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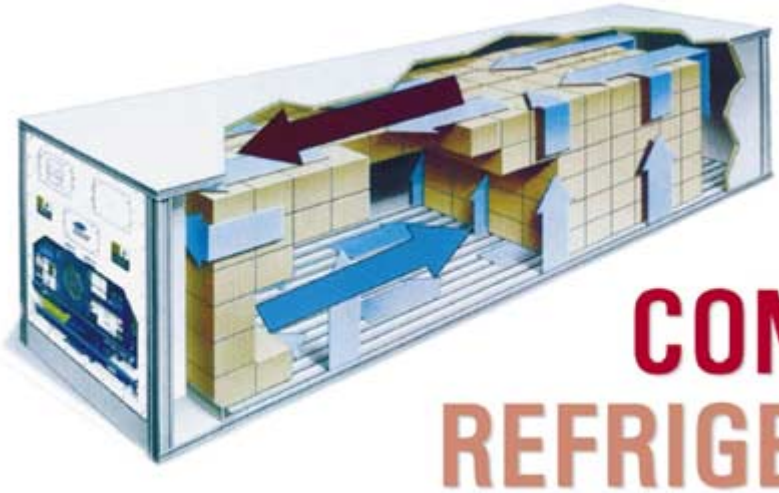


CONTAINER REFRIGERATION

(Part 1)

By C. Maheshwar

Faculty, Training Ship Chanakya

Navi Mumbai

C.Maheshwar is a marine engineer, from Marine Engineering College, Kolkata, (DMET) 1980. He has sailed on board foreign - going ships of Shipping Corporation of India Ltd., from 1980 to 1997, the last 5 years of which were as chief engineer officer. Ashore, he has worked from 1997 to 1999 with the Taj Group of Hotels as chief engineer of Taj Connemara Hotel, Chennai, and as customer service manager, Reefer Container Group of Carrier Transicold for the region of South Asia from 1999 to 2001. Currently, he is working as engineering faculty at TS Chanakya, Navi Mumbai, a Merchant Navy Training Institute, belonging to the Govt. of India and affliated to University of Mumbai and IGNOU. He is a consultant for Anglo-Eastern Maritime Training Centre and conducts training programmes on reefer containers for seagoing engineers on a regular basis. He can be contacted at ***cmaheshwar@hotmail.com***

This is the first of a series of articles on container refrigeration. These articles are intended to familiarize the reader with the basics of containerization, and will lead the reader through the complexities of the design and usage of refrigeration equipment when fitted on containers. This article in particular will deal with an introduction to containerization as a concept, container refrigeration, its evolution and commercial aspects. Subsequent articles will deal with various other aspects of interest to HVACR engineers.

Refrigerated containers will be henceforth referred to as reefer containers. It is to be understood that merely reading of these articles will not make the reader an expert or an authority on reefer containers and practical knowledge is essential. When working on any particular make or model of equipment, the appropriate Instruction Manual is to be consulted and instructions to be followed.

It is assumed that the reader is already familiar with the basic concepts of refrigeration.

Introduction to Containerization

Containerization dates back to the early 1950s. As the worldwide shipping trade grew by leaps and bounds, conventional break bulk cargo has been slowly replaced by containers. Commercial pressures and competition forced companies to reduce their cost of operations. This had a direct impact on the advanced countries where the cost of labour was more than the cost of technology. The cargo loading and unloading labourers get paid in dollars on an hourly basis with extra incentive in the form of overtime for working on weekends and holidays. There was an urgent need to bring down the labour component involved in cargo operations.

Additionally, cargo pilferage and losses were not accepted and tolerated any more. Shipping lines had to discharge the exact amount of cargo at the discharge port that was loaded on the ship at the loading port. The allowance due to loss/pilferage of cargo was drastically reduced. Further, the same conditions applied for the cargo during its onward journey from the discharge port to its final destination.

Unitization of cargo became an important concept for bringing down the labour costs. Pre-slinging of cargoes, palletization, containerization, barge-carrying ships, Ro-Ro ships are all examples of the unitization concept. Containerization was the need of the hour. Containerization became the most effective and efficient method of cargo handling. With containerization, per capita labour output improved dramatically.

A container is a box of internationally accepted standard dimensions. The standard sizes recommended by ISO (International Standards Organization) are 20ft (length) × 8 ft (width) × 8ft (height) and 40ft (length) × 8ft (width) × 8ft (height). The former was known as a TEU (Twenty Foot Equivalent Unit) and the latter was referred to as FEU (Forty Feet Equivalent Unit). One FEU is equal to two TEUs. Generally the capacity of a container ship is referred to in terms of TEUs. In addition to the above two sizes, the height may be also 8' 6." The length may also be 45 ft.

Material of Construction: The sides, roof and floor of a container may be made up of Steel, Stainless Steel, Aluminium, Fiberglass, Plywood, etc., depending upon the application. The structure is generally made of steel.

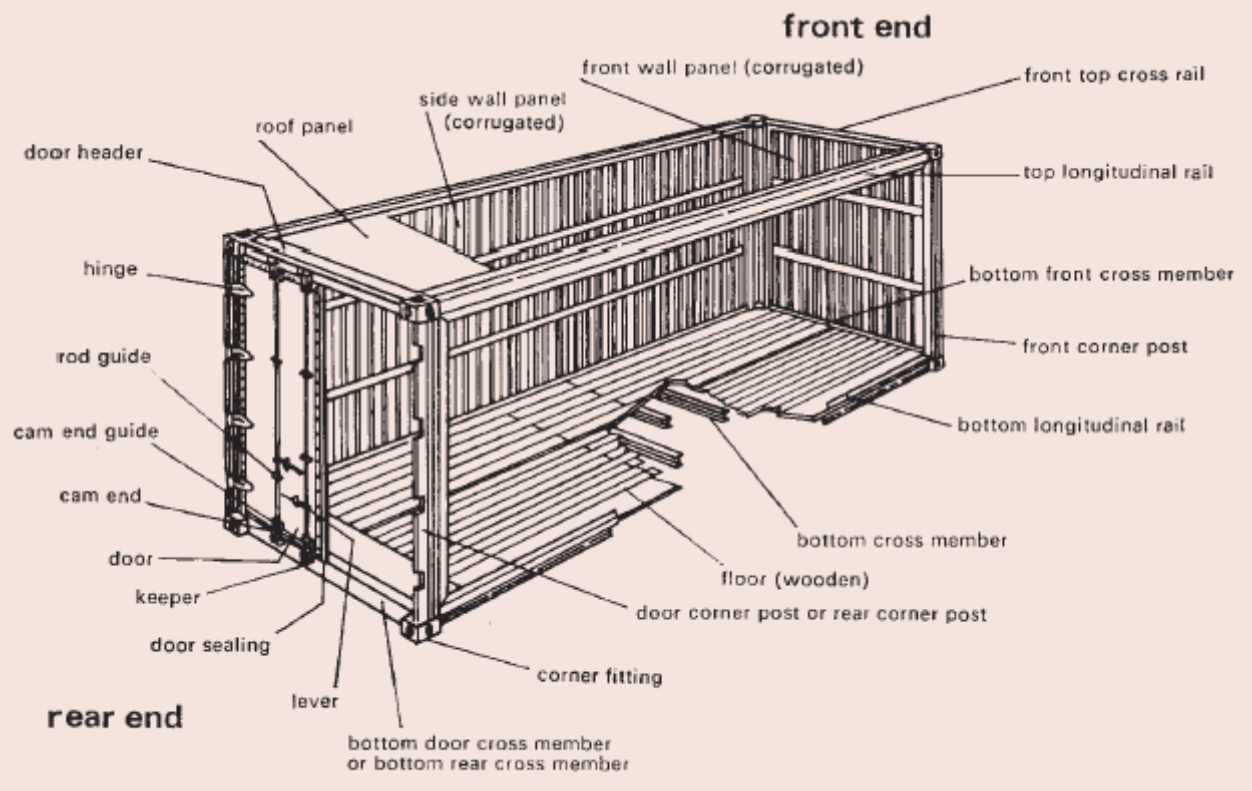
Features of a Container

1. It is of a permanent character, strong enough for repeated use.
2. It is designed to facilitate the transport of goods from one mode to another, i.e., from road to sea or rail to sea without intermediate reloading.
3. It is designed for easy stuffing and destuffing.
4. It is fitted with facilities to permit easy handling and transferring from one mode of transport to another.

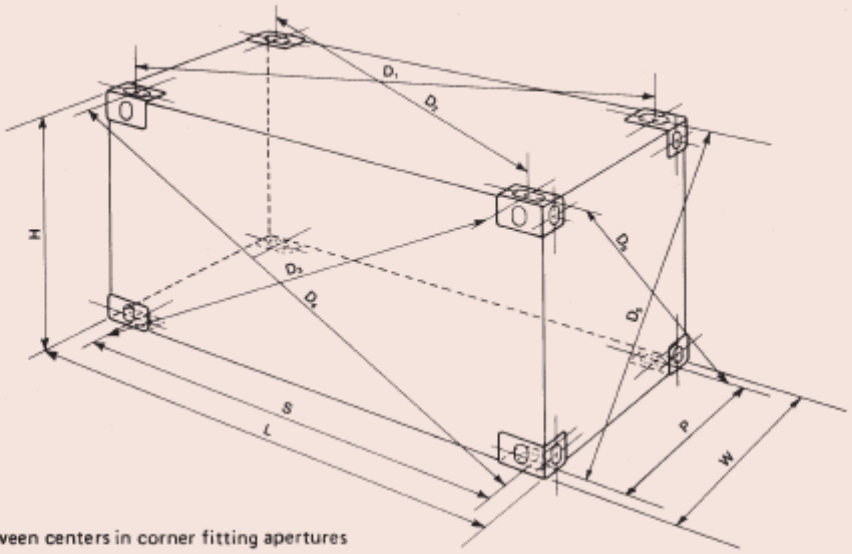
Advantages of Container Transportation

1. Faster and reliable delivery
2. Greater protection of fragile and easily contaminated cargoes
3. Ensures original quality of goods
4. Reduces pilferage
5. Enables Physical seperation of dirty cargoes
6. Simplification of documentary procedures
7. Reduction in cost of cargo handling and ships' stay in ports.
8. Reduction in packing cost to the shipper.

A container has a strengthened deck (floor) and corners. The floor is lined with wood. The sides are corrugated to provide strength as the sides and roof of a container are highly susceptible to damage. The main strength of the container lies in the frame. The ICSC (International Convention for Safe Containers) specifies structural requirements for containers and contains regulations for inspection, approval and maintenance of containers. Most containers are built with fork lift pockets.



Parts of a marine freight container.



S = Length between centers in corner fitting apertures

P = Width between centers in corner fitting apertures

L = External length of the container

W = External width of the container

D = Distance between centers of apertures of diagonally opposite corner fittings

K_1 = Difference between D_1 and D_2 or D_3 and D_4

K_2 = Difference between D_5 and D_6

H = Overall height

Width (external) – All containers: $2\,438^{+0}_{-5}$ mm ($8\text{ ft }0^{+0}_{-3/16}$ in)

Height (external) – 8 ft. high: $2\,438^{+0}_{-5}$ mm ($8\text{ ft }0^{+0}_{-3/16}$ in)

Height (external) – 8 1/2 ft. high: $2\,591^{+0}_{-5}$ mm ($8\text{ ft }6\text{ in}^{+0}_{-3/16}$ in)

Dimensions and tolerances in millimeters and in feet and inches

Freight container designation	Length (external)			S			P			K_1 max.		K_2 max.	
	mm	ft	in	mm	ft	in	mm	ft	in	mm	in	mm	in
40'	$12\,192^{+0}_{-10}$	40	$0^{+0}_{-3/8}$	11 985	39	3 7/8	2 259	7	4 31/32	19	3/4	10	3/8
30'	$9\,125^{+0}_{-10}$	29	$11\ 1/4^{+0}_{-3/8}$	8 918	29	3 1/8	2 259	7	4 31/32	16	5/8	10	3/8
20'	$6\,058^{+0}_{-6}$	19	$10\ 1/2^{+0}_{-1/4}$	5 853	19	2 7/16	2 259	7	4 31/32	13	1/2	10	3/8

ISO Dimensions and Tolerances.

Types of Containers

1. Closed box or general purpose containers most commonly used for various types of cargoes.
2. Open sided containers which can be loaded from either side forward or aft and have hatch covers that drop down on either side.
3. Bulktainers (Dry bulk containers) have loading hatches in the roof and one or more discharge hatches

on the sides.

4. Tanktainers (Tank Containers) are used for carrying bulk liquids.
5. Half height containers are normally used to carry high density cargo.
6. Reefer containers are used to carry refrigerated cargo and are equipped with refrigeration machinery.
7. Other special types are Pen Containers for livestock, Tiltable Containers for grain, Open Top Containers, Collapsible Containers, End Open Containers for carrying long cargo, Fantainers which are equipped with fans or blowers to blow air through the cargo, Hangtainers, which have hangers used for carrying garments and so on.

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. They can be of two types – the Individual System in which the container is equipped with its own individual refrigerating machinery and the Collective System, in which a separate refrigerating source handles the distribution of cooling to a group of containers which is generally a permanently fitted refrigeration equipment on board the ship or a portable unit which is fitted on a temporary basis on the ship for that voyage or a charter connecting to a group of cargo carrying containers.

Question: By looking from outside, how can we make out if a container is a refrigerated container?

A. Yes, we can identify a reefer container from its external appearance, At the front end of the container, look for the presence of the refrigeration machinery. Also, the sides of a reefer container are smooth due to the external aluminium sheeting, where as, a normal GP (General Purpose) container will have corrugated sides made up of steel sheeting. The corrugations provide additional strength and stiffening to the container. A refrigerated container has external aluminium sheeting and internal stainless steel sheeting. There are intermediate strengthening vertical members spaced evenly apart. The space between the internal and external sheets is filled with insulating material, generally poly urethene foam (PUF) which is injected between the two layers at high pressure displacing air through vent holes at the top.

Question: Does the size of the container increase because of the additional refrigeration equipment?

A. No, the refrigeration equipment is fitted within the overall standard dimensions of the container, i.e., 40 × 8 × 8 ft or 20 × 8 × 8 ft. Some of the cargo carrying space is utilized to accommodate the refrigeration machinery. This is known as the picture frame type reefer container. Most of the marine reefer containers are of this type. 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. The other type of reefer containers are Over Hanging type in which the refrigeration equipment projects beyond the overall standard dimensions of the container. These are generally used ashore for over land transportation of the containers by trailer or rail.

Question: What about the power supply for the refrigeration machinery?

A. Generally power supply is taken from the ship's main power supply when the container is on the ship. While in port, the shore power supply is utilized to run the refrigeration machinery. When transporting across land in a truck, trailer or a train, power supply is generally taken through a genset from the main prime mover of the truck or trailer or main power supply of the freight carrying train. In some instances, an additional genset is permanently installed between the container trailer chassis and the driver's cabin. Some of the containers are installed with clip-on gensets which are dedicated to supply power only to the refrigeration machinery. These clip-on gensets can be removed when not required. Some of the older containers had gensets permanently fitted within the picture frame of the container. The genset with its own fuel tank occupied the lower half of one end of the container and the refrigeration machinery occupied the upper half.

Question: What about the extra power required for the reefer containers from the ship's main power supply?

A. Yes, the ship's main power supply should be able to cater to the extra load due to running of the reefer container machinery. Generally the ship's power supply will be designed after taking into consideration the maximum number of reefer containers it can carry at a time. However, if required, an additional generator is installed on board the ship exclusively to cater for the extra load due to running of the reefer container machinery.

Question: What about the extra deadweight, loss of volumetric space and the extra maintenance required for to the reefer container machinery?

A. Yes, the extra deadweight due to the reefer machinery results in a loss of freight for the ship. Similarly, a reefer container requires a lot of inspection and maintenance during the voyage which is a downtime equivalent of 1% per day. Similarly, there is a considerable loss of volume of cargo space which is required not only for the location and efficient

functioning of the refrigeration machinery, but also for sufficient access space around the machinery for regular inspection and repairs if required. But all these factors are compensated more than adequately as the freight for reefer containers is much higher than a normal container. In fact, any shipping line will run after a reefer cargo and will be willing to carry out necessary modifications in the ship and providing additional machinery for power generation and other fixtures.

Question: What about the heat given out from the condenser of the refrigeration equipment?

A. Yes, a lot of heat is given out by the condensers, in fact, whatever heat has been removed from the inside of the container through the evaporator is given out by the condenser. When the reefer containers are stored on the deck in the open air, the heat from the condensers is discharged into the atmosphere. They use air-cooled condensers.

Question: Does it mean that they can store loaded reefer containers only on the deck?

A. No, not necessarily. Reefer containers can also be stored inside the cargo holds. But the heat given out by the condensers of all the running reefer containers inside the cargo hold should be led outside efficiently. Otherwise, there will be heat accumulation inside the cargo hold and the refrigeration machinery will not function efficiently. That means the ship's cargo hold ventilation system should be so designed to allow the required number of air changes so as to maintain the temperature inside the cargo hold within the permissible limits. Alternatively, they may use water-cooled condensers. In such a case, the cargo hold should be equipped with water circulating system with pipelines running along the sides of the cargo hold which can be connected to the individual reefer containers through a pair of flexible pipes – one for the inlet and the other for the outlet. Often, such containers are marked "IN HATCH STOWAGE ALLOWED". By looking at a reefer container, by noticing the water-cooled condenser inlet and outlet water pipe connection couplings, we should be able to determine its suitability for storage inside the cargo hatch. Generally, all reefer containers are equipped with air-cooled condensers, water-cooled condenser, if fitted, is an additional optional feature. It implies, that all reefer containers are by default designed to run as air cooled units. However, some of them are also designed optionally to run as water-cooled units.

Question: Can a reefer unit run as air-cooled and water-cooled unit at the same time?

A. No, to improve the heat transfer across the condenser coil, all reefer units are provided with a condenser fan. When fitted with an optional water-cooled condenser, and running as a water-cooled unit, the condenser fan cuts off when sufficient water pressure is available in the water pipelines of the water-cooled condenser – a pressure switch switches off the condenser fan and switches it on at low water pressures. In older units, there was a manual toggle switch which could be operated if water-cooled condenser was connected and was in operation.

Question: Does it have any bearing on the loading of the containers on the ship?

A. Yes, it should be noted that no two reefer containers should be loaded with the machinery facing each other. The hot air discharge from each of the condensers will enter the condenser of the other unit, affecting the performance of both the machineries adversely. Also, even when two reefer containers are loaded with their machinery not facing each other, enough space should be left near the condenser of each unit so as to facilitate free flow of air to and from the condenser, otherwise the performance of the machinery will be affected adversely.

Evolution of Container Refrigeration

Refrigerated containers have been employed on ships since 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 high resulting in huge cargo insurance claims. Reefer container machinery has come a long way over the last 40 years and has evolved brilliantly. Each of the components has undergone a metamorphosis. Present systems are power efficient with foolproof and tamperproof recording, back ups for all important components, advanced warning systems in the form of alarms and cutouts, 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 two distinct components – the refrigeration machinery and the box. The refrigeration machinery with standard features costs about US$ 10,000. A 20 ft. reefer box costs about US$ 5,000. The major reefer machinery manufacturers are Carrier, Thermo King, Daikin, Mitsubishi etc. The major reefer box manufacturers are Freuhauf, CIMC, Moon, GE, Transafe, Balmer Lawrie, etc. When a reefer container has to be bought, the orders are placed separately on 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 delivered to the customer's representative by the machinery manufacturer's representative in the presence of the box manufacturer.

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