

formations cement-sealed. The attachment of wall and ceiling panels with suitable adhesives precludes the need of waterproof paper inner linings.

While the floor is the weakest point in the ship's refrigerator, the weakest element in the floor is at the floor drain or scupper. This is a minor item of major importance. The weakness comes with the difficulty in bonding the top floor covering with the metal drain fitting and water will often find its way between the covering and the insulation. The conventional floor drain is fitted with a perforated plate flush with the floor covering and hidden by the floor gratings. If the perforations become clogged by debris, it will permit water accumulation at the scupper. A drain fitting near a wall or corner will on most occasions provide a weak section in the floor covering and cracks will develop, running to the wall or across the corner. A satisfactory scupper fitting is shown in Fig. 7. It has the features of being flush with the top of the gratings, a lift-out cover for easy cleaning and is bonded to the floor covering with expansion joint material. Drains between decks should be omitted wherever practicable.

Refrigerator doors are generally a satisfactorily manufactured product and but little need be written on the subject. They should have generously designed hardware of steel, the doors and door frames should be metal sheathed, have a flat sill and double gasket. Very large or double doors should have additional dogs to insure proper sealing when closed.

Sliding doors should be installed wherever possible to reduce interferences and to conserve adjacent revenue space. When used, there should be installed brackets to support portable horizontal spars inside the doors to prevent cargo from falling against the doors in a seaway.

There are available moulded fiberglass swinging doors insulated with urethane foams poured in place. They are strong and lightweight, are easily handled, and can be fitted with lightweight hardware.

In finishing, wooden surfaces should be varnished, not shellacked, the latter material having little protective penetration. Manufactured non-metallic surfaced materials may be painted or varnished but if non-hygroscopic, their original

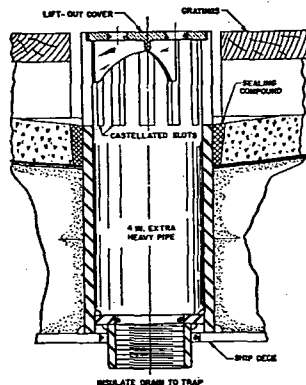


Fig. 7 Floor Drain Fitting

surface will usually present good appearance longer than a painted coating. Cement and asbestos panelling should not be shellacked but remain uncoated or may be waxed.

In the matter of insulating low temperature apparatus or piping, it is recommended that critical inspection should be made during the installation of this covering. All joints and surfaces should have total and generous sealing to prevent the ingress of atmospheric moisture to any surface where water may condense as sweat or form frost. Special attention should be given at pipe covering ends, at valves and bulkhead penetrations. On subzero services special composition adhesives should be used. The smallest omission or breach of a seal will signal the beginning of progressive destruction of the covering.

On shipboard where piping systems are relatively short the function of the insulation is more that of preventing the sweating or frosting of cold surfaces than it is to prevent heat gain, a factor quite generally overlooked.

REFRIGERATION SYSTEM

Components

Refrigerants. Refrigerant 12 is universally used in reciprocating compressors and Refrigerant 11 is used in centrifugal units.

Refrigerant 22 has temperature-pressure characteristics similar to ammonia, but it is not recommended that it be used with evaporator temperatures above -20 F because of the critical oil miscibility properties in such a cycle. Except for specialized marine services, this refrigerant would not meet requirements.

It must be conceded that ammonia is still our best refrigerant in its overall properties, toxicity excepted. Ammonia is widely used on fishing and sea food processing vessels. This section will describe halogenated hydrocarbon systems only.

Compressors. Modern ships are now outfitted with refrigerators having a design minimum temperature of -10 F. This range may be reached without excessive compression ratios with Refrigerant 12 units in compound compression or brine cascading.

Transport at -5 F is marginal with single-stage compression when operating in tropic waters.

The difficulties accompanying the leakage of air and air-borne moisture into a refrigerating system are well known, and these problems are minimized when the low side can be maintained at or above atmospheric pressure. Centrifugal compressors using Refrigerant 11 and operating at pressures below atmosphere have little trouble from this source because of the effectiveness of shaft seals characteristic of rotative machinery and the continuously operating purging units auxiliary to this type of compressor. The use of brine circulation is mandatory for centrifugal systems using Refrigerant 11.

Conservative design in terms of piston speeds of reciprocating units is also looked upon with favor by the practical shipowner.

Reciprocating Refrigerant 12 compressors cannot be operated in parallel because of the tendency of the oil to leave the crank case with the refrigerant flow and in returning to flood one unit and starve another. In consequence, each direct expansion evaporator system should be served by its own compressor. In multiple evaporator direct expansion plants, the large number of compressor units is undesirable, and the use of paralleling brine systems with fewer condensing units is recommended.

Capacity controls of compressors may be effected by speed

Marine and Air Transport

Table 1 Operating and Reserve Capacities of Condensing Units

No. of Units, 100% Load	Additional or Reserve Units, %	Total No. of Units
1	100	2
2	50	3
3	33 1/3	4
4	25	5
5 or more	20	6 or more

variations or by automatic cylinder cutouts, unloaders or by-passes. Intermittent operation or cycling should be reduced to a minimum by speed regulation or unit sizing to provide maximum uniformity in plant conditions.

Centrifugal compressors are essentially large tonnage units and the capacities are varied by speed controls, by-passing, throttling or metering of refrigerant, and the condenser pressure control by circulating water flow.

Reciprocating units are V-belt driven or direct connected to an electric motor. Centrifugal compressors may be driven by a step-up gear and motor or by steam turbine direct drive. The use of a steam turbine reduces electric generator demands and often fits nicely in the main steam plant heat balance.

Compressors of all types should be installed in a fore-and-aft centerline position to reduce the effect of gyroscopic bearing loads when the ship rolls. This position also favors lubrication of the unit.

Reserve compressor capacity and spare part lists are specified by the American Bureau of Shipping. This agency recommends two condensing units, one of which running continuously should be capable of maintaining full cargo lading in tropic waters. The rules further state that when refrigerated spaces are of 15,000 cu ft total capacity or less, consideration would be given to the installation of a single condensing unit, there being carried adequate spare parts. An experienced ship operator would consider that numerical machine reserves are as necessary as reserve in tonnage capacity and would not doubt exceed these minimums. Table 1 indicates recommended types and sizes of installations, giving full consideration to flexibility, reliability and plant efficiency.

It is not an unusual arrangement for reciprocating compressor units of the cargo system to be interconnected with those of the ship's air conditioning system.

Condensers. Halocarbon condensers are of the conventional shell-and-tube design and since these refrigerants are non-corrosive to all commercial metals commonly used in refrigeration, a wide choice of materials is available. High heat transfer characteristics and resistance to corrosion erosion by circulating sea water should be considered in selection and design.

The refrigerant is usually between the tubes and shell of the condenser and the sea water circulates through the tubes in multiple pass arrangement. Steel or copper material for shells with cupro nickel tubes and cupro nickel tube sheets are usual. Water boxes may be of cast iron or bronze, preferably the latter. The tendency to substitute high velocities of circulating water for cooling surface in heat exchange should be resisted, to provide long life. Water velocity in the tubes of 6 fps is considered high and water box velocities above 2 fps are conducive to turbulence and accelerated erosion of tubes.

Cooling surface requirements are subject to calculation for known maximum conditions.

Condensers should be so installed that during the roll or pitch of the vessel or with a list, the condensed liquid refrigerant will properly drain to the receiver.

Receivers. Receivers may be of welded steel and should be arranged to insure submergence of the liquid outlet under all sea conditions. The receiver should have sufficient capacity to hold a complete charge of the system, plus 20 percent reserve volume. Means should be provided for the operators to observe the liquid level.

Brine coolers. Brine coolers are subject to specifications similar to those of the condensers except that the materials must resist corrosive effects of the brine, steel tubes and tube sheets being usual. In conventional design the refrigerant circulates through the tubes to reduce the refrigerant charge to a minimum and provides maximum wetting of cooling surfaces. Large size coolers may have two or more independent tube groups, in parallel arrangement, each with its own expansion valve. Multiple parallel expansion results in improved flexibility, increased reliability and better control at partial loads.

Distribution of Refrigeration

Distribution of refrigeration may be provided by direct-expansion systems or with brine as the secondary refrigerant.

With the refrigerated compartments located remotely from the machinery, direct-expansion systems have many shortcomings. The extended return lines require considerable total pressure drop to produce velocities at low load that will return the oil to the machinery. The full load condition on the same line will add considerable duty to the machinery, and the resultant rarified vapor reduces the capacity of the compressor cylinders. When the evaporator or the return lines are lower than the compressor suction, oil traps are possible which may cause, under certain conditions, alternate starving and slugging of the compressors. When the velocity of vapor in vertical return lines falls below 1500 fpm when one compressor is operating, dual risers of smaller dimension, the bottom of one of which forms a trap, are recommended to provide a suitable oil lift. The long low-side lines are generally concealed by insulation or are inaccessible for repair at sea or when the ship is loaded. If, through vibration, the flexing of the ship, or by damage, these lines develop leaks, serious consequences may follow. In addition, the extended systems require large charges of refrigerant with many more scattered points where moisture or air could find ingress to the system.

Because of its historic background, brine is often wrongly associated with obsolescence; yet the distribution of refrigeration by this means has many advantages over direct-expansion systems. It permits the confinement of an escaping refrigerant to the machinery room, and the short lines result in small total pressure drops, efficient layout with fewer units, and in arrangements that facilitate the return of the oil to the compressors. The brine having a large sensible heat capacity, absorbs abrupt variations and eliminates the unwanted sensitivity of control that is characteristic of direct-expansion, latent heat systems. While the brine-cooling refrigerant should be automatically controlled, best results in room conditions are obtained with manual control of return brine flow. Thermostatic operation of brine valves require temperature variations for actuation, while stable conditions can be established satisfactorily with constant rates of brine flow, the human element notwithstanding. As stated before, it is not feasible to parallel halocarbon compressors aboard ship, but any combination of brine systems can be arranged to compound or divide refrigeration loads.