozen cargoes do not get dama even if temperature goes below the set point for prolon periods of time. Instead of –20°C, if we maintain temperature of Ice Cream at –25°C, it does not cause damage or deterioration to the cargo. For frozen cargo, there is no evolution of heat from the cargo, it is much ea to maintain the temperature.

Packages for Chilled and Frozen Cargoes

For chilled cargoes, each piece of the cargo (fruit or vegeta

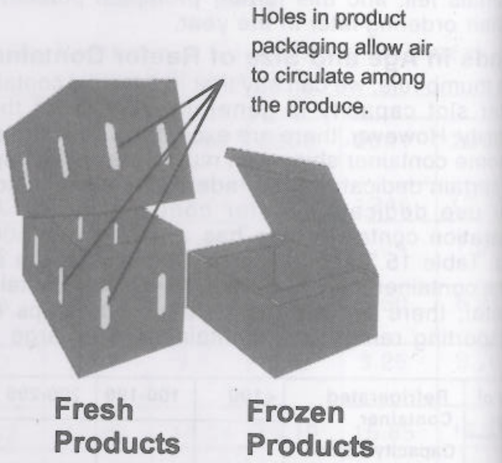


Fig. 9 Packages for Chilled and Frozen products

has to be cooled by exposing it to the cooled air. Each piec the cargo should be wrapped in material which can allow air to pass through. Generally, each piece of cargo is car in plastic net or thin porous paper. Chilled cargo pieces sho not be wrapped in completely enclosed plastic wrapper plastic is an insulator. A totally sealed plastic wrapper d not allow the cargo piece to breathe. After a little passag time, there will be a deficiency of oxygen, an excess of carb di-oxide and accumulation of heat and gases, like ethyl being liberated from the cargo because of ripening. If pla is used as a wrapping material, it must have sufficient ho to allow the cold air to touch the cargo piece, and to a breathing of each individual piece of cargo.

The cardboard or wooden boxes in which each indivi pieces of cargo are packed should not be air tight or sealed containers. They should have sufficient air holes around the sides to allow cold air to pass through and each individual piece of cargo.

The same logic holds good for frozen cargo. The cold should be allowed to touch the individual pieces of ca However, since frozen cargo does not generate heat nor ga as it is not a live cargo, the individual pieces of cargo ma packed in fully sealed air tight wooden or cardboard boxe Proper lashing of stacked cargo should be done. Suita separating dunnage should be used to obviate any possib of shifting of cargo during transportation and causing forma of hot pockets. Packing material should have suffic stacking strength to withstand the weight of the upper tie cargo. This is particularly important if the cargo is to transported across oceans in a refrigerated container, where it is subjected to severe weather conditions and mechanical movement due to rolling, pitching, pounding, panting, yawing and heaving.

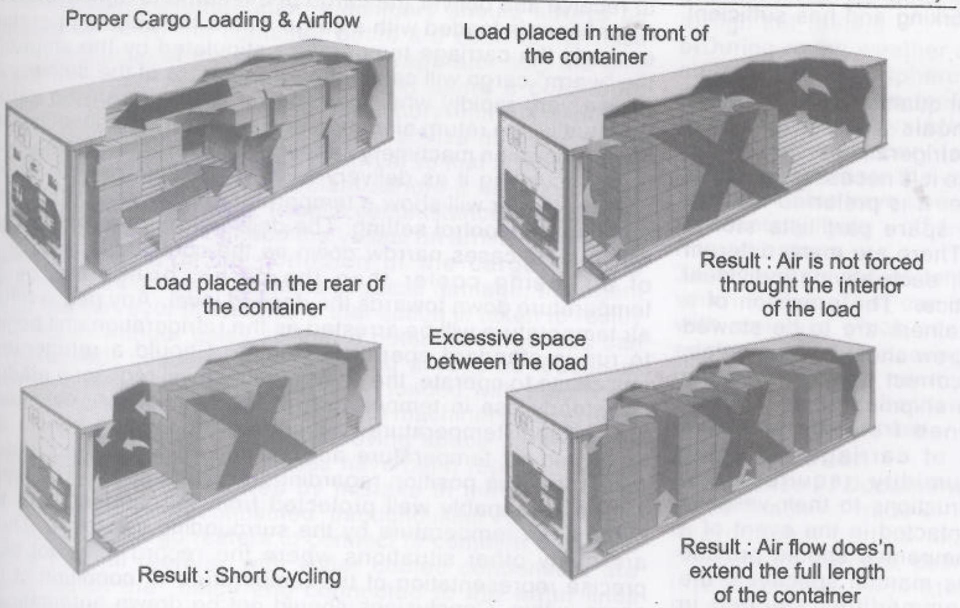


Fig. 10 Loading of cargo inside the Reefer Container

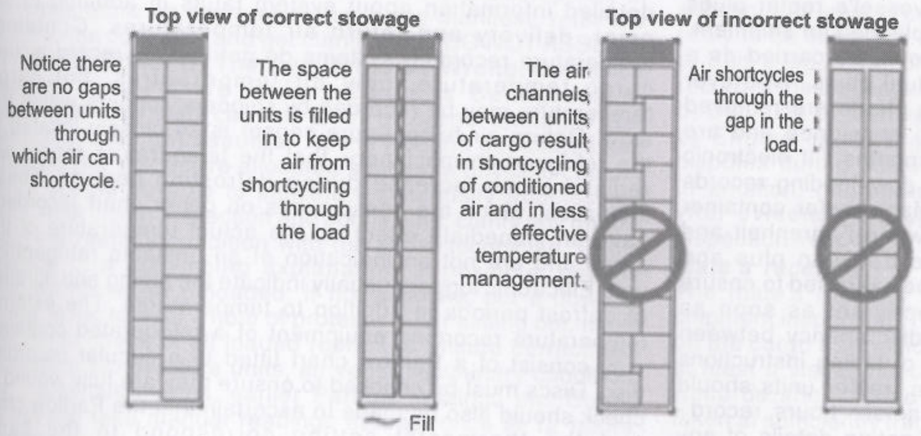


Fig. 11 Cargo Stowing Patterns

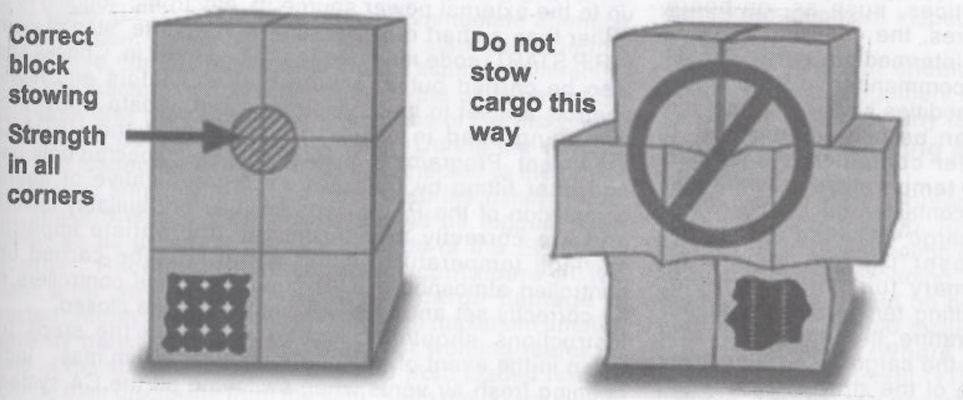


Fig. 12 Stowage of Packages

If the product is of inferior quality at the time of harvesting or not packed in the right manner or not stowed in the right manner inside the refrigerated chamber or if the temperature is not maintained accurately within a narrow range, even the Humidification System cannot prevent the cargo from deterioration or damage. GARBAGE IN - GARBAGE OUT!

Guidelines for loading Cargo into Reefer Cargo Holds and Containers

Do not stuff if container interior or cargo hold is not found to be clean, dry and odour free. Make sure that there is no damage to the cargo hold and container walls, and that door seals are in good condition and floor drains are open. Make sure that refrigeration unit is properly operating. Advise the booking party before stuffing whenever the container is not fit to receive the cargo due to physical damage to the container box and/ or machinery, or due to any other reason. Ensure that the reefer unit is set at the proper carrying settings for the specific goods including temperature - check for Celsius or Fahrenheit specification and ventilation opening as per the booking order. Check that the label attached to the reefer machinery has the correct details of the settings as per the booking order. The reefer may be pre-cooled only when "cold tunnel" is used to connect between the reefer to the cold storage. In all other cases, pre-cooling of the reefer should never take place. Thereefer machinery should not be running whilst loading. Ensure that cargo is loaded into the reefer at the carrying temperature. Reefer containers are not designed nor intended to reduce the temperature of cargo. They are designed to maintain temperatures. If goods require their temperature to be lowered then this should be done in cold storage prior to stuffing in the container. If there are combined products in the container, they must be compatible with respect to temperature, humidity, gases and odours. Cargo should be stable and evenly stowed. The total cargo weight should not exceed the maximum payload of the container. Cargo should be stowed on clean pallets, away from walls and rear door, and properly braced. Cargo on pallets must be properly unitized and well secured to the pallets. Cargo should not touch air chute, or block air circulation, and airflow should not be blocked by ice, dunnage or plastic. Cargo should never be stowed above the red load line. Ensure that there will not be loose packing materials as these can restrict proprer air circulation and reefer operation. Check that any portable temperature recording devices are properly in place, adjusted, functioning, and their location recorded. Their charts should be marked with load identification, start time, date and location. Make sure that the Genset unit is working and has sufficient fuel for the land transport.

Carriage Guidelines

Vessels should always carry sufficient quantity of basic reefer spares, suitable tools, repair manuals and refrigerants, specifically relating to the type(s) of refrigeration units carried, for use by the reefer technician in case it is necessary to effect emergency repairs during the voyage. It is preferred to have all the operation manuals and the spare part lists stored electronically in a single CD ROM. There are many different types of reefer units in general use, each having individual repair and maintenance characteristics. The provision of a working platform is essential if containers are to be stowed more than one tier high. The ship's crew should make certain that the spares provided are of the correct type and quantity before loading commences. Prior to shipment it is essential that written confirmation is obtained from the shippers addressing all cargo conditions of carriage including temperature, ventilation and humidity requirements. Companies should give precise instructions to their vessels, listing details of all parties to be contacted in the event of a malfunctioning reefer container. Companies should provide the vessels with a reefer operations manual specifying the carriage particulars of various commodities shipped in refrigerated containers, possible problems and a summary of troubleshooting procedures. If there is any doubt, the advice of cargo care experts should be obtained. Before loading starts, crew should reconfirm that the vessel's reefer plugs are compatible with all reefer containers planned for shipment. A number of reefer extension leads should be carried as a precaution against the failure of individual plugs. Wherever chart recorders are fitted, the recording charts are removed before the container is released to the consignee and are retained for a period of at least twelve months. If electronic logging is incorporated, procedures for downloading records should be established and observed. Many reefer container losses have arisen from confusion between Fahrenheit and Celsius temperature scales, and also between plus and minus temperatures. Great care should be exercised to ensure that carriage temperatures are correctly set as soon as containers are placed on board. Any discrepancy between container settings as received and bill of lading instructions should be reported immediately. At sea, reefer units should be inspected at intervals of not more than six hours, record - ing the times of such inspections and noting details of any problems in an appropriate log book. Alternatively, automatic logging systems may transmit signals via power cables to a central point. Such systems should be checked for error messages on a regular basis. Basic instruction in customary reefer container practices, such as, on-board monitoring and recording procedures, the checking of seals and the shifting of containers at intermediate ports, should be given to crew members. It is recommended to keep crews informed of the values of the commodities shipped so that the significance of a potential loss can be fully appreciated. **It must be remembered that a reefer container is designed only to maintain cargo at the pulp temperature prevailing at the time of stuffing.** Although the container machinery, over a longer period of time, can bring cargo delivered at too high a temperature down to (or closer to) the designated temperature, this is not the primary function of a reefer container. In cases where the stuffing temperature is higher than the stipulated carriage temperature, the refrigeration unit will cool down the surface layer of the cargo relatively quickly (within days). However, the centre of the stow will not reach the desired temperature for a considerable period of time.

The temperature of a cargo stuffed into a refrigerated contai should not, in general, deviate by more than 3ºC (5ºF) from specified carriage temperature. Chilled cargo (excludi bananas) should not deviate by more than 0.4ºC (1ºF). E these deviations should not be encouraged; the objective to receive and deliver the cargo at the carriage temperature a container is loaded with a cargo where the pulp temperat exceeds the carriage temperature stipulated by the shippe the "warm" cargo will cause the temperature of the delivery to rise very rapidly when passing up and through the car Eventually, the return air may reach a temperature level here the refrigeration machinery cannot cool it down sufficiently p to re-circulating it as delivery air. The tracking pattern on chart or logger will show a temperature higher than that of temperature control setting. The delivery/return air differen will in most cases narrow down as the continuous circulat of air, being cooler than the cargo, brings the car temperature down towards the desired level. Any rise in ret air temperature will be arrested as the refrigeration unit beg to run in standard operational mode. Should a refrigerat unit cease to operate, the chart or logger will register a grad but steady rise in temperature to the point where eventua the ambient temperature is recorded. Again, the sensor record an air temperature and the record will not accurat reflect the true position regarding the cargo itself. The ca will be reasonably well protected from the influences of external air temperature by the surrounding insulation. Th are many other situations where the record may not b precise representation of the temperature or condition of cargo within. Conclusions should not be drawn automatic from the temperature tracking pattern alone. Recorder ch do not identify refrigeration unit defects, but do give use indications of correct operation. Data logger records may g detailed information about system faults in addition to point, delivery and return air temperatures. Contai temperature recording systems do not usually record act cargo temperature, only air temperatures, but ca temperature may be recorded by shippers' loggers within stow. Return air temperature sensor is so closely located the refrigeration machinery, that the temperature record register some increase during defrosting periods. Th increases, which are conspicuous on paper chart record have an immediate effect on the actual temperature of cargo and are not an indication of an unstable refrigera unit. Electronic loggers usually indicate the timing and dura of defrost periods in addition to temperatures. The exte temperature recording equipment of a refrigerated conta may consist of a Partlow chart fitted to a circular recor disc. Discs must be checked to ensure they are fully woun check should also be made to ascertain that the Partlow c and the thermostat setting correspond to the sa temperature scale as specified by shippers. All rele shipping details must be entered on the Partlow chart by carrier's representative or agent, and commencemen tracking must correspond with the date and time of the h up to the external power source. If electronic logging is u rather than a chart recorder, an appropriate "start of jour (TRIP START) code may needed to be keyed in. Checks sh also be carried out to ensure that ventilators and hum controls are set to the levels requested. If data logger pr are being used in order to comply with the USDA C Treatment Programme, they should be inspected both be and after fitting by the carrier's representative or agen completion of the PTI, to ensure they are suitably calibr and are correctly monitoring the appropriate importa carriage temperature. If the cargo is to be carried u controlled atmosphere (CA) conditions, gas controllers r be correctly set and fresh air vents must be closed.

Instructions should be issued regarding the steps t taken in the event of gas control failure, which may inc opening fresh air vents when switching off the CA syster tropical or sub-tropical regions, it is preferable that contai are loaded in a temperature controlled environment (e.g., chilled warehouse). However, if loading in ambient conditions, containers should not be pre-cooled before stuffing except, in exceptional circumstances, as this may lead to the development of excessive condensation on the inner surfaces of the container. Refrigeration machinery should always be switched off when the container doors are open to minimise the accumulation of moisture on the evaporator coil, the only exception being loading or devanning using a cold store tunnel. In the event of a reefer machinery unit appearing to function erratically, the vessel should advise its owners and the agents at the next port prior to arrival so that arrangements can be made to rectify the problem ashore if nothing can be done during the sea transit. In such circumstances, a surveyor should be appointed to attend the vessel on arrival, in order to inspect and report on the condition of the cargo and the container. If a container sustains physical damage, the agent and/or the surveyor must ensure that action is taken to rectify the problem without delay so that a potential cargo loss can be minimised. Loaded Reefers should always be loaded at lower tiers.Reefers should always be loaded with machinery aft. Do not stow two loaded reefers with machinery facing each other. Leave sufficient working/moving space all around a loaded reefer. Many cargo losses have been reported due to loaded reefers being stowed by mistake in the wrong stow and so had not been connected throughout the voyage. Try to load all chilled cargo reefers to connect to common breakers. Ensure that all reefers with water cooled condensers are stowed inside the hatch and connected to the water lines before connecting the power. If loaded reefers with air cooled condensers are stowed inside the hatch, the blower capacity should be sufficient to provide sufficient air exchange to take away the heat extracted. Wherever, there is a discrepancy in the temperature on the reefer and in the manifest, refer the matter to the company and get clarification. DO NOT ASSUME ANYTHING. **Either Of The Two Could Be Wrong.** Confusion between temperature units – Degrees Centigrade or Fahrenheit has also caused a lot of cargo damage. Get Clarification. **Do not assume.** As the Reefers get loaded and stowed in the respective allocated spaces, a physical cursory glance should be able to indicate a potentially troublesome reefer. After closer inspection and connecting, clarify any doubts about the reefer's condition with the shore technician. In the absence of a convincing explanation, if possible, get the troublesome reefer offloaded. If not possible, put it down in writing, in the form of a note of protest. After sailing out, make a thorough check of all loaded reefers to ensure correctness of setpoint, temperature units, air vents, machinery condition, any previous alarms, earlier Partlow readings etc. During the voyage take manual readings at least once in 12 hours. Most of the units have an IN RANGE LED which tells us if the temperature is within range. This can be read from a distance. Even if IN RANGE LED is not lit, it does not indicate any malfunction. Make a mental note and check up after some time, during the next round. Most of the units have a CRITICAL ALARM signal (LED) which when lit need immediate attention and investigation. Some of the non critical alarms like Defrost Sensor Failure, Battery failure, etc., do not signify a failure, but indicate the machinery condition. Most of the units have LED indicators to give the current running status of the machinery and which can be read from a distance. During the voyage, ensure that loaded reefers are always connected to the power supply. Power shutdowns should be kept to the minimum. All power shutdowns and breakdowns should be logged down diligently, so as to match with the records of the Electronic Datacorder. Reconnect Chilled Cargo containers at the earliest after any power shutdown. If cargo damage is suspected, inform the company, and salvage maximum amount possible by transferring into an empty but working reefer. At the end of the voyage, disconnect power from loaded reefers just before their discharge from the ship. Keep the power supply on as long as practicable. Keep copies of Partlow Charts, if changed during the voyage. Replenish spares and refrigerants used during the voyage. Ensure documentation is properly completed.

Safety Guidelines

1.Take care of personal safety when working on:
a)High tier reefers
b)During rough weather and rain
c)Controlled Atmosphere Reefers

2. Keep away from leaking refrigerants - they may cause frostbite and asphyxiation. When operating valves on refrigerated machinery (or any pressurized machinery) do not be in line where the valve spindle or parts can fly off. Many fatal accidents have been reported due to the valve spindle accidentally flying off from the valve housing and piercing human organs.

3.Refrigerants at high temperature can liberate phosgene gas which is toxic. They can also form hydrofluoric acid in contact with moisture which can attack metals. A generator diesel engine crankshaft bearings got wiped out because of leaking refrigerant from a nearby refrigeration machinery which got sucked into the turbocharger air side and eventually found its way into the crankcase.

Documentation

Importance of Documents

Since seaborne trade of refrigerated products involves many international parties like exporters, importers, shippers, consignees, carriers, charterers etc. and are subject to many international regulations, maintenance of proper Documentation is of paramount importance. Documents are fundamentally important in the investigation of any claim involving damage to cargo. They will be examined by the technical surveyors, and may be used as evidence in any subsequent legal proceedings. The following documents are likely to be important in the event of a claim:

a) Ship's log. b) Bill of lading. c) Mate's receipts and attached record of the inspection of the cargo prior to and during loading. d) Deck log of loading and unloading. e) Stowage plan. e) Engine Room log. f) Any documentation arising from disputes during unloading and/or receipt of cargo.

In addition, photographs and video recordings can provide vital evidence in support of statements in the logs and inspection reports.

Mate's receipts

The mate's receipts should include the record of the pre-shipment inspection. This record should detail all observations on the cargo's condition at time of receipt, including results of at least a visual inspection of each part of the consignment. Records should also include temperature measurements, taken at sufficiently frequent intervals to provide a fair indication of the average temperature of the cargo.

Any observations which indicate that cargo temperature is high, or that cargo was delivered in a damaged or deteriorated condition, should be supported as far as possible by further evidence. This evidence might include photographs taken during pre-shipment inspection or results of reports by cargo surveyors.

The mate's receipt should include any information on the nature of the consignment supplementary to the bill of lading, as well as details of any labels

Deck Log for Loading and Unloading

Loading

Many charter party agreements specify a minimum rate of transhipment or loading. To demonstrate compliance with this, and to provide evidence in case of claims concerning damage to the cargo during loading, the timing and sequence of events during loading should be noted in the deck log. At minimum, the log record should include the following:

•Time alongside. •Where cargo was loaded from – quay, lighter, fishing vessel. •Times of opening and closing of hatches. •Arrival and departure of stevedores onboard. •Times when the refrigeration system was turned on and off.

•Start and finish of cargo stowage. •Any breaks in loading. •Weather conditions (sun, wind, rain, ambient temperature). •Any unusual or irregular events which might affect the condition of the cargo during stowage or subsequent carriage.

Unloading

Normally, unloading is the responsibility of the receiver, and the master of the vessel may consider that his responsibility for the cargo is over. However, the deck log should continue to record conditions during discharge, logging similar information as listed above for loading.

Stowage plan

A stowage plan should be drawn up for all cargoes – an accurate plan is a central piece of evidence in any damage claims arising against the vessel. The stowage plan should indicate the location of each consignment and part of the consignment and should include the following information: •Number of units (pallets, cartons or blocks) in each location. •Gross and net weight. •Origin of each part. •The corresponding bill of lading.

Engine Room log

The engine room log is one of the most important documents,since it contributes evidence about the temperature of the ship's cargo during stowage and carriage. The log should document at least the following: •All power breakdowns or power shutdowns to the reefer containers, accurate to the minute. The reefer containers' data recorders have a minute by minute recordings of all events pertaining to the machinery and temperature readings inside the container. •The locations of temperature sensors in the holds. •Temperatures at the sensors in the holds. •Times when compressors were turned on and off. •In air cooled systems, the temperatures in the air streams entering and leaving the holds and compartments. •In pipe cooled systems, the temperatures of refrigerant to and from the cooling pipes.

Actions In Case of Dispute

Action By The Master of The Vessel

The Master must load the cargo in apparent good order and condition and act to maintain it in this state. This section describes actions to be taken when a potential problem is identified.

In the event of any concern or dispute over the condition of the cargo while loading or unloading, the Master of the vessel should contact his Owners or Charterers or his P&I correspondent. Best practice would indicate that loading or unloading should cease until instructions have been received, although this may not always be possible.

As soon as any question is raised over the condition of the cargo, the ship's Master should begin to document the events surrounding the discovery of defective material, and the nature and possible extent of the alleged defects.

If possible, loading or unloading of the vessel should be halted and the hatches closed until a cargo Surveyor is present. Ideally, cargo should be inspected and sampled while still in the hold, or even during discharge, allowing the Surveyor to determine if the nature and extent of the damage is in any way related to position in the hold.

Once the cargo has been discharged into store, relating damage to location in the hold is obviously more difficult, or impossible, unless the cargo is adequately labelled. Therefore, if loading or unloading must continue, the Master should ensure that each cargo unit is labelled with the hatch number and deck, as well as location within the hatch and deck, as it leaves the hold. The Deck Log should also record the destination of the material and the agent responsible for handling it.

Records

The Master should ensure that all records and documents relevant to the dispute are secure, and that they are only made available to parties representing the ship's interests.

Services of Surveyors

When a problem is identified during loading or unloading – for example, if the temperature of the material is too hig loading or unloading should cease until the cargo has b inspected by a specialist surveyor.

If the dispute concerns the quality of the product, it will prob be necessary to call in at least one specialist surveyo examine the cargo, establish its current quality and deter the nature and cause of any defects.

If it is suspected that defects result from maritime cause for example, physical damage from movement of cargo from contamination with seawater, fuel oil or bilge water - expert in ship operations should be called in. However, if defects could be attributed to the initial quality of the mate when loaded, or to the way the product was stowed and car on the vessel, a specialist Surveyor would be appropriate Many of the Surveyors appointed by local shipping agents general marine Surveyors, often with a seagoing backgrou they are not necessarily skilled in the evaluation of the qu of fish cargoes. Masters and Agents are therefore advise check the expertise and qualifications of Surveyors care to ensure that their technical background and experience appropriate for the particular job.

As a general rule, a single Surveyor should not commissioned for both a cargo survey and a survey of ve condition. Since the skills required for each type of assessm are very different, it is unlikely that one person would h experience in both areas at the levels of expertise require fish cargo Surveyor should have a background in food sci and the inspection of food products, and, ideally, s experience in assessing the quality of frozen fishery produ

Official Inspectors and Sampling Procedures

Where official inspectors – for example, port health office veterinarians – are involved, the master should documen authority under which the officers visited the vessel and name and status of each officer.

The Master is also advised to record the nature and amo of any samples taken by representatives of the owners o officials. Such records should include the location of samples within the hatch or deck, the authority under w the samples were taken and the destination of the samp If part of the sample is given to the master, he should en that it is fully labelled, and, if possible, that it is sealed container under the impress of the person taking the sa The master should store the sample in a secure place, u conditions such that the quality of the sample will not cha If the cargo is in store, the surveyor should take into acc the manner of discharge and delivery to the store, in these operations could have affected the quality of the pro or could in themselves be responsible for any damage.

Refrigerated Cargo Losses

In spite of having so many elaborate guidelines procedures, losses of refrigerated cargoes do occur. Ironi most of reefer cargo damage occurs not because of tech reasons, but because of poor communication systems, management practices, poor administrative procedures, so on. Most of these losses could have been avoided if p checklists were made and strictly adhered to and sys followed.

ITIC Claims Review reports that there has been an incre number of claims (about 15 in the past year varying bet US$ 15,000 and US$ 150,000 each in value) which resulted from reefer containers either being left off pow the load or discharge port or carried at the wrong temper due to Agent error.

Reefer Containers not plugged

The following claims resulted from Ship Agents faili arrange for reefer containers to be plugged in whilst i port area:

Frozen Prawns from Lagos left off power on the qu Newcastle, England for ten days.

Ice Cream for export from the U.K. to Beirut left off power be the Agent failed to inform the Reefer Engineers of its arriv

Pumpkins, Yams And Sweet Potatoes off power at Kingston, Jamaica for a week found to be bad on arrival at the London fruit market.

Frozen Pineapple Concentrate off power at Valencia for four days over a holiday weekend.

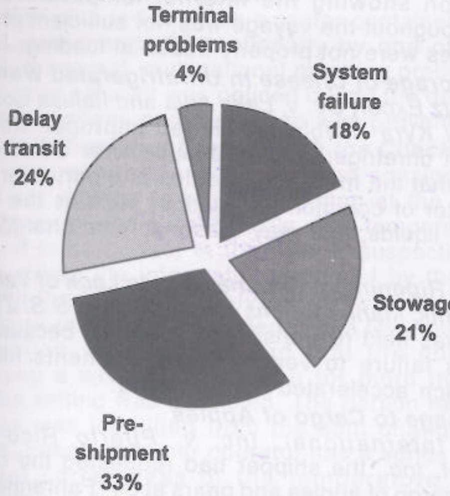


Fig. 13 Analysis of Reefer Cargo Losses

Incorrect Temperatures Maintained Due To Poor Paperwork

The following claims resulted from errors by Ship Agents whem entering temperatures on ship's documents or by inputting incorrect details into computers:

Cheese from Denmark to the U.K. carried at 0º C instead of -20º C.

Concrete Additives from Bremerhaven to Helsinki which needed to be maintained at +10º C to prevent frost damage, carried at -6º.

Bottles Of Wine from Antwerp to the U.S. carried at -20º C.

Frozen Beef at +2º C because the temperatures for two reefers had been transposed by the Agent.

Frozen lobster in general stow: A liner agent Member in Taiwan booked a 20 foot reefer container of lobster from Keelung to Melbourne. When the agent prepared the stowage plan for the port of Keelung the container of lobster was shown as part of the general stow. The container was therefore off power for the voyage, and on arrival at Melbourne the lobster was declared a total loss. The receiver claimed US$74,000 from the line and the line claimed the same amount from its Agent. Although it was initially felt that the line had failed to mitigate its loss and had paid too much, after consulting lawyers the Club paid the claim in full.

Agents accepted a booking for the shipment of a reefer container containing lobster meat. As agents for the Line one of their responsibilities was the preparation of the ship's stowage plan at the loading port. Due to a clerical error in the Agents' office the reefer container was loaded in a general cargo stow and when out-turned at the discharge port, the contents had to be destroyed. The receivers made a claim for US$ 74,000 against the Line to which they had no defence and they in turn claimed indemnity from the Agents. After taking legal advice, the Line's claim was settled in full. It is pertinent to mention here that the financial consequences of simple errors are impossible to foresee.

In this instance the value of the cargo was US$ 74,000 but it could well have been many times that figure.

Incorrect Instructions for Reefer Temperature Setting

A port agent in the UK received a container list from his principal's South American Agent which included two containers of frozen meat shipped at -18°C. When this information was transferred to the Agent's computer system, the containers were incorrectly shown as containing film with a temperature setting of +13°C. Unfortunately, the error was not picked up on additional checking with the result that when the containers were discharged at the UK port they were set to +13°C in accordance with the Agent's instructions. Three days after arrival at the container depot blood was seen to be seeping from the doors of the containers, which were then opened to reveal rapidly thawing frozen beef. The temperature control was re-set to -18°C to try to stabilise the consignment. Surveyors were immediately instructed by the carrier's P&I Club and the Port Health Authority issued notices stating that the consignment could not be used for human consumption. An offer was accepted for salvage thereby reducing the claim against the Agent which was settled by the Club.

Failure to instruct Terminal of Storage Conditions

Importers of wines from France into the United States had previously encountered problems with consignments imported through New York during the winter months when the wine could be subjected to sub-zero temperatures causing it to freeze and so lose its quality.

In response to this problem, the Line issued instructions which required the Agent to instruct the terminal operator to open the container as soon as it was delivered and place portable heaters inside to keep the temperature in the container above freezing.

Unfortunately, the agent failed to give the necessary instructions in respect of a cargo of nine containers of wine, and whilst eight of the containers suffered no damage, the carriers received a claim for US$ 120,000 for freezing damage to the remaining container.

A claim was made against the Agent and after lengthy negotiations a satisfactory settlement in the sum of US$ 32,650 was agreed.

Hyundai Fortune: Failure To Maintain The Required Temperature

The claimants were the owners of a cargo of Hami-melons that were loaded into a reefer container in Shenzen, China. The reefer container was then loaded onboard the vessel "Hyundai Fortune" in Hong Kong for carriage to Singapore. The melons were supposed to be carried at a temperature of 3ºC at all times. However, evidence was adduced to the effect that the reefer container did not maintain the required temperature. According to the evidence, the temperature rose to as high as 25 ºC during transit. Consequently, the melons arrived at Singapore in a badly damaged state.

The claimants wrote to the shipowners demanding compensation but the shipowners ignored their demands for a period of almost 1 year. The claimants then commenced an action in rem against the owners of the "Hyundai Fortune" in Singapore.

The shipowners applied to court to stay the proceedings in Singapore by relying on the exclusive jurisdiction clause in the Bill of Lading, which referred all claims arising from or in connection with or relating to the Bill of Lading to the Seoul District Court in Korea.

The High Court refused to stay the proceedings in Singapore after taking into consideration the following factors:

a. there was really no defence on the merits of the claim;
b. no trial would be held in Korea as the action had become time barred there;
c. the connecting factors of the case were all related to Singapore; and
d. the overall justice of the case was with the claimants.

The shipowners appealed against the decision refusing a stay of proceedings in Singapore.

Judgment: The shipowners' appeal was dismissed.

Deterioration of Banana Cargo due to Improper Ventilation

In *Transatlantic Marine Claims Agency, Inc. v. S.S. Zyrardow*, the carrier was found liable for the deterioration of a cargo of bananas where it had failed to heed the charterer's instructions calling for the ventilation of the storage holds sixty hours after the closing of the compartments, in order to rid the compartments of high levels of carbon dioxide and ethylene, which accelerate the ripening process.

Practice of Carrying Unrefrigerated Cargo in Reefer Containers

In *Agfa Gevaert Inc v SS TFL Adams and Trans Freight Lines*, the failure to effect refrigerated stowage in breach of the contract with the shipper was held to be an unreasonable deviation preventing the carrier from relying on the package limitation under the Hague Rules and COGSA. This lapse has occurred because of the practice of carrying ordinary unrefrigerated cargo in reefer containers to maximize use and mistakes occurring with cargo requiring refrigeration and not receiving it.

Olive Oil Damaged By Rust Due To Being Carried In Unventilated Containers

In *Cigna Insurance Co. of Puerto Rico* v. *M/V Skanderborg*, the carrier was not held responsible where tins of olive oil were ruined by rust as a result of being packed by the shipper in unventilated containers provided by the carrier, where the inadequacy of the packing was non-apparent to the carrier and the shipper had given no special instructions as to the type of containers needed.

Frozen Shrimp Damage due to failure of Ship's Equipment

In *A.R. Lantz Co, Inc.* v. *United Trans-Caribbean*, the Court found that the vessel was unseaworthy to carry frozen shrimp, because it was missing the necessary spare parts to maintain the refrigeration unit and one generator was inoperative, making the "vessel's refrigeration system unsuitable before the vessel broke ground." In making this decision, the Court followed the finding of the Second Circuit in *Atlantic Banana Co.* v. *M/V Calanca*, which found that improper maintenance and the inoperative refrigeration equipment made the vessel unseaworthy.

Damage to Fruit Cargo due to Fire damage to Ship's Reefer Equipment

In *Banana Services Inc. v. M/S Tasman Star*, a fruit cargo was damaged when a fire on board disabled the ship's refrigeration control panel, making it impossible to refrigerate the fruit properly. The Court found that the real cause of the loss was the fire, which, although it did not directly ignite the cargo, nevertheless validly exculpated the carrier from liability under the fire exception of sect. 4(2) (b) of U.S. COGSA(76) and the U.S. Fire Statute. (77)

Thaw Damage to Cargo of Frozen Orange Juice Concentrate

In *Ins. Co. of N. America* v. *M/V Frio*, involving thaw damage to a cargo of frozen orange juice concentrate, the carrier failed to establish either the defence of insufficient packaging or the exception of inherent defect of the goods, and was held liable because it had not rebutted the presumption resulting from the plaintiff's proof that the concentrate had been loaded in good condition and was discharged damaged.

Damage to Soyabean Cargo due to Lack of Ventilation

In *Granite State Ins. Co.* v. *M/V La Pampa*, where the claimant proved that the carrier had failed to take all reasonable and necessary measures to prevent sweat damage to a cargo of soybeans, and to ventilate the hold in question, the carrier was held liable for the entire loss under the *Vallescura* Rule, because, despite some evidence that the soybeans had a higher than normal moisture content upon loading, the carrier has not met the burden of showing what part, if any, of the damage is attributable to such a condition."

Damage to Orange Juice Concentrate stowed beside Warmer Cargo

In *Insurance Co. of N. America v. M/V Frio Brazil*, the carrier failed to maintain the reefer unit containing pallets of orange juice concentrate at the required cool temperature and stowed it beside drums of warmer concentrate, resulting in a heat transfer between the drums and the pallets. The resultingdeterioration of the orange juice concentrate rendered the carrier liable.

Damage to Cargo of Frozen Raspberries due to Improper Temperature maintenance

The Court held a carrier responsible for thaw damage to a cargo of frozen raspberries, because they were not kept at contracted temperature throughout the voyage. In this c the Court made it very clear that substantial proof mus presented in order to invoke the exception of act of the ship under art. 27(g) of Law No. 66-420 of June 18, 1966. In case, a graph showing the internal temperature of container throughout the voyage was not sufficient proof the raspberries were not properly frozen at loading.

Improper Storage of Cheese in Unrefrigerated Wareho

In *M. Golodetz Export Co. v. Lake Anja and Italusa Corp.* v *V Thalassini Kyra* involving alleged improper storag cheese in an unrefrigerated warehouse after discharge, Court noted that the melting properties of a particular che is not a matter of common knowledge, such as the free properties of liquids, that may reasonably be charged to carrier."

Accelerated Ripening of Bananas due to Lack of Ventila

In *Transatlantic Marine Claims Agency, Inc. v. S.S. Zyrar* the carrier was held responsible for the loss because of the carrier's failure to ventilate compartments filled bananas which accelerated their ripening.

Freeze Damage to Cargo of Apples

In *Pueblo International, Inc.* v. *Puerto Rico Ma Management, Inc.*, the shipper had requested the carrie maintain its cargo of apples and pears at 34º Fahrenheit du transit in reefer containers. The bill of lading provided f permissible margin of error of plus or minus 5º Fahrenh Because the shipper knew or should have known that ap and pears suffer injury at temperatures below 29.3º F. 29.2º F. respectively, it had exposed the fruit to a serious of freeze damage by specifying a carrying temperature of F., in view of the 5º F. margin of error. The temperature ins the reefer units had never fluctuated above or below the variance permitted, nor was there any malfunction in refrigeration system. The carrier thus established that freeze damage resulted from the act of the shipper (COG sect. 4(2)(i)), rather than from any improper care of the ca on its part.

Damage to Peanut Cargo due to Aflatoxin Contaminati

In *Hershey Foods Corp. v. Waterman Steamship Corp.*, a ca of peanuts was contaminated by aflatoxin when delivered the consignee. Although the carrier had exposed the carg heat caused by direct sunlight and had not properly ventila it during the voyage (conditions conducive to the growth of mould which causes aflatoxin), the Court held that the ship had failed to prove its *prima facie* case that the peanuts w free of aflatoxin when delivered to the carrier, because testing methods employed at loading were outdated and sample used was inadequate. Nor was there proof that peanuts had taken any harm while being transported to carrying ship aboard the defendant's barges.

Damage to Meat Cargo due to Hot Loading

Cargo: Meat
Load Port: JNPT
Discharge Port (Transhipment) Sallalah
Loaded for Onward: After 3 days
Discharged at Hodeidah: After 3 days
Result on inspection: Rejected by Health Authority
Reason: Blood Stains observed on Meat surface
Alleged Cause: Improper Temperature Maintenance du the voyage.

ANALYSIS

1.Very Hot Cargo was loaded, the temperature being (Return Air Temp) when the Container was loaded into ship and power was given for the first time. The tempera setpoint was -18°C. The machinery took almost 17 hou bring the temperature within range.

2.When the Container was loaded on board again and pow up, the temperature was -5°C. The container was wi power for almost 4.5 hrs during the transshipment pe when the temperature started rising fast, because of ambient temperature. This time, the machinery took only about 1 hour to bring the temperature within range.

3. Machinery was working satisfactorily as it could bring down the temperature within range of setpoint within 1 hour the second time.

Change of Setpoint Temperature

A case was reported in which a reefer container temperature setpoint was changed intentionally by one of the officers because of internal multinational manning problems. Luckily, the change in setpoint was noticed during the daily inspection rounds and serious cargo damage was prevented

Failure to Adhere and Comply with the Checklists

A case was reported in which a cargo consignment of egg powder was noticed to be deteriorating at the docks while waiting to be loaded onto the ship. The temperature setpoint was found to be correct at the time of suspecting the cargo damage. When the information recorded by the Datacorder was downloaded and analysed, it was found that the temperature setting was changed only a few hours before the deterioration was noticed and that the container was maintaining a wrong temperature for more than 24 hours before the setting was corrected. The person responsible for this lapse was identified from the shift changeover timing schedule. Every container operator has a series of checklists to ensure correctness of the temperature setting and maintenance of the cargo temperature. However, sometimes, due to carelessness, complacence or due to work pressure, these checklists are disregarded or bypassed resulting in cargo damage.

Cargo Damage due to Misinterpretation of Frozen and Deep Frozen

There was a case related to a cargo of lobster tails which were described by the shipper as "frozen", the carrier should have verified the actual condition of the cargo which in fact was deep frozen and therefore required being kept at -18º C. The Court had declared that the carrier was a specialist who must enquire as to how the cargo should be carried, being alerted by the word "frozen" appearing on the bill of lading. The lower court held that the carrier was not responsible for products which should have been carried at -18º C when the goods were shipped as merely requiring "refrigerated stowage" and the tariff rate was for goods that were frozen rather than deep frozen.

Insufficient Capacity of Reefer Plant

A reefer ship loaded a reefer cargo of lychees in bulk. Prior to berthing, the ship's holds had been pre-cooled to 12ºC as per the charterers' instructions, and carriage temperature was to be 1ºC. The cargo was delivered to the ship at an ambient temperature of 26ºC and duly loaded, and the mate's receipts and bill of lading were signed clean. The carriage instructions required the cargo temperatures to be reduced from 26ºC to 1ºC within 72 hours.

The ship arrived at the discharge port, however, during discharge, mould damage to the cargo was apparent and approximately 70% of the cargo was affected. The surveyor further advised that prior to loading, the fruit had been treated with sulphur di-oxide, a chemical used to inhibit mould growth. However, the sulphur di-oxide treatment had been uneven and this may have been a factor that contributed to the damage. Low carriage temperatures inhibit the growth of fungus, but the ship's refrigeration capacity was apparently unable to reduce the temperature of the cargo from 26ºC to 1ºC within 3 days. Cooling down in some compartments took 10 days and cargo interests allege that the mould developed during this time. The managers should have contacted the charterers to obtain updated stowage and carriage instructions.

On the basis of the load port survey, the way the fruit was loaded, fumigated and packed probably led to the mould developing in the first instance. The other contributing factors were: The reefer plant was unable to cool the fruit within the required period (reduce temperature from 26ºC to 1ºC within 72 hours). The master did not query the member's pre-stow instructions especially when the recommended temperatures were not achieved even after 72 hours.

Agent's Liability for Cargo Survey

A Lloyd's agent was instructed to carry out pre-shipment surveys on twelve consignments of frozen swordfish chunks and the surveys were completed over a period of approximately four months. he buyer required the agent to warrant that laboratory tests had been carried out prior to shipment to establish the mercury content of not less than 5% of the swordfish selected on a random representative basis.

The agent asked the State Laboratory to carry out the surveys. The correct number of cartons were opened, samples were taken and the analysis report showed that the mercury content was within the specifications. Unfortunately, the agent had omitted to tell the Laboratory that all samples must be analysed separately and the Laboratory, in accordance with their normal practice, mixed the samples together and analysed only one or two composite samples. Furthermore, the wording of the agent's survey reports suggested that 5% of the cartons had been both sampled and tested.

On arrival in the United States the consignments were subjected to additional analysis by the US Authorities and the majority were found to contain mercury in excess of the permitted maximum. The cargo was rejected as being unfit for human consumption and the US importer suffered considerable financial loss which was only partially covered by his cargo insurers.

Contamination of Tank Container of Wine

Member, acting as agent for the carrier, arranged for the provision of a tank container to a wine exporter for the shipment of 21,000 litres of wine from Australia to the USA. On arrival, the consignee refused to take delivery as the accompanying documents did not include the relevant certificate of food quality. He also alleged that the wine was contaminated. Arrangements were made for the tank container to be returned to Australia where tests could be carried out and, if necessary, the wine distilled to remove its alcohol content.

Enquiries revealed that the tank container had been used previously for a cargo of liquid detergent and a steam clean as well as the replacement of all gaskets and seals to remove all traces of the detergent would have been necessary to bring it up to food quality standard. Unfortunately, this was not done and the wine had become contaminated. The tank container had been ordered by the agent from a yard which was not conversant with food quality standards as the yard in question was not normally used for the storage of tanks intended for the carriage of commodities requiring food quality standards.

The agent's written instructions to the yard specified the tank required by container number and also that it was intended for the carriage of a cargo of wine but this did not oblige the yard to undertake any course of action to ensure that contamination of the contents would not occur. It was incumbent on the agent to ascertain the previous content of the tank from import container files but this was not done.

A claim for US$50,000 was made, but finally a settlement was made for US$ 35,000.

Orange Juice Cargo Damage due to Port Strike

When port employees went on strike at a South American port, 50 containers of orange juice had to wait two weeks on the dock until the next ship sailed. The sheer volume of reefer cargo which congested the strike-bound port meant that there were not enough reefer points or clip-on refrigeration units available to keep the cargo cool. The orange juice was found to be unfit for human consumption at its destination and cargo interests presented a claim for US$ 400,000. The agent at the load port had verbally informed the shipper of the problem in cooling his cargo but the shipper denied receiving any such notification. The shipper further said that he would have taken the orange juice back to his own cooling facility if he had been made aware of the situation. The carrier paid the shipper and claimed reimbursement from his agent. *This is a good example of the necessity to put everything in writing.*

Damage to Cases and Pallets of Oranges shipped from Morocco to the US

Oranges were packed in cases, then palletised, with 63 cases to the pallet, on board the *Ocean Rex*. The pallets consisted of nine cases to a tier and were stacked seven tiers high, secured by reinforced angles and nylon straps. The charter provided for "free in/liner out till first point of rest in warehouse". The cargo was delivered to the vessel in apparent good order and condition and clean bills of lading were issued. Although the master filed a note of protest with respect to delays in loading and the effect of such delays on the product's pulp temperature, he did not register a complaint with respect to the packaging, longshoremen handling or onboard stowage.

On discharge at New Bedford in the US, significant physical damage was observed to a number of pallets, although the owner and charterer disagreed as to the extent and cause of same.

After discharge, the cargo was moved from the pier by forklift and flatbed truck to an adjacent cold storage warehouse, where it was stored in accordance with government regulations for fourteen days. Thereafter, some of the damaged cargo was sent to a repacking facility, from where it was sold. Other pallets were shipped directly to cargo buyers. Reefer Express maintained that there were a number of possible causes of damage, for example pre-shipment condition and/or insufficient packing, heavy weather and negligent handling during discharge to the wharf and subsequent delivery to the warehouse.

The panel majority found that Reefer Express was liable for the damage to the cargo, awarding Bacchus $ 218,246 in damages.

Reefer Cargo Losses During Transhipment

In carrying reefer cargo, it is not only the temperature which needs to be correct, but it is also vital that other carrying instructions are passed along the line, particularly where cargo will be stored in more than one port terminal and transshipped to more than one ship.

One example involves a cargo of onions in a 40ft dry container. The agent was instructed that the doors of the container should be tied back and left open. This instruction, although given as part of the booking, was not passed on to the operational staff involved. The result was the total loss of the onions, plus storage and destruction costs.

Another example was a booking of several containers of cocoa butter. The booking note provided that they should be stowed away from heat, i.e., in the middle of the stow and away from the engines. The special instructions were complied with by the first carrying ship, but were not passed on by the agent to the transshipment port agent and the cargo sustained heat damage on the second ship and was a total loss.

In a third case, two containers of flower bulbs shipped from the Netherlands to South Africa were destroyed because the agent failed to pass on instructions for container vents to be left open. In a fourth case, a ship agent put the instruction to carry a container of live worms at +4 degrees Centigrade on the reefer manifest, but failed to pass on an instruction to keep the air vents open. When the worms arrived approximately two thirds had suffocated. As the worms were intended for fishing, dead worms were of no use. The value of the dead worms was US$ 68,000.

Banana Cargo Loss because of Switchboard Arcing and Fire

A full cargo of bananas worth US$ 1.5 million was lost because of arcing on the switchboard and a subsequent loss of power for the refrigeration system and the steering gear. During the previous night there had been a small fire in the main switchboard panel and the next day a Filipino electrician, on his own initiative, tried to clean the carbon deposits from the contacts with a long-handled paint brush whilst the switchboard was live. The brush had the usual metal bind which had not been insulated, and which caused arc between the bus bars and the paint brush, resulting i catastrophic failure of all electrical power.

The electrician had worked as an electrician ashore for years, but this was only his second trip at sea and his first on a reefer vessel. He should not have been allowed exercise the amount of autonomy that he was given. Th was no proper supervision and no planning of what sho have been done to clear the problem. This incident illustra clearly the dangers of over confidence and inadequate work practices. Proper training, and supervision of his activit should have taken place.

Banana Cargo Loss because of Incorrect Adjustmen Expansion Valves

In another incident, a twelve year old reefer ship carrie cargo of bananas from Honduras to the United Kingdom. T bananas were found to be overripe on discharge; the mem and the Club have had to pay damages of $1.2m.

Although the ship was only twelve years old there w problems with both the brine delivery valves and, m importantly, the main expansion valves for the refrigerant. B were being manually adjusted because the automatic con equipment had failed. The chief engineer had by-passed expansion valves and this led to a reduced flow of refriger so that the brine was not cold enough to cool the ca sufficiently and certainly not quickly enough. A cargo bananas loaded in a humid location is one of the most diffi cargoes to carry, since bananas have to be carried withi very fine tolerance. It is extremely important that the ree plant is in full working order and that the chief engineer kno what action he should take in the event of the failure of principal components in the reefer plant. If he had been tak regular pulp temperatures he would have been aware of need to increase the refrigerant flow and could possibly ha avoided the claim. However, if the expansion valves are working it is very difficult to carry a chilled cargo successf by setting the expansion valves manually.

Garlic Claims

Dubai has recently seen a spate of claims in respect alleged damage to consignments of garlic imported fr China. The garlic market in Dubai is controlled by a limi number of traders, one of whom is the main importer Chinese garlic. The Chinese harvest season runs from J to August. The cargo is imported either in bulk, on ree vessels or in reefer containers. The quality and condition garlic is particularly affected by temperature and moisture well by gases such as CO_2 forming from this living pl material. Any problems can result in the deteriorati temperature abuse and reduction of storage life. The stor life of garlic is typically 6-9 months, depending on the stor conditions. The shippers and/or charterers should prov vessel interests with clear carriage instructions regard temperature, humidity levels and ventilation exchanges.

Carriage Instructions – Difficulties For The Vessel

A feature in the recent cases is that vessel interests ha accepted carriage instructions from the shippers/charterer causing difficulties of compliance for the vessel. For examp in one case the instructions were:

• Holds pre-cooled to -5°C before loading• Delivery temperature of 0°C during loading • Carriage temperature -3°C • Humidity 60-65%• CO_2 below 1%• Air exchan minimum twice daily • A return air temperature of -3°C achie within 3 days of the completion of loading

Apart from the requirements as regards monitoring and rec keeping, these instructions caused a number of difficult for the vessel, even with refrigeration machinery work perfectly. Most notable is the difficulty posed by high p temperatures at the time of loading. The cargo is reporte brought from the place of harvest to the port in open tru and is at times stored on the quayside without cooling quite some time prior to loading. Garlic can also self-heat, particularly if wet. In at least one instance the pulp temperature at the time of loading was between +28°C and +32°C. As a result of the high temperature of the goods at loading, the required return air temperature was only reached 9 days after loading and for some cargo spaces as long as 13 days after loading. In other words, the vessel was unable to bring the temperature down to the required level in the agreed 3 day period.

The Claims

A charter party will frequently require the Charterer and consignee to be provided with daily temperature reports from the vessel. When the consignee finds that the temperature requirements have not been fully complied with, the ship is held responsible for alleged damage to the garlic even before the vessel arrives at the discharge port. It is a common practice to threaten arrest of the vessel and to demand a guarantee as security for the claim. The damage usually alleged by the Consignee to have occurred is "internal sprouting" of the garlic. Samples of the garlic will be cut at random and an allegation of an unacceptably high rate of sprouting is made. Consignees allege that, as the carriage temperature was not maintained at –3°C, the sprouting has increased, resulting in a reduced storage/shelf life of the garlic, forcing the Consignees to sell the garlic at a reduced price. The alleged loss is quantified either as a percentage of the invoice value by the Consignees' Surveyor or by producing sales invoices at a later stage. Claims frequently run to hundreds of thousands of dollars.

It can be difficult to defend these claims in the United Arab Emirates, particularly when a clean bill of lading has been issued. Vessel interests face the very difficult burden of proving that problems with the garlic would not have been apparent at the time of loading and thus clausing would not have been an option, but that the damage was due to inherent vice. In many cases, it is suspected that the real cause of the damage is high pulp temperatures prior to shipment. Vessel interests may be left with little option but to a negotiate settlement on best terms possible.

Recommendations

Vessel interests are advised to take special precautions when loading garlic, particularly in China but also elsewhere where pre-shipment conditions are likely to cause problems when complying with carriage instructions. Among the precautions that vessel interests can take are:

1.Not to accept carriage instructions with which the vessel is likely to have difficulty in complying. In particular, the requirement of a return air temperature should not be accepted as that can depend on factors beyond the vessel's control, e.g. pulp temperature, quayside storage etc. Required carriage temperatures should only be accepted as delivery air temperatures as that is under the vessel's control.

2.The acceptance of carriage instructions, particularly under a charter party, could be on the express condition that the garlic is dry and that pulp temperatures are within an acceptable range at the time of loading. Vessel interests can reserve the right to reject for shipment non-compliant cargo and to require charterers/shippers to have it dried and/or cooled before shipment.

3.If there is no alternative but to ship garlic with high pulp temperatures, an appropriate remark such as *"shipped at pulp temperatures......at shippers risk without responsibility for loss or damage howsoever caused"* could be inserted in the bill of lading.

4.Shippers should be requested to provide information and evidence at the load port as to where the garlic originated, how old it is and how it has been stored ashore, failing which vessel interests should seek to obtain the same. Photographs, including "close-ups" of the garlic, can be taken and records of weather conditions prior to loading should be kept.

5.Pre-shipment inspections of the garlic, with a view to clausing the bills of lading should include any signs of rotting, staining and wetting. Packing should also be inspected, including whether it provides sufficient ventilation. If there is no routine monitoring of pulp temperatures and the vessel suspects these to be high, a surveyor can be instructed to attend on the vessel's behalf. His inspection can include a check for internal sprouting.

6.Tight stowage should be avoided as this makes it more difficult for refrigerated air to circulate and for gases to be vented off.

7.Monitoring equipment should be calibrated and in full working order. Full and proper carriage records should be kept.

8.With shipper's approval, a small sample of garlic can be placed in the vessel's own stores. Together with temperature monitoring and records this may provide a useful comparison at a later stage to the garlic in the holds.

Inconsistency of Temperatures

Sometimes, the temperature setpoint mentioned in the cargo manifest is different from the actual setting on the unit. Which of them is correct?

Never Assume. Either of them could be correct. Please confirm from the charterers or shippers before effecting any change in the unit's temperature setpoint.

Use of Partlow Chart

A Partlow Chart, if fitted, can be a very useful source of information about how temperature has been maintained in the container in the past. A cursory glance at the Partlow Chart as the container gets loaded can reveal the way the temperature had fluctuated inside the container and any potential problems of the container. However, with the advent of Electronic Datarecorder, lesser number of customers are opting to fit Partlow Recorder to save costs.

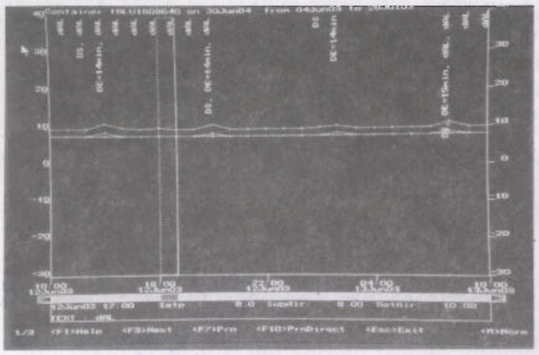
Information Recorded In The Electronic Datarecorder

A Datarecorder records all the events taking place inside the container. Most commonly, the following are recorded:

Setpoint which is shown as a White line.
Supply Air Temperature which is shown as a Yellow line.
Return Air Temperature which is shown as a Blue line.
Power on (ONwb) and Off (OFFwb).
Defrost Start (DS), Defrost End (DE) and duration of Defrost.
Dehumidification Start (DHS) and End (DHE).
All alarms
Trip Start (TS)
Pre-Trip Start (PS) Sequence and Results.
The Controller and Datacorder Software Version and Configuration.

The Container No., the date of downloading, the dates between which the data has been downloaded are shown as a title of the graph. The temperature is shown in the Y axis from -30°C to +30°C and the date with time are shown in the X axis. The time duration between two successive defrost start periods gives the defrost interval that the container is running with. Even if there is a power interruption, a continuous recording is provided by the back up battery. It becomes the shipstaff's responsibility that sufficient power is available in the back up battery to provide a continuous non-interrupted recording of the data. Normally, there are enough spare batteries available in the spare part kit. If an interruption in the recording is noticed when the data is downloaded and analysed (in case there is a cargo damage), it could be held against the shipstaff for having intentionally removed the battery to conceal some information and protect the carrier's interest.

In many instances, shipstaff have been pulled up for not recording power breakdowns – whether planned or unplanned. This happens, particularly, if any cargo damage is noticed at the consignee's end, when the datarecorder has recorded a power interruption, but same has not been logged by the shipstaff. The Datacorder is a "Black Box". Nothing escapes its notice. It



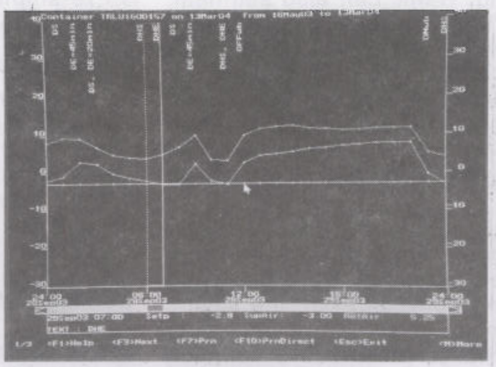
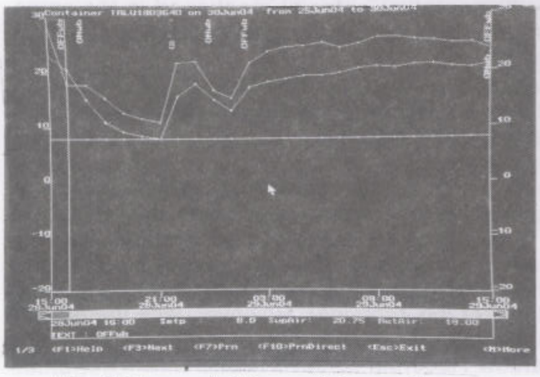


Fig. 14 Good Cargo – Temperature being maintained properly

Fig. 15 Power Breakdown - Recording with back up Battery



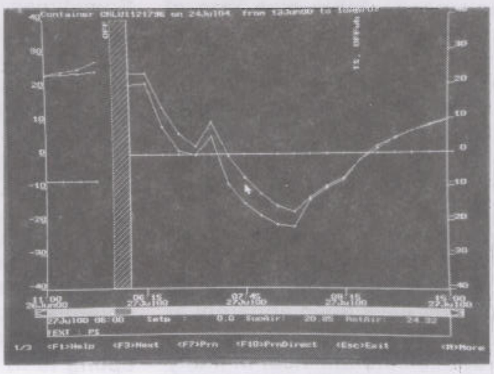


Fig. 16 Frequent Power Interruptions

Fig. 17 Power Breakdown with battery non-functional (break in recording)

records even the slightest variation in temperature – **minute by minute. BE CAREFUL – BIG BROTHER IS WATCHING!**

By analysing the data from the datacorder, we can infer if the unit is running or not, if and when the doors of the container are open, if the cont- ainer is loaded or not, the ambient temp- erature during day and night etc.

Do not act like Consultants or Advisors

Finally, it is important to understand the shipboard personnel's role. We are not to act as advisers to charterers or shippers, even though we may be in the same trade for ages. We are not trained in the subject, nor are we experts in the field. It is best left to the shipper to decide the conditions of carriage of his cargo in terms of temperature, humidity, atmosphere etc. etc. Our respon sibility is simply to maintain the temperature and other para meters as per the shipper's and charterer's requirements.

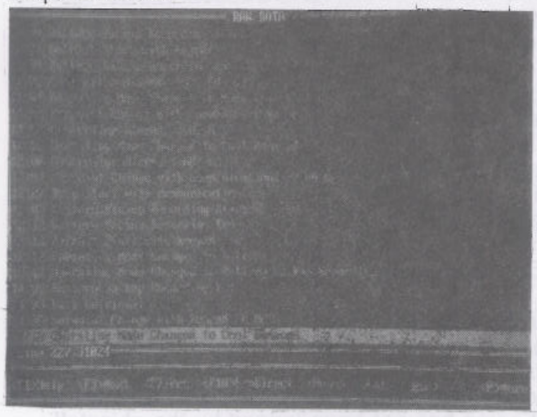


Fig. 18 Minute by Minute Recording of Data

Value of Reefer Cargo

Reefer cargo, being high freight cargo is expensive. The value of reefer cargo is in the following range.

a) Fruits, Vegetables and Plants : < US$ 60,000

b) Frozen Fish, Frozen Meat, Cut Flowers: US$ 60,0 to 120,000

c) Chilled Meat. Frozen Sh fish, flower bulbs: US$120,0 to 300,000

d) Temperature Sensiti Cargoes viz., electron equipment, photographic fil computer chips, print cartridges, medical supplie etc.: > US$ 300,000

It is important that the operati staff - ashore and on board a made aware of the high val of the reefer cargo they are responsible for.

The Blame Game

Whenever there is a car damage, each party tries blame the other. **The Name the Game is Blame!** Often is the carrier which compris of the shipstaff is the first o to be blamed. It is importa that shipstaff should be only smart and technica sound, but also the paperw should be perfect. A deviation from the norm operating condition should identified and informed to respective parties at earliest. As long as information is within the s the ship is responsible. informing the charterer shipper and seeking th advice, the responsibility shifts to them. Recently, a vess master was pulled up for not informing the charterer of increase in temperature of the cargo during the course of voyage.

Control from Shore

It is now possible not only to track the precise position of container, whether on the ship or on land. It is now possible only to monitor temperature of reefer cargoes from ashore also to correct a temperature variance through an electr message directly to the instrumentation of the reefer. T technology has been pioneered and perfected by Tri-mex Anglo-Norwegian company and uses LEOs (Low Earth Orbi Satellites). This will bring the perishable cargo losses fur down.

References:

1. www.carrier.transicold.com 2. www.thermoking.c
3. Ocean Shipping Consultants Ltd. 4. B M De Beer
5. World Cargo News 6. U K P&I Club 7. ITIC Ltd. 8. Stan
P&I Club 9. Prof. William Tetley 10. www.maritimeadvocate.
11. Carriage of Reefer Cargo by Capt. C V Sathyendra
12. GARD

ABOUT THE AUTHOR

Mr. Chilukuri Maheshwar is a Marine Engineer , ha passed out from Marine Engineering College (DM Kolkata, India in 1980. He is a life member (Fellow Institute of Marine Engineers (India) and Institutio Engineers (India). He is also an Insurance Regula Development Authority (IRDA) approved Insurance Surv and Loss Assessor, a Chartered Engineer, an Appr Valuer and an Institute of International Container Les (IICL) certified Container Inspector.

He can be reached at cmaheshwar@hotmail.com.