Marine Refrigeration

Some Tips on Design, Installation, and Servicing

Oregon State University
Extension Marine Advisory Program
A Land Grant / Sea Grant Cooperative
Special Report 488
June 1977

MARINE REFRIGERATION

SOME TIPS ON DESIGN, INSTALLATION, AND SERVICING

A Summary of Two OSU Workshops Conducted by
Mr. Jack Appelt

Notes Prepared By: Edward Kolbe, Commercial Fisheries Engineer
Department of Agricultural Engineering
Oregon State University

December 1976

Introduction

The topics of design, installation, servicing, and troubleshooting of marine refrigeration and brine spray freezing systems were discussed at two Sea Grant Marine Advisory Program - sponsored seminars, held at the Oregon State University Marine Science Center. These notes are a summary of the seminars, which were conducted primarily by Mr. Jack Appelt, President of the Quality Refrigeration Company of Wilmington, California. The rules-of-thumb, opinions, and recommendations are based upon Mr. Appelt's experience of over 30 years in the marine refrigeration business. They do not necessarily reflect the findings of the OSU Sea Grant Marine Advisory Program.

Throughout the notes, attempts are made to fill in information and to define refrigeration terms and new concepts where they are needed to understand the point being made. But the notes do not include a separate discussion of "Basic Refrigeration," and many readers may wish to review this topic. Several good information sources exist; a few are the following:

1. "Refrigeration Principles," Chapter Two of John Mead's book <u>Marine Refrigeration and Fish Preservation</u>. If not in the local library, it can be purchased for $18.45 (as of January, 1977) from International Marine Publishing Company, 21 Elm Street, Camden, Maine 04843.

2. The Carrier Corporation has a collection of educational materials which include a series of 16 booklets entitled "Fundamentals of Refrigeration." The first two of these booklets give a good description of refrigeration basics, but the whole series is a good general reference. As of January, 1977, the series cost $8.64. To order or to obtain information on other educational materials, write to: APT Administrative Services, Carrier Corporation, Carrier Parkway, Syracuse, New York 13201.

Note: Assistance from Dale Kirk, Professor of Agricultural Engineering, is gratefully acknowledged.

3. Thermo King Service School Training Manual on Basic Refrigeration. A limited supply is free and available in this area by contacting: Don Bachelder or Bill Pascoe, Standard Parts and Equipment Company, P. O. Box 42294, 5251 S.E. McLoughlin Boulevard, Portland, Oregon 97202 (1-800-452-8407).

Information in these notes is organized according to the following outline:

Brand names are used in this publication for illustrative purposes only; their mention does not in any way constitute endorsement of these products.

I. Engineering Design

A. Refrigeration System Design

1. Sizing of the System

When designing a system, several questions must be answered.

--What areas will the vessel fish in? Water temperature will influence the condenser performance.

--What type of fishing will be done? For example, for a tuna freezing system, the size will depend upon whether the boat is engaged in bait fishing, purse seining, or jig fishing. Should the system be sized for the maximum possible catch rate, or should some average (such as a ton a day) be anticipated?

--What power source is available to operate the refrigeration? A choice of electric or hydraulic motor, auxiliary engine, or direct drive off the main engine will influence the methods of control (discussed in the next section).

--Is the hold insulated? How much heat leakage into the hold must be assumed (through the deck, hull, engine room bulkhead)?

--What is the tonnage capacity of the boat? How much will frozen fish, already in the hold, help refrigerate warmer fish dumped on top?*

--How continuously will the refrigeration equipment be operating?

For tuna, the system should be capable of freezing the fish in 24 hours. If a ton of fish were caught every 24 hours, the amount of heat which must be removed to cool and freeze the fish from 60 °F to about 18 °F is equivalent to about one refrigeration ton.** (But a "one ton" compressor will not be adequate for the job, as will be explained below.)

---

*This characteristic is known as the "flywheel effect." Some boats have made use of "ice builders" to achieve the same effect. During the night, when no warm fish are loading the system, ice frozen on coils can provide a certain amount of residual cooling during the next day's fishing, when the refrigeration capacity of the equipment may be inadequate.

**A refrigeration ton is defined as the amount of heat that must be removed from a ton of 32° fresh water, in order to turn it into ice within 24 hours. It is equivalent to 12,000 BTU/hr.

The following rule-of-thumb for sizing a refrigeration system is applied to California boats; it should serve equally well for the smaller Oregon albacore trollers:

> Provide 30 horsepower of refrigeration capacity for 100 tons of hold capacity (or 10 horsepower for a 30-ton boat, or 6 horsepower for a 20-ton boat).

This rule-of-thumb is based on the following assumptions:

a. a "reasonable" amount of insulation,
b. about 85° condenser water temperature,
c. designed for "peak" day, and
d. no overloading (for example, one-fifth of the hold capacity dumped into warm brine the first day).

How does "horsepower" relate to "refrigeration tons?" "Refrigeration tons" describes a rate of removing heat, say, from the fish hold or brine. It is the capacity of the refrigeration system. "Horsepower" describes the amount of work you need to put into the compressor to remove that heat. The capacity will change with different conditions of evaporator and condenser temperature, compressor speed, and type of refrigerant. But if the latter three conditions--condenser temperature, compressor speed, and type of refrigerant--are held more or less constant (as they usually are), the capacity will vary a lot with evaporator temperature. Figure 1 shows this variation under some typical conditions* for a common three cylinder compressor.

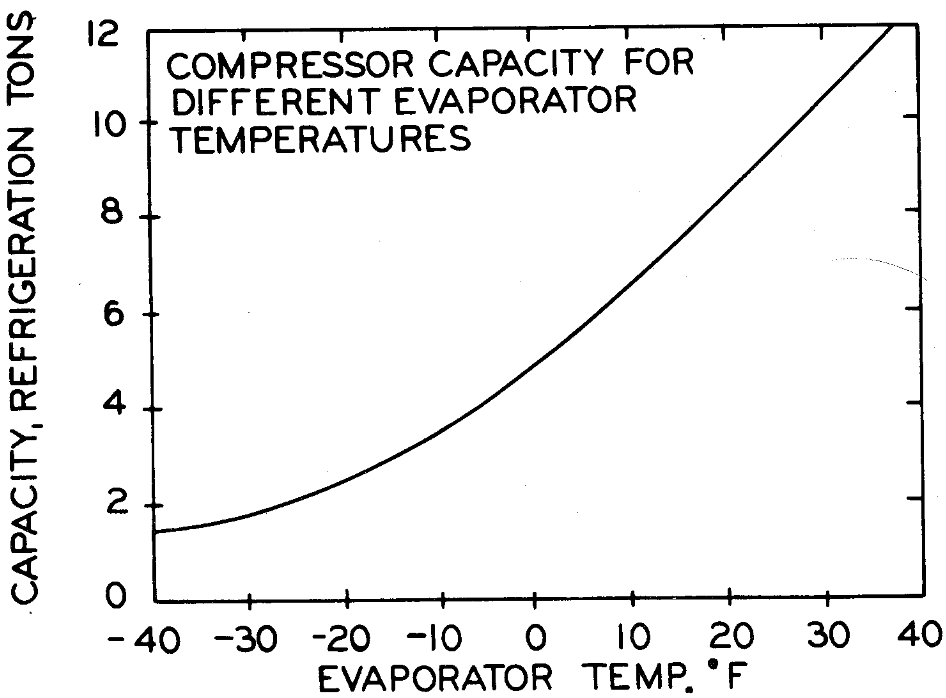


FIGURE 1

*Compressor running at 1,750 RPM, using R-22, condenser temperature at 108 °F, liquid is subcooled 15° after leaving condenser and before entering expansion valve.

As the temperature of the evaporating refrigerant gets lower (and therefore, as the suction pressure goes down), the system is able to deliver less and less capacity.

Horsepower required by the compressor also decreases with evaporator temperature, but not as much. Figure 2 shows this variation pictured with the results of Figure 1. At an evaporator temperature of around 40 °F, the "horsepower" and "tons" of this system are about the same, and the terms can be used interchangeably. However, as temperature decreases, the tons are a lot lower, but the power must still be designed into the system to drive it when the temperatures go back up. This is why "horsepower" is a better description of a system than "tons." A "7-1/2 ton compressor" is rated at a certain suction temperature (often +40 °F), a given speed,* and with a given refrigerant.

As an example, assume you were initially operating with warm brine, and warm fish are dumped into the hold. The system may be operating at 40 °F suction temperature, using about 13 horsepower to get 13 tons of refrigeration. As the temperature decreases to, say, 10 °F suction temperature, you're now using the 13 horsepower available in the motor to get only 6-1/2 tons of refrigeration. Seiners with freezing coils frequently use a 5 °F suction temperature and, therefore, don't get much work out of their compressors. In refrigerated seawater sprayers, 25 °F

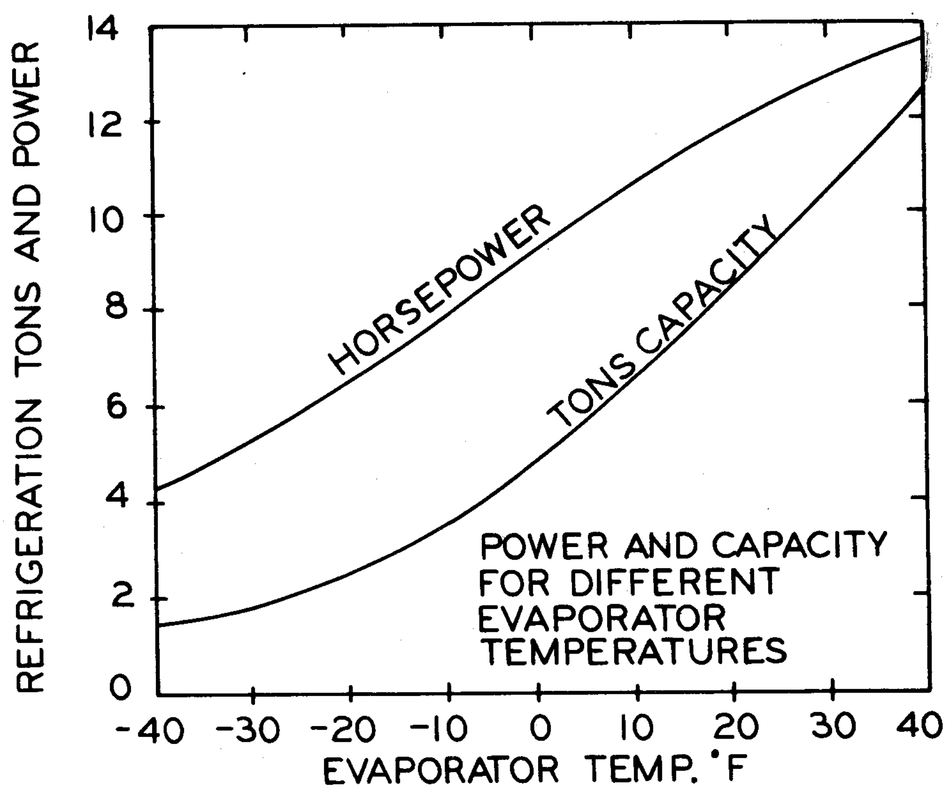


FIGURE 2

*A 10-ton unit at 1,200 RPM might put out 14 tons at 1,750 RPM.

suction temperature is common; so a higher capacity is possible with the same horsepower driving motor.*

Heat leakage into the fish hold depends on insulation, seawater and air temperature, frequency of opening the hatch, and hold temperature. Tuna boats with spray brine systems frequently use 18°-20° brine temperature.** It is necessary to have a water-tight fish hold and shaft alley and ventilation around the ribs. But it's not always necessary to have insulation all around, especially on wooden boats (Figure 3). Sometimes it is simpler and less expensive just to increase the refrigeration capacity to take care of a higher amount of heat leakage. Many of the San Pedro purse seiners with 75-120 ton hold capacities have no insulation.

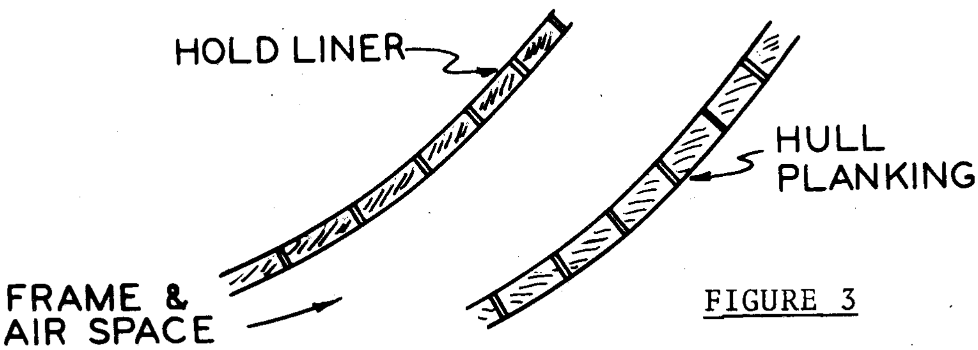


FIGURE 3

Much of the discussion in this section has been directed to brine freezing of tuna. Many of these systems, with some modification, would also be capable of chilling shrimp. For example, a system consisting of a three cylinder "RA" Tecumseh*** compressor and a small W. E. Stone chiller would probably be adequate for chilling 15,000 lb/day of shrimp to 34 °F.

2. Configuration and Controls

A basic refrigeration system appears in Figure 4. High pressure refrigerant gas coming from the compressor condenses into liquid in the condenser and collects in the receiver. At the expansion valve, the high pressure liquid changes into a low pressure liquid which evaporates as it flows through the

*This is why, when changing from a freezer to a chiller, it may be necessary to re-size the condenser. The suction pressure would go up, the compressor would do more work, thus the condenser must be increased in size so it can remove more heat.

**In southern California, the practice is to maintain this until close to delivery time, when temperature is increased to 26-27°. This is said to increase the weight of the fish.

***The use of product names anywhere in these notes does not imply endorsement of those products by Oregon State University.

coils, picking up heat from warm fish or brine. When refrigerant arrives at the control bulb, it is heat-laden gas. The diagram implies that the condenser is installed higher than the receiver, which, in turn, is installed higher than the compressor. Although this is the usual configuration, the elevation is not important, and any arrangement would work. The thermostatic control bulb should be located in the engine room as shown. This is to make it accessible and to keep copper materials out of the fish hold. The piping leaving the coils (A) is shown to loop up before going through the bulkhead, then, after leaving the control bulb, down (B) into the compressor. This loop is important for proper return of oil, as explained below.

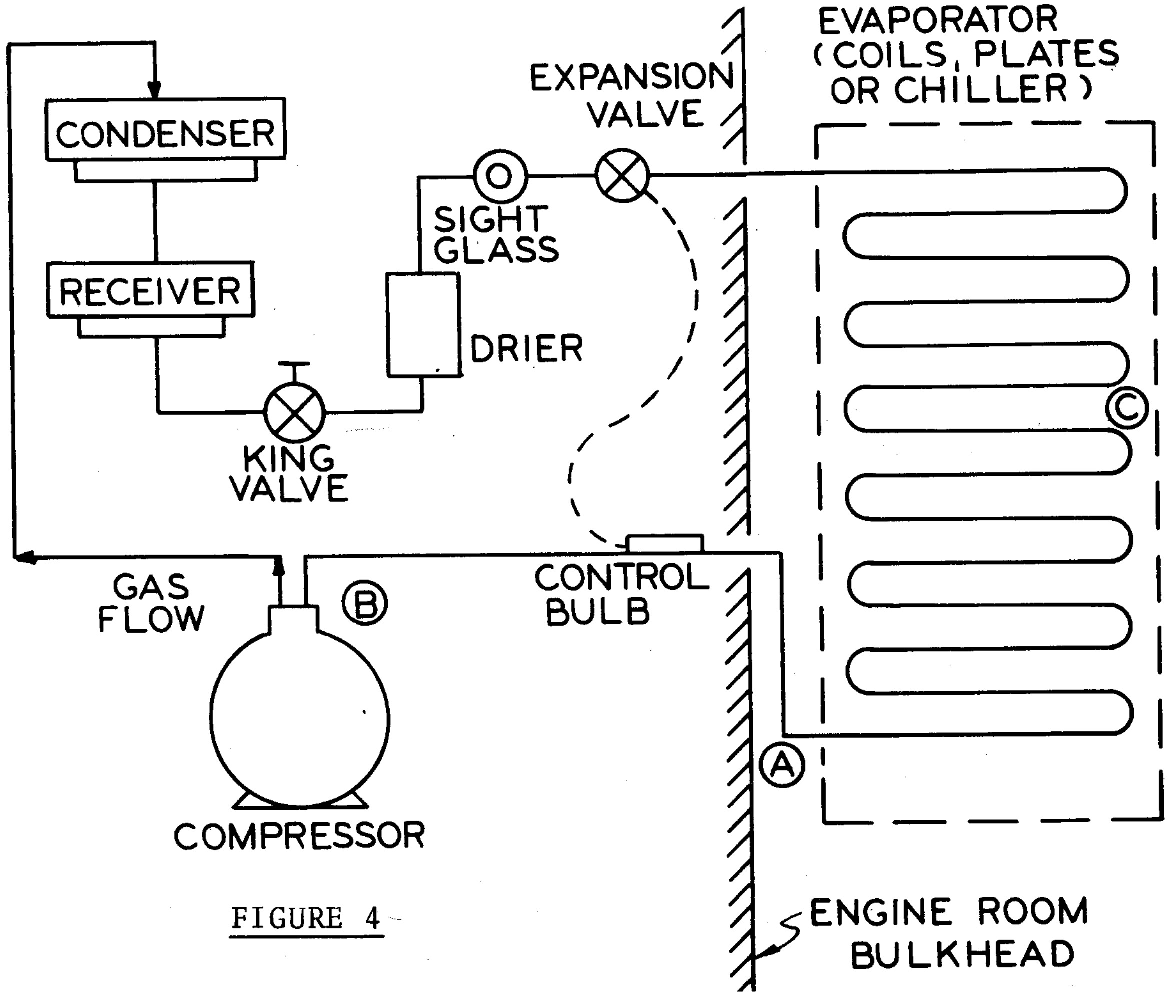


FIGURE 4

Any compressor will pump some lubricating oil into the system. Proper return of the oil is an important consideration in piping design. Oil is easily carried through the system when liquid refrigerant is present, especially with R-12, which mixes with oil like oil with gasoline--you can't tell them apart. However, when the refrigerant is evaporated to a vapor and the lubricating oil is left behind, piping should be sized so that the speed of the gas flow is high enough to carry the oil back to the compressor. This is important. Suppose the design calls for 1-1/8 inch pipe and you happen to use a 2-inch pipe because that's what is available. It will only fill up with oil until the cross-sectional area is back down to that of a 1-1/8 inch pipe, and the gas velocity is high enough to carry the remaining oil along.*

Try to avoid collecting points where oil can accumulate in the piping circuit. One common collecting point might be somewhere in the middle of the evaporator coils. If, for example, an expansion valve were undersized, or if a drier were partially clogged, or if you were short of refrigerant, chances are that the refrigerant liquid would be completely boiled away before it reached the end of the coil (point "C" of Figure 4, instead of near the control bulb). The result for relatively large diameter coils is that it is very difficult for the oil to be forced out past point (A) and back into the compressor (B). For similar reasons, it is generally recommended that for coil banks, series piping should be used instead of parallel runs, which have lower gas velocities and sometimes "dry" sections which collect oil. The oil may accumulate in the coils to the extent that evaporator temperatures are thrown way off. Another possibility is that the compressor could be robbed of adequate lubrication, resulting in failure.

On multiple refrigerant circuits, it's important to drop each return line <u>down</u> into the main suction header, rather than push the gas <u>up</u> into the main header (Figure 5). This will prevent slugs of oil from clogging individual circuits, leading to uneven distribution of refrigerant and perhaps to erratic behavior of the expansion valve. This configuration might make it necessary for oil separated out near the control bulb to be pushed <u>up</u> to the compressor through a return line illustrated by (D) in Figure 5. If the return line is properly sized, the gas velocity will usually be sufficient to carry the oil up the vertical rise to the compressor. However, if this is more than 10 or 20 feet, it may be necessary to use a "P-trap" and double suction riser, which serves as a gas velocity increaser

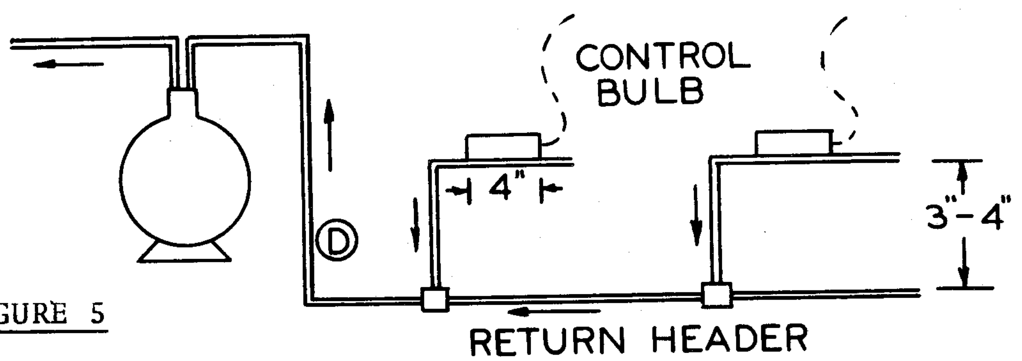


FIGURE 5

*Note that too <u>small</u> a pipe is also bad, because excessive pressure drops will affect system performance.

to carry oil upward (Figure 6). During periods of low refrigerant flow, the P-trap fills with oil, forcing refrigerant gas up the right-hand riser (E). Because all the gas goes up one riser, the velocity is higher and the remaining oil droplets are carried along. Later, when the refrigerant gas flow returns to a high volume, the pressure at point (F) increases to a value sufficient to blow the oil out of the P-trap and into the compressor, after which gas is returned along both risers at a high velocity. Note that both legs of the double suction riser have loops at the top where they join the main return line. This prevents oil from draining into one of the legs during a period of low flow. In general, one P-trap is needed for every 20 feet of rise. If the rise is only a few feet, a P-trap is not necessary.

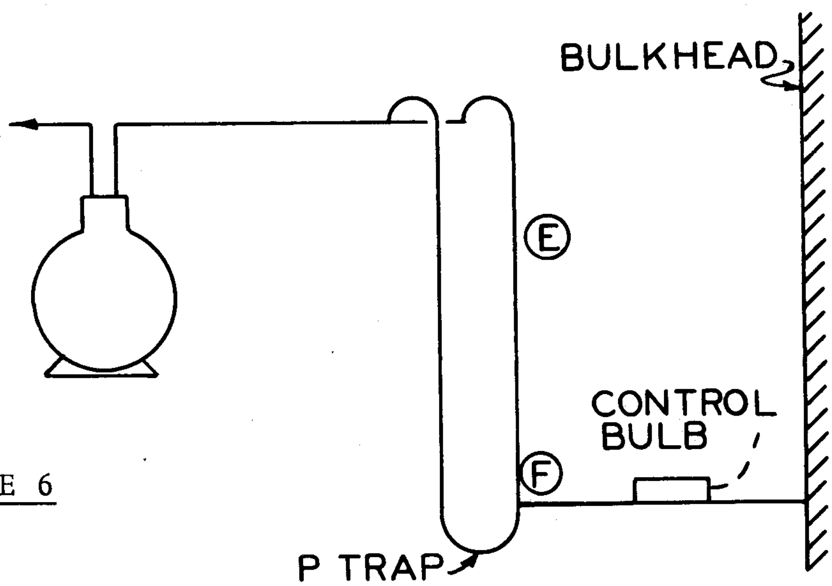


FIGURE 6

Oil return can also be a problem on headered coil systems. The recommended procedure is to have the refrigerant inlet at the bottom, thus making it like a flooded, or "wet expansion" (WX) system. In general, the inlet header is smaller than the outlet header. As seen in Figure 7, the oil return problems are apparent. Another type of evaporator, the dry expansion (DX) system, feeds from the top; the refrigerant goes downhill. The oil return problems will be similar.

How about using an oil separator to take care of oil return problems? These are not recommended. Often, an oil separator is a crutch to compensate for improper system design. Unless it is <u>way</u> oversized, some oil will leak past; the ultimate method of returning oil must be in the sizing and configuration

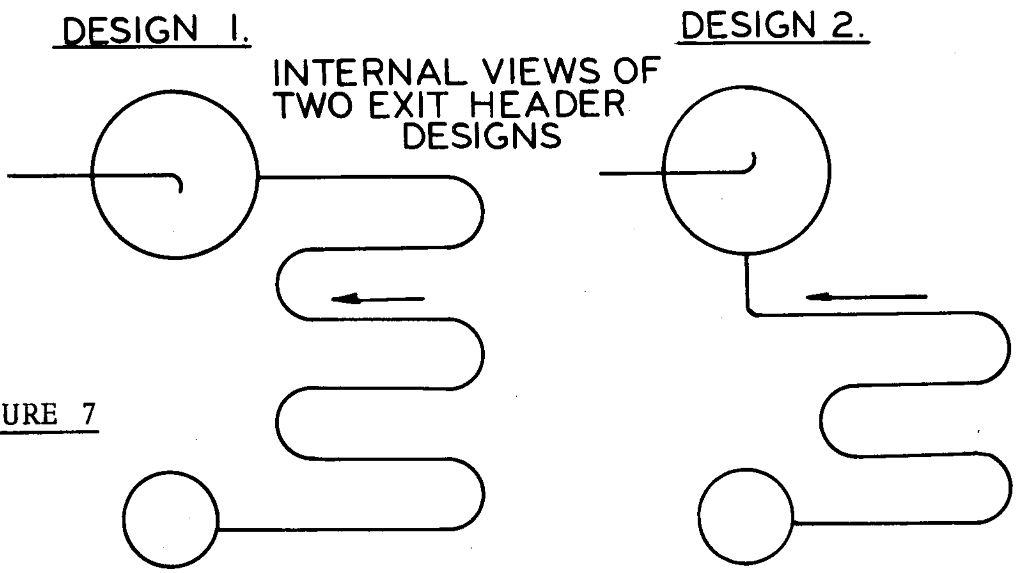


FIGURE 7

of piping. Besides, if the float sticks while you're at sea, you have real problems. Standard separators used in Freon systems are tiny compared to those used in ammonia systems. If you must use an oil separator, take a look at the manufacturer's size recommendation, then go one or two sizes larger.

The general philosophy of system control should be to make things as automatic but as simple as possible. You shouldn't have to continually adjust hand valves in order to control temperatures.

Some controls are for emergency situations. If there is a force-feed oil system on the compressor, by all means have an oil pressure safety switch. If you were to lose refrigerant, causing oil to collect in the evaporator coils, you could destroy a compressor rather quickly. Other sensors might be installed to shut down in emergencies. Some examples are sensors to detect high condenser water temperature (caused, for example, by seaweed plugging up a condenser intake), or high head pressure.

Sensors that detect refrigerant suction pressure or temperature, or brine and hold temperature can also control by cycling the compressor on and off. This is obviously easiest with an electric motor drive--the sensor activates the switch. With a hydraulic system, the sensor could activate a solenoid valve to bypass hydraulic oil.* With the direct-drive auxiliary engine system, this type of control is difficult.**

*Note that in this case, a solenoid valve on the hydraulics alone is sufficient--it's not necessary to have one also on the liquid refrigerant line.

**For emergency shut-off of an auxiliary engine, put a solenoid valve on the fuel line.

One example of a temperature control system is to put a sensor in the brine pump discharge line, set it for maybe 31° in a Refrigerated Seawater (RSW) system. This would switch the compressor on and off while allowing the seawater (or brine) pump to keep going. Even if your system is direct-drive and difficult to cycle on and off, it's a good idea to monitor brine pump discharge. Often, during a slow fishing period when the temperatures start going down, the operator forgets about things--perhaps causing a chiller to freeze-up. It's easy to install a thermostat that will ring a bell in the pilot house when the temperature gets down to, say, 30 or 31 °F. It's an inexpensive item ($20-$25) and you can set it to any temperature just like a room thermostat. Simply install a stainless steel well on the brine pump discharge line (avoid copper and cupro-nickel in contact with brine or refrigerated seawater); the thermostat-sensing bulb goes in the well. In the event a closed chiller does freeze-up, some systems have a valve in the compressor discharge line to allow hot gas to bypass the condenser, and thaw out the chiller.

Other types of controllers regulate temperatures in a more continuous way. For example, head pressure can be regulated by a condenser water flow regulator--an increased water flow will maintain a constant condenser temperature (and head pressure) when the refrigeration load increases. Brine temperatures are sometimes controlled, on hydraulically-driven systems, by regulating hydraulic fluid flow--less oil will cause the compressor to turn slower. Evaporator temperatures can be regulated in several ways. One common system has an evaporator pressure regulator (also called a back pressure regulator) in the line from the evaporator to the compressor. This valve senses upstream (evaporator) pressure and works to control to some pre-set value--constant evaporator pressure means constant evaporator temperature.

A disadvantage of the back pressure regulator is that at low refrigeration demand, it will shut way down while trying to maintain a constant (pre-set) back pressure. When it does this, the downstream (suction) pressure decreases to such an extent that it goes into a vacuum--a bad situation from the standpoint of leakage. A better alternative for controlling evaporator pressure/temperature is a variable capacity compressor. An example is the three cylinder Carrier which senses suction pressure and unloads down to two or one cylinders when the capacity required is low.

3. Sizing and Selection of Components

a. Refrigerant Selection

Three refrigerants commonly used for marine refrigeration systems are R-12, R-22, and R-502. Selection of the proper one depends on the operating temperatures and pressures and on the maximum compressor efficiency point (this occurs at high suction pressures and densities). At the evaporator design temperature, you also want to make sure that the compressor suction is not running at a vacuum, since this would tend to suck in air and moisture if a leak occurred.

For brine freezing or refrigerated seawater in the fishing industry, we can just about rule out R-502, which has an application for low temperature work (-20 to -50 °F). It is the most expensive of the three (about $1.65/lb wholesale in 1976) and at common brine freezing or RSW conditions, its operating pressure and discharge temperature are unnecessarily high.

Some characteristics of the remaining two:

--R-12 will dissolve in oil and so it carries oil through ~~the~~ system well. High-side pressure is on the order of 120 psig.* Wholesale cost is around $.80/lb (1976).

--R-22 will not completely dissolve in oil but is an acceptable refrigerant for proper oil circulation. High-side pressure is on the order of 200 psig. Wholesale cost is around $1.20/lb (1976).

The best refrigerant to use is R-22. Because R-22 has a much higher heat-carrying capacity than R-12, you don't have to pump as much of it. Thus, it is possible to run a compressor so much slower (about one-third slower) to get the same refrigeration capacity. At a slower running speed, the equipment lasts longer.** By using R-22 instead of R-12, it's sometimes possible to buy a one size smaller compressor, which could save you $400-$500. A compressor will be more efficient with R-22 than with R-12 because the suction pressure will be higher. And although R-22 costs a bit more, because of the lower pumping rate, you can go one size smaller on all pipes and valves, thus more than saving any increased refrigerant expense. (More on this in the following section, "Sizing and Selection of Hardware").

How about changing an R-12 system to R-22? First of all, you must have an open-type (belt-driven or direct-drive) com-

---

*psig = pounds per square inch gauge.

**For Carrier compressors, try to run them under 1,200 RPM for a trouble-free long life.

pressor on which you can vary the speed. Changing to R-22 in a hermetically-sealed, electric motor-driven compressor just won't work. It will try to pump too much capacity, draw too many amps, overheat, and shut off. The capacity will increase about one-third; so, to get the same capacity with R-22 as you got with R-12, decrease the compressor speed about one-third (from 1,200 RPM to 800 RPM, for example). Heat transfer characteristics in the evaporator will be about the same with either refrigerant, so it's not necessary to make any changes there. But the expansion valve will have to be changed. For example, a three ton R-12 valve would run about four and one-half tons of R-22 at the same pressure, making it too large for the job.

b. Sizing and Selection of Hardware

Balanced design is important. It is necessary to match the compressor, condenser, evaporator, expansion valve, and other components.

Compressor

We've already looked at recommended system and compressor sizing (Section 1, "Sizing of the System"): a boat with 30 tons of hold capacity would need a compressor of about 10 horsepower, which, rated at 40 °F suction temperature, would be close to 10 refrigeration tons. Remember that compressor speed, refrigerant, and operating pressures strongly affect its capacity. If you happen to have a compressor that's too big for the job, just slow it down. For example, a compressor putting out 15 tons at 1,200 RPM would put out five tons at around 400-500 RPM. A manufacturer will generally give a minimum allowable speed of 600-700 RPM. This is their recommended minimum for adequate lubrication on compressors with force-feed oil systems. Usually it's possible to go below this (to, say, 400-500 RPM) without having any problems.

A previous section ("Configuration and Controls") discussed evaporator temperature control, and how this might influence the selection of a compressor. For RSW (refrigerated seawater) systems, temperature control is more critical than in brine spray/freezer systems. There are two ways to go. The cheaper way is to buy a conventional compressor plus some intricate valves ("gadgets") such as back pressure regulators. The better way (although more expensive) is to buy a variable capacity compressor* which will unload cylinders to maintain a constant suction temperature.

A variable capacity compressor has another advantage. Frequently, when starting-up a system with warm brine, the high initial horsepower required (Figure 2) will overload or stall a

*Carrier is one company making compressors with this capability.

motor if it's not sized quite right. With a conventional compressor, it's possible to overcome this by putting a throttle (flow restricting device) in the suction line to limit capacity. But a variable capacity compressor is generally designed to start-up on only one cylinder--the others don't start working until oil pressure in the compressor is sufficiently high.

Electric Power

If one is using electric power to drive pumps and compressors, a rule-of-thumb is to choose a generator size that will put out one kw per horsepower needed. For example, if one installation had a 10 horsepower compressor, a three horsepower brine pump, one horsepower condenser pump, plus six horsepower for other convenience items, a 20 kw generator would be needed.

Expansion Valve

Choosing the proper size for an expansion valve is a matter of experience. One doesn't necessarily choose a 10-ton valve with a 10-ton compressor. Frequently, it depends on the length of pipe used in the evaporator coil. As an example, for an open coil spray-brine freezing system having 150-200 feet of one inch pipe submerged in brine, one would probably choose around a three ton valve.

In general, expansion valves are adjusted to 7° superheat. "Superheat" is the amount (measured in degrees) that the refrigerant gas heats up <u>after</u> all the liquid has been evaporated. Because the pressure through the evaporator (that is, the coils, chiller, or freezer plates) is more or less constant, boiling off of the liquid refrigerant will take place at a temperature which is also more or less constant. Say, as in the example in Figure 8, this temperature is 20 °F. As the refrigerant flows through the evaporator, it picks up heat and boils away at the constant evaporator (suction) pressure, until it gets toward the end of the

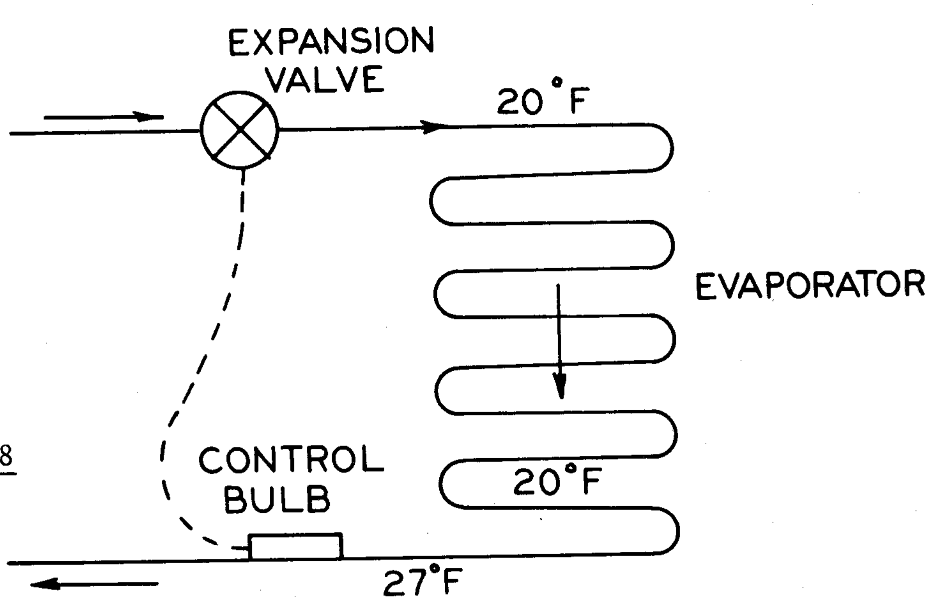


FIGURE 8

evaporator where the liquid portion disappears, leaving only gas at 20 °F. Beyond this point, as more heat flows into the refrigerant, its temperature will begin to rise. It is this temperature rise that is called "superheat." Seven degrees superheat means that by the time it gets to the control bulb, it will have warmed up 7°, as in Figure 8.

The expansion valve will sense superheat (in the example, 27 °F). If it falls below, the valve will close slightly, causing the evaporator temperature to rise back up to 27°. If the temperature increases, the valve will open and let in more refrigerant, causing the evaporator temperature to cool back down to 27°. Thus, expansion valves sense temperature <u>difference</u> or the amount of superheat. Although 7 °F superheat is the standard amount anticipated for conditions of start-up with warm brine, higher superheats are sometimes adjusted. This is not common, however, and in general, we try for the lowest superheat possible without flooding the compressor.

The performance of the expansion valve is shown by the frost point occurring around the control bulb, or thermostat bulb.* When several different refrigeration circuits or return lines are dumped back into a common suction line (as in Figure 5), it's possible to see which circuits are not running properly (and, therefore, which expansion valves may need adjustment) by looking at the frost line for each circuit.

Most valves, such as Alco, will modulate the capacity or tonnage over a range of 25-30%. For example, a three ton valve will vary from almost two to four tons in capacity.

Be sure to buy good quality expansion valves, since they are very important. It's also a good idea to buy the type of valve (such as that made by Alco) that allows you to interchange the valve stems, making it easy to change to a larger or smaller size without taking the valve out of the line. For example, if a three ton valve were found to be too small, it's better to put in an orifice capable of making it a four ton valve, rather than trying to adjust the smaller one to the limit of its capacity. Finally, buy a valve that can be silver-soldered in. Stay away from threaded connections--in cold lines, water will follow the threads back--alternate freezing and thawing will loosen the nut.

Evaporator

(All comments related to evaporators appear in a later section entitled "Chillers.")

*This frost point frequently extends two to five feet beyond the bulb, which is o.k.

Filters/Driers

An undersized filter or drier can initiate premature evaporation of refrigerant. Be sure these are sized to take the maximum expected flow of refrigerant. In fact, it's generally a good idea to install a drier that is a size or two larger than the manufacturer's recommendation; thus, it can be used to dry out a system after a repair. (More on this in a later section entitled "Maintenance, Troubleshooting, and Repair.")

Receiver

Receivers can be purchased in a range of sizes. It is also fairly easy to make a receiver out of a Freon* bottle. Try to run with the receiver no more than about one-quarter full of liquid. If a leak occurs, it will show up rather quickly. Also, if most of the spare refrigerant were stored in the receiver, it might all be lost before the leak is detected. Store spare refrigerant in a bottle elsewhere.

Condenser

Several types of condensers are available. Air-cooled units are not too satisfactory because of the corrosive atmosphere eating up the fins. Water-cooled types consist of keel-coolers, double pipe heat exchangers, and shell-and-tube heat exchangers. Generally, try to operate the condenser with a 5 to 6 °F temperature rise in the seawater flowing through.

Piping

Pipe sizing has already been discussed in relation to the need for high gas velocities to produce an adequate oil return. Piping sizes relate, therefore, to a choice of refrigerants. We know that to produce a given amount of refrigeration, less R-22 is needed than R-12. Therefore, although R-22 costs a little more, it's possible to use smaller line sizes than with R-12 and save money. As an example, instead of a 1-1/8 inch suction line needed for R-12, we could drop it one size to 7/8-inch to get the same high flow velocity necessary to return the oil. Another example: a 100-ton boat using 1-3/8 inch liquid line for Refrigerant 12 would require a 1-1/8 inch liquid line for Refrigerant 22.**

It is also important that pressure drop in the evaporator is minimized. A common design might be for a coil bank to be

---

*Note that "Freon" is a trade name of the Dupont Company. Probably, any liquid refrigerant bottle would do.

**It's interesting to note that a 1-3/8 inch valve costs $25 more than a 1-1/8 inch valve, and the same differential might be true as the size reduces further.

200 feet long, consisting of one inch pipe. Using R-22, you might have no appreciable pressure drop. However, if R-12 were put into the same lines and the same capacity were needed, the pressure drop would be excessive. Therefore, we would have to either decrease the length of the lines (to 125 feet or so) or increase the diameter to operate without excessive pressure drop.

B. Brine Spray System Design

1. Pumps

When choosing a pump for seawater or brine, keep in mind the following characteristics:

a. It should be of the open-impeller type. Closed or semi-enclosed impellers will clog up. Although screens are generally not necessary, a metal shield with 1/2-inch punched or drilled holes is often used to keep out any trash that might clog the pump. Open impellers are like "garbage disposals"--they're able to grind up almost everything and send it through. (One problem with this is getting trash through the spray heads.)

b. The pump should be made out of some material that can withstand strong brines. Electrolysis is not generally a problem with pumps in brine, because the temperatures are too low.*

c. The seal should consist of a stuffing box rather than a mechanical seal. The latter will not stand up; servicing a bad mechanical seal at sea is difficult and wastes precious time.

d. The capacity of pump needed for spray brine systems is on the order of four gallons-per-minute per ton of fish aboard. (It usually works out that this flow is needed to get the proper heat transfer on the coils.) It is possible to have too large a pump--brine pumps used around here (Oregon) are often oversized because they also serve to circulate seawater through crab tanks. One consequence is erosion on the baffles of a closed chiller (obviously not a problem on open coil chillers). Another consequence is that excess power means heat into the system. An oversized pump controlled by bypassing the circulation adds a lot of heat. One horsepower is equivalent to about 2,500 BTU/hr, requiring almost another one-quarter ton of refrigeration.

---

*Note that Canadian laboratories recommend "all iron" open-impeller pumps for the RSW systems used on board salmon packers.

e. The head pressure of the pump should be on the order of 35-45 feet of seawater. Translated into pressure, this is approximately 15-20 psi on a pressure gauge. (Thirty-three feet of seawater is equivalent to one atmosphere of pressure, or 14.7 psi.)

f. It's nice to have pumps driven with hydraulics because you can control the speed. Foaming, which frequently occurs under high rates of spray, could be reduced when such a high rate is not needed. (A later section contains some notes on anti-foaming additives.) There is one problem with hydraulic "sump pumps" in the bilge. If the hydraulic lines need changing, the results are messy.

g. Some of the pump manufacturers who turn out satisfactory pumps for this type of job are: Pacific, Jacuzzi, and Gould.

2. Chillers

There are two basic types of chillers in use: closed chillers and open coil chillers. For reasons that will be discussed, open coil chillers are generally recommended.

Closed Chillers

This consists of a box or cylinder containing horizontal refrigerant pipes and vertical half-baffles to force the brine (or seawater) up and down over the horizontal pipes. At average operating conditions, brine temperatures will drop 6 to 7 °F. This could increase to 8 or 9 °F for a high refrigeration load, or decrease to 2 to 3 °F if the brine were cooled to 18 °F and the load decreased.

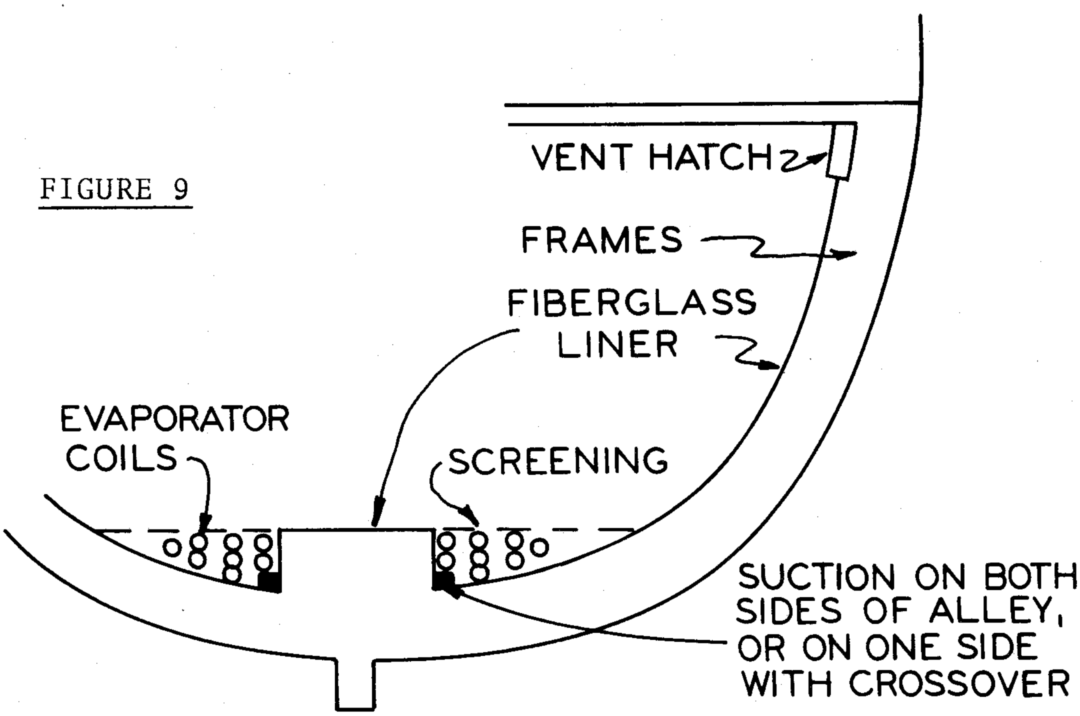
One problem with closed chillers is that they are susceptible to plugging up with dirt and fish parts. They will also freeze-up if the brine strength drops, if the brine flow is restricted, or if the evaporator coil temperature drops too low. (For example, you're in danger of freezing-up a closed chiller if you try to cool seawater to less than 34 °F.) It is a good idea to have a thermometer on the discharge of the brine pump after the brine has cooled. Common types of stainless steel thermometers for heat exchangers are made by Weston and Texas Gauge. They are dial-type, have adapters for pipe plugs, and can be oriented in any direction. (One problem is that they are sensitive to vibration.)

Another problem with closed chillers is that an excessively high brine flow rate or insufficient spacing between baffle plates can lead to erosion. A Bell and Gossett chiller that was made several years ago originally used eight inch spacing on the vertical half-baffles. They later changed to three inch spacing, but the brine was overly restricted and erosion took place. To remedy the situation, it was necessary to notch the baffles on the upper and lower edges by an area equivalent to that of a one inch pipe. This bypassed some of the brine (that is, didn't force it back and forth over the refrigerated coils) and decreased efficiency, but the flushing helped to keep fish scales and debris from piling up in dead corners.

Open Coil Chillers

Open coil systems similar to that diagrammed in Figure 9 are recommended. The sketch shows a wooden boat with a fiberglass liner in the hold. The vent hatch, normally closed during a trip, might be opened while the boat is in port to allow proper air circulation between the ribs. The waterproof cover over the shaft alley also has a fiberglass coating. Install the evaporator coils in the bilge below the top of the shaft alley cover; then place screening over the top of the coil bundle. For spray brine freezing systems in southern California waters, use 12 feet of one inch pipe per ton of fish. So for a 25-ton boat, use about 300 feet of one inch submerged pipe; a 10-ton boat would require about 120 feet. An acceptable design for the evaporator coils is to use iron pipe on four inch centers with standard elbows. This ~~is probably~~ the cheapest way to go. If you were to use welded return bends, you could space the coils closer, but this is more expensive.

FIGURE 9



Electrolysis is not really a problem, since the brine temperatures are generally quite low. Also not a problem is freeze-up on the coils due to loss of brine strength or drop in evaporator coil temperature. It is important to note, however, that if freeze-up does occur in the hold, the brine washing over ice will not cool as much as brine washing over refrigerated coils--it might get down to about 40 °F.

One possible difficulty with installing an open coil chiller occurs when the hold has a relatively flat bottom (if, for example, the engine room were aft), allowing no sump. But the advantages over closed chillers are many--you can see what's going on, freeze-ups and plug-ups are not a problem. In addition, experience has shown that for boats with a hold capacity of about 35 tons or less, open-pipe submerged coil chillers are far more economical than closed chillers.

Operating Temperatures

Assuming you know the freezing temperature of your brine, make sure that the operating temperature of the brine flowing out of the chiller is kept 5-7 °F above the freezing point. Also, in cupronickel chillers, don't let the refrigerant suction temperature be any colder than 10° below the brine freezing temperature. On a steel chiller you can go a little lower because the heat transfer is not as good.

To monitor these temperatures, good gauges are important, especially for measuring suction pressure. A cheap suction gauge which might be off by 5 psi could throw your calculations off, causing a freeze-up of the chiller. A head pressure gauge is not as important as that for low pressure (suction). Most of these pressure gauges have the corresponding saturation (boiling) temperatures of both R-12 and R-22 printed on the face.

3. Brine Preparation, Circulation, and Spray

Brine Preparation

Spray seawater systems are presently being installed for the purposes of holding shrimp. It appears that they might be held on the boat longer than the present two- or three-day limit; also, RSW systems appear to eliminate labor, save time, and get around the problem of ice scarcity. But some questions remain to be answered:

> What temperatures are necessary for adequate preservation?
>
> How long can the shrimp be held?

How much warm shrimp can be added and over what period of time?

What is the effect of salt (in seawater or brine) on the product?

Some experiments with additives have taken place. National Marine Fisheries Service in Seattle has looked at CO_2 in seawater as a preservative to enhance peelability, combat salt uptake, and maintain color. Shrimp in the Gulf of Mexico are generally frozen in a glucose-salt brine. And obviously, if you want to operate with seawater (or brine) at 33 °F or lower, salt is a necessary additive to prevent chiller freeze-ups. Seawater freezes at 27½ °F, and as stated in the previous section, this should be 5-7 °F below the temperature of the seawater leaving the chiller.

Salt brine has been most commonly used for freezing on bait boats of San Pedro and on some albacore boats in this area. Practice in San Pedro is to run brine temperatures at 18 or 19° while on the trip. The brine should be kept at a freezing point of about 10 °F below the operating temperature of the brine--so for this case, freezing point should be about 8-10 °F. This corresponds to a total salt weight of about 17% (and a reading of 65 salometer degrees). You need this 10° leeway or "margin of error" because the brine will always dilute as you add wet fish. It's difficult to mix in more salt when the brine is cold, but it dissolves easily when it is warm.* Make sure you don't just dump the salt into a pile in the bilge and forget about it, because it may not dissolve and may clog things up. When you add salt to the brine, check its salinity. If you notice that it does not rise, find out where the excess salt is going and why it is not dissolving. A good practice is to calculate how much salt is needed, add that much and no more.**

Defoamers represent another frequently used additive. Foaming in the brine results occasionally from impurities in the "kiln-dried rock salt" but more commonly from fat and other material from the fish. It does not relate to the salinity of the brine. A major problem with foam is that it may cause loss of prime in the circulating pump. There are several types of defoamers. One brand is put out by Dow Corning. Make sure that the defoamer used is FDA-approved. It should be premixed in a bucket of hot or warm brine, then poured into the hold. If it is dumped in directly, it might not mix properly. Sometimes the spraying characteristics can affect foaming--more

---

*However, sometimes it is necessary to add makeup salt on a long trip. The experience of one local fisherman was to add 4 bags (200 lbs) of salt on a 15-day trip.

**A helpful bulletin on this subject is "Preparation of Salt Brines for the Fishing Industry," OSU Sea Grant Publication #22. It includes techniques and tables.

spray holes and, therefore, lower velocities might reduce foaming. Foams can also be knocked down "mechanically"--a system observed in a California cat food plant used a brine spray supplied from overhead sprinklers to break up foam bubbles.

Circulation and Spray

A typical Oregon fishing vessel might have 300 to 400 gallons of brine in the system. This requires a tight tank in the hold and no leaks (fiberglass lining makes a good seal). The intake screen at the brine pump should be accompanied by a large open area. For example, for a 25-ton hold, provide an open area of 12 square feet--a cylindrical screen should be six to ten feet long.

PVC plastic pipe is quite suitable for brine pumping. For the spraying system, the pipe and sprinkler heads should be laid out as if the tank were a lawn and you were designing a full-coverage irrigation system. This might mean providing some kind of swing-out or detachable line on the underside of the hatch cover. Figure 10 is a sample configuration. Try to put

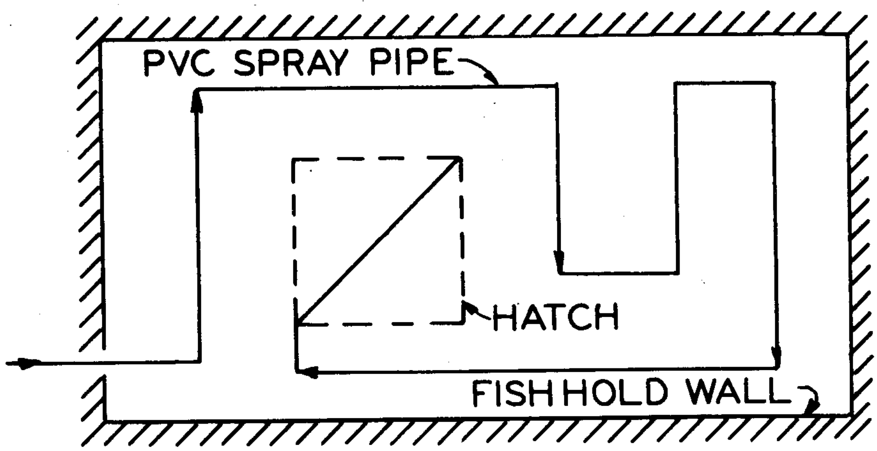


FIGURE 10

the pipe in series as far as possible to prevent dead ends, accumulation of debris, and clogging. By avoiding parallel lines in the pipe circuit, it is possible to flush the system by opening just one end and flushing either on deck or into a sock or nylon stocking placed over the end to catch scales and debris. One typical installation at the hatch combing appears in Figure 11. Another scheme (Figure 12) uses a rubber elbow that allows the hatch line to be swung out of the way; it has a plug at the end to allow easy flushing.

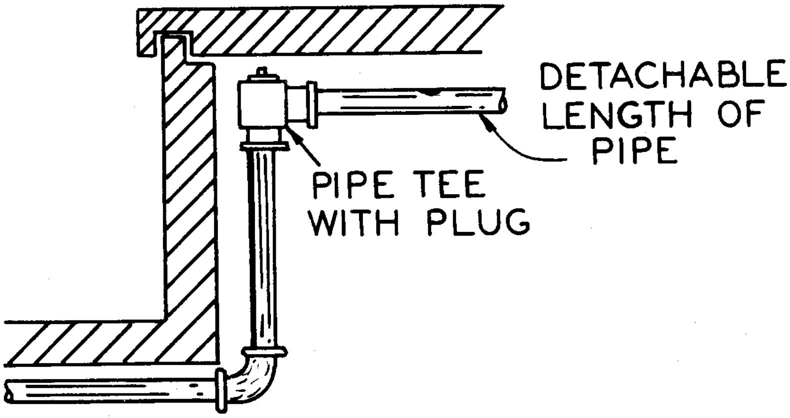


FIGURE 11

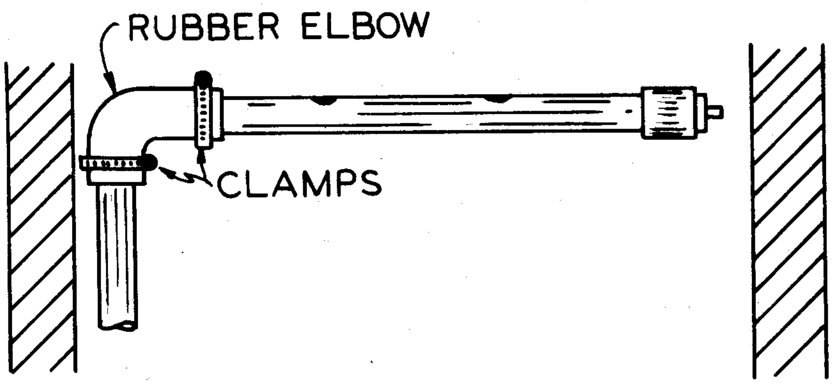


FIGURE 12

Figure 13 shows an elbow and pipe plug with a horizontal slot cut into the middle. This produces a spray over the area covered by the hatch combing.

Still another configuration (Figure 14) employs a gate valve at the end of the pipe which is easily reached to control the spray strength (might be important if you have an oversized pump). One trick recently seen was to run a boot or a fire

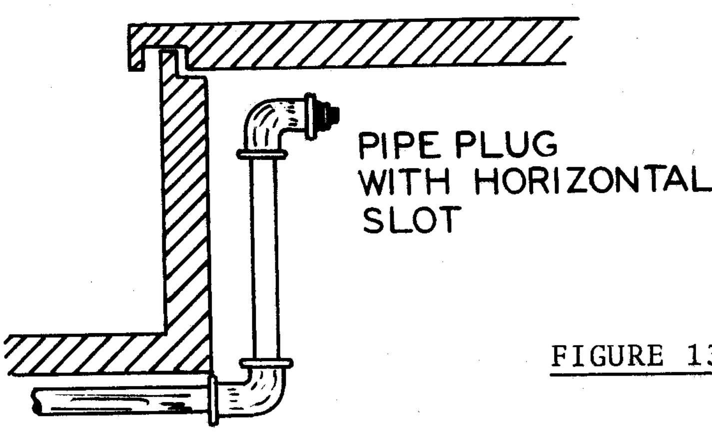


FIGURE 13

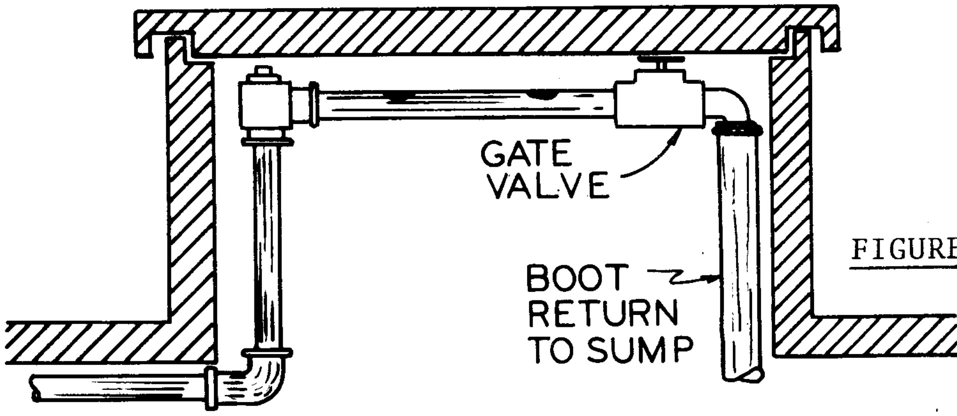


FIGURE 14

hose type arrangement from the gate valve all the way back to the bilge; this serves to control foaming when excess brine is being pumped through the system.

A typical spray system design uses a 2½ x 2 pump (about 150 gal/min) and a 2-inch diameter PVC pipe with 12 or 13 holes having a diameter of 7/16-inch. The holes, which could be in either the top or bottom of the pipe, need to be small enough to spray out with some velocity, although this spray action does create a lot of foam. You will have to raise or lower the pipe to get the best spraying pattern and adjust baffles and holes as appropriate. There are two ideas frequently used for deflectors. One is to use engine block soft plugs (around two inches in diameter) fastened to the ceiling of the hold with a screw or nail. This is placed directly over the hole in the top of the brine spray pipe (Figure 15). The second idea is shown in Figure 16. A tablespoon is bent at right angles and fastened to the PVC spray pipe with tape or a hose clamp. The difficulty with tablespoons is that they frequently bend out of shape, and it is hard to get at them to adjust.

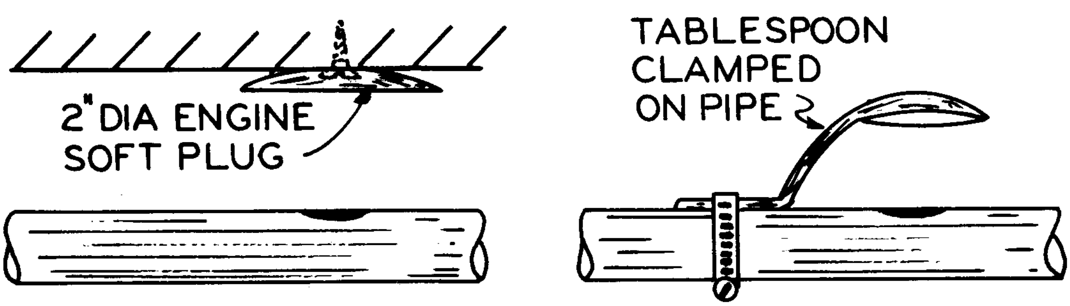


FIGURE 15

FIGURE 16

C. Installation of Equipment

Materials

Copper and brine don't mix. Copper ions are bad because they can be toxic and preliminary findings show they can lead to discoloration in canned tuna meat. This may even result from cupronickel chillers, especially if they're on deck in warm climates. Coated copper coils in brine tanks are bad because any coating tends to come off. Coils made of galvanized or black iron are no problem with brine and fish. In fact, you might as well make them out of black iron versus galvanized. First of all, black iron is cheaper, and when you weld, the galvanizing is destroyed anyway. (It is possible to use "galvalloy" to protect the weld, but it's still the most vulnerable part of the metal.)

Piping

Figure 17 shows a through-bulkhead piping design discussed earlier--steel pipe in the fish hold, copper in the engine room. The riser in the fish hold is frequently installed as a matter of convenience--the engine room is often too crowded to go in very low. Oil return is no problem as long as the copper pipe for that particular circuit drops down into the top of the suction line before it rises back up into the compressor. Make sure

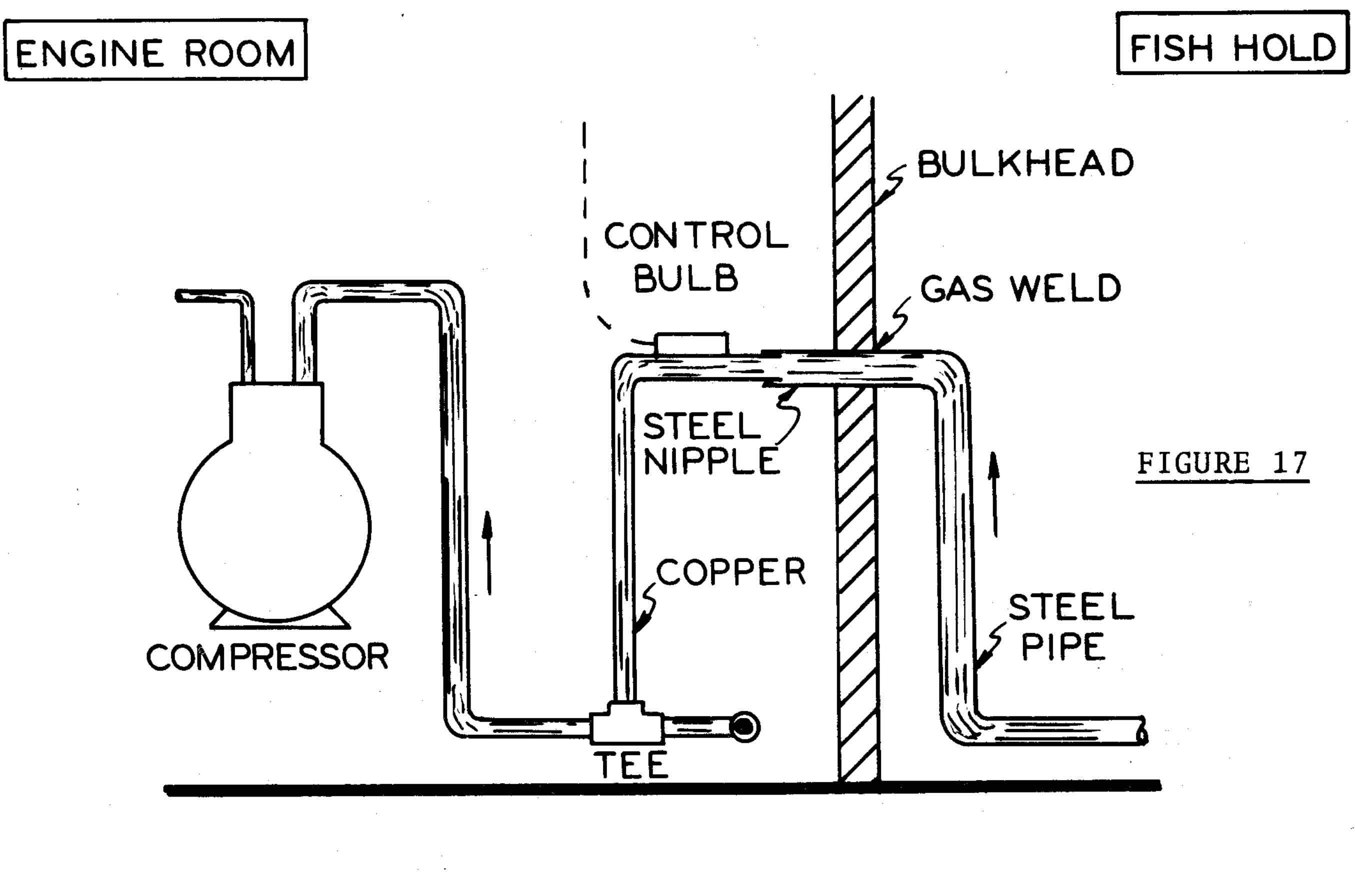


FIGURE 17

that the control bulb for the expansion valve is located on the (horizontal) copper line for good heat transfer and rapid response.

When piping up the system, the main thing is cleanliness. Keep things closed as much as possible--a common problem is sand from sand blasting. As a precaution, install a good suction line filter. When first starting-up the system, this filter will keep any dirt out of the compressor. (No manufacturer will take back a failed compressor containing foreign matter.) If a system is clean when installed and kept closed, it should operate like a home refrigerator and last indefinitely.

Copper pipe and fittings should be joined by silver solder. Regular solder (10-50% lead) is too soft and does not have sufficient strength. Steel pipe and fittings should be joined by welding. Occasionally, copper must be joined to steel as in the through-bulkhead fitting shown in Figure 17. For this case, it's common to bore out, for example, a one inch pipe to 1-1/8 inches or a 3/4-inch pipe to 7/8-inch, insert the copper pipe or tubing and join with 45% silver solder. The pipe or nipple is welded to the bulkhead and to the steel evaporator coils. If stainless steel (instead of black iron) were used for the through-bulkhead fitting, it would be appropriate to use Sil-Fos.* Try to avoid using threaded unions to join pipe sections in refrigerant lines. Especially avoid threaded connections between two different kinds of metal. The expansion and contraction resulting from temperature changes will cause the union or threaded joint to loosen and leak.

Also stay away from flared fittings if you can. Sometimes, they're hard to avoid--gauges frequently connect in with a flared** fitting. But there are a lot of breaks in these 1/4-inch lines. One problem is that they're usually tapped in at or near the compressor--a region of high vibration. A solution is to get away from the compressor. For example, on the high-side, go all the way back to the receiver to tee in a high pressure gauge or switch.

---

*Sil-Fos is a brazing alloy composed of a phosphor-bronze alloy mixed with about 15% silver. Its melting point of 1,250 °F is higher than soft solder. (From Air Conditioning and Refrigeration System Servicing, by Joe Ammons; Nickerson & Collins, 1971.)

**A tip on installation--use a few drops of oil (grease, butter, whatever is available)--on the flare block to prevent galling of the tube, and around the nut to prevent twisting the tube while tightening or loosening.

Always fit a flexible section between the compressor and the refrigerant lines carrying vapor to and from the compressor. Make sure that the refrigerant line is rigidly clamped to the boat structure, just beyond the point where the flexible fitting fastens on.

Expansion Valve

Buy an expansion valve with soldered connections--in and out. Install it in the engine room, not in the hold. This is to avoid having copper materials in the fish hold, and to make it easier to service in case of a problem.

Condenser

Condensers are designed to be "counter-flow," that is, seawater entering at the bottom and flowing out the top will be flowing at a direction opposite to the refrigerant which enters as a gas at the top and leaves as a liquid at the bottom (Figure 18). Usually the refrigerant pipes make four passes. If the seawater exit and inlet are installed in opposite ways (that is, in the top and out the bottom), the performance of the condenser will be reduced. A similar problem occurs when chillers are not installed right-side up.

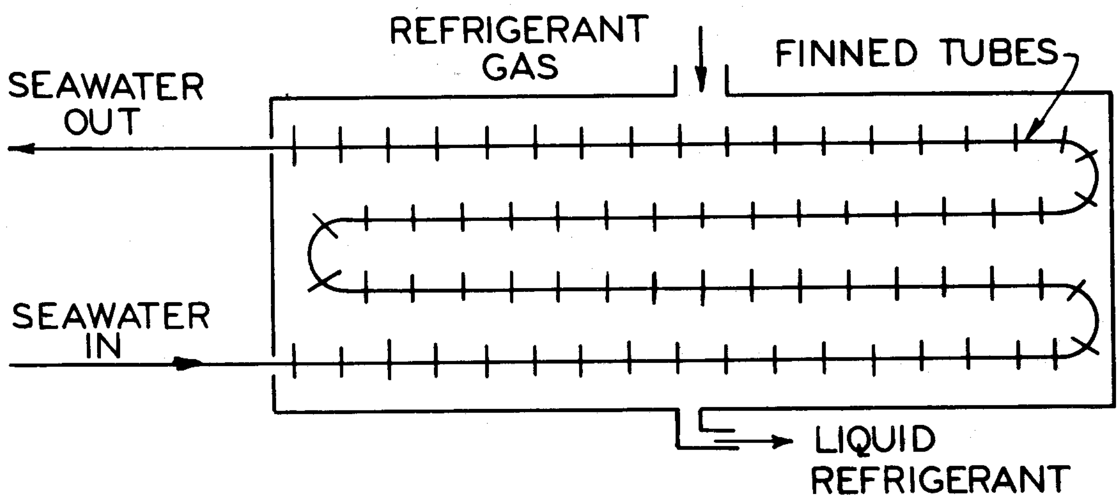


FIGURE 18

II. MAINTENANCE, TROUBLESHOOTING, AND REPAIR

A. System Shutdown

When you're through using the system for a while, it's a good idea to close the king valve (just downstream of the receiver) and pump the system partially down. That is, pump most of the refrigerant liquid into the receiver. (You don't have to pump it all back.) The reason for doing this is to prevent a slug of liquid entering the compressor crankcase on start-up, causing oil to be blown out.

Once the system has been pumped down, chances are the compressor valves will leak a little and eventually pressurize the suction side. This is o.k., since pressure is better than vacuum in the event of system leaks. However, if the shutdown is to be for an extended period of time, you should also close the service valves to isolate the low side as much as possible. Without oil sloshing against the compressor shaft seal, it'll tend to dry out and leak. If the service valves weren't shut off, you might then find yourself out of refrigerant when you go to start-up at the beginning of the season.

How do you check whether the system is performing well at the beginning of the season? One way is to have a curve of temperature versus time, made when the system was working well--then compare the new curve with that of the original system. It might be only necessary to see how many hours it takes to get down to the proper temperature. For this, you would need to have a thermometer on the brine pump discharge. If you have a chiller, it's easy to look at the temperature difference across the chiller--for example, 5° might indicate it is working properly. For an open coil chiller, obviously this is difficult.

B. Refrigerant Shortage

A shortage of refrigerant often shows up as a shortage of oil. As discussed in a previous section ("Configuration and Controls"), inadequate refrigerant will cause the BP (boil-off point) to locate partway through the evaporator coils. Because liquid refrigerant in this case will not flow all the way through the coils, compressor oil will not be returned. Instead, it collects in the coils--and a shortage is indicated.

But be careful about troubleshooting. There are other reasons that an oil shortage might show up: a slowed-down compressor, a heavy load of warm fish dumped into a system having an undersized expansion valve, improper pipe sizing for some flow conditions,* a plugged or restricted expansion valve or drier.

---

*A good system design will allow the BP to go to the evaporator exit no matter what the operating engine speed and load.

This brings us to an important general rule for troubleshooting:

> Troubleshooting should consist of 95% diagnosing and thinking, without any wrenches or screwdrivers in your hand. Generally, a problem will have just one cause--think it out before making a move.

For the case of oil shortage, this means that you shouldn't--add oil, tear down a compressor, change a drier, adjust an expansion valve--before thinking the situation over. Check for an oil leak. If there isn't one, and if the compressor is short, the oil <u>must</u> be in the system somewhere--probably in the evaporator coils.* The cause might be a shortage of refrigerant. Check the sight glasses. Frequently, the receiver will have sight glasses in the side, showing whether or not the level of liquid is adequate. If it doesn't, there are two ways to determine the position of the liquid level in the receiver. One way is to briefly turn off the water to the condenser while the system is in operation. Hot gas will heat up the non-liquid area of the receiver, which you can feel with your hand; below the liquid level, the walls of the receiver will be cold. The second way of determining liquid level is to pour boiling water on the receiver. Again, the metal below the level of the liquid will be cold.**

Check the liquid-line sight glass. If bubbles are seen, it's usually a good indication of a shortage of refrigerant; and this means a leak somewhere.*** If you're at sea, the best solution is usually to add some refrigerant and worry about the leak when you get home. Adding more refrigerant--whether you're using R-12 or R-22--will return the oil from the coils.

Leaks can mean losing refrigerant or "gaining" air and moisture (if the low side were to be in a vacuum). Loss of refrigerant can be detected in several ways. With R-12 systems, watch for any signs of oil accumulating on a joint or fitting. This is a sign of a leak--enough refrigerant gas has leaked out to

---

*One refrigeration serviceman removed 27 gallons of oil from coils on a 50-ton boat.

**How much liquid should be in the receiver? You actually need only just enough to cover the outlet. The receiver should be no more than one-fourth full.

***It's difficult to identify a refrigerant shortage by merely observing the frost line on the coils. Often, this frost line is some distance downstream of the actual BP, due to cold gas creating frost.

leave behind a residue of oil on the outside surface.* Look for leaks around gauge and pressure switch lines which are connected directly to the compressor. Cracks in lines or flares can often be spotted and capped until the end of the trip.

Leak detectors are of generally two types:

1. Electronic type: These cost about $120, are quite sensitive, but have filters which, when dirty, can prevent the instrument from functioning.

2. Halide torch: These have a copper reaction plate, and when the user has had a little practice, are capable of detecting leaks of 1/2-ounce per year (a leak so small, it would hardly raise a bubble on a soap film). One recommended make is the Prestolite leak detector.

The electronic type is quite fragile, easily broken, and therefore not recommended for use on fishing vessels. In fact, the halide torch shouln't be kept aboard a boat either. Usually by the time you go to use it, the copper reaction plate is corroded and it won't work.

Another leak problem is to have air leaking <u>into</u> the system. You can detect this by looking at tables for equilibrium temperature/pressure conditions appropriate for different gases. For example, with R-12, 70 °F will correspond to about 70 psig,** 60 °F corresponds to about 60 psig (actually 57.8 psig). If the pressures are higher than these, it could indicate that there is air in the system. (Be careful about diagnosing this, however--bad gauges are the problem more often than air in the system.) To purge the system of air, run the condenser water well after the refrigeration has been shut off. This will condense all possible liquid. Both R-12 and R-22 vapors are much heavier than air--the Freon/air mixture above the liquid will separate, with the air going to the highest point. This point is where you can open a valve (for example, a service valve on the compressor high-side) and let the air out.

To make a repair on the system, such as fixing a leak or changing an expansion valve, keep the following steps in mind:

1. Get <u>everything</u> ready beforehand--tools, equipment, parts.
2. Pump the system down to 1 or 2 psig.
3. Break the connection with this small amount of refrigerant pressure on the system.
4. Make the repair as quickly as possible.

---

*This won't occur on systems using R-22, which doesn't combine with oil in the same way.

**psig = pounds per square inch gauge, the amount of pressure above ambient.

With 1 or 2 psig in the piping, refrigerant vapor comes out at all times; nothing gets in. Of course, you could evacuate the system before making a repair, but it's almost never necessary.

How about welding on pipes containing Freon? It's true that Freon plus high temperature leads to phosgene, a poisonous gas. But at 1 psig, there won't be enough phosgene around to do any harm. Be careful about welding on a pressurized pipe, however. Often the heat will build up the pressure to such a level that gas will bubble out through the weld. In this case, you'll have to go to the other end of the pipe and vent it.

During some repairs, the system does have to be left open for quite a while, and air and moisture do get into the piping. One textbook solution to this is to first evacuate with a two-stage vacuum pump, then purge with dry nitrogen followed by another evacuation with the vacuum pump. As a practical matter, few people have either a two-stage vacuum pump (plus gauges) on hand or the time (several days to a week) to go through this process. A better solution is to get rid of the moisture with drier elements. Put in an oversized drier--instead of a $20 drier, put in a $50 drier--one or two element changes will take all the moisture out, and you're done. Once the moisture is out, the air can be purged as described earlier.

How about adding more refrigerant to the system? Adding refrigerant is just like transferring fuel (Figure 19). The filling bottle, usually disposable, commonly holds 25 pounds of refrigerant. The filling valve is opened and the main (king)

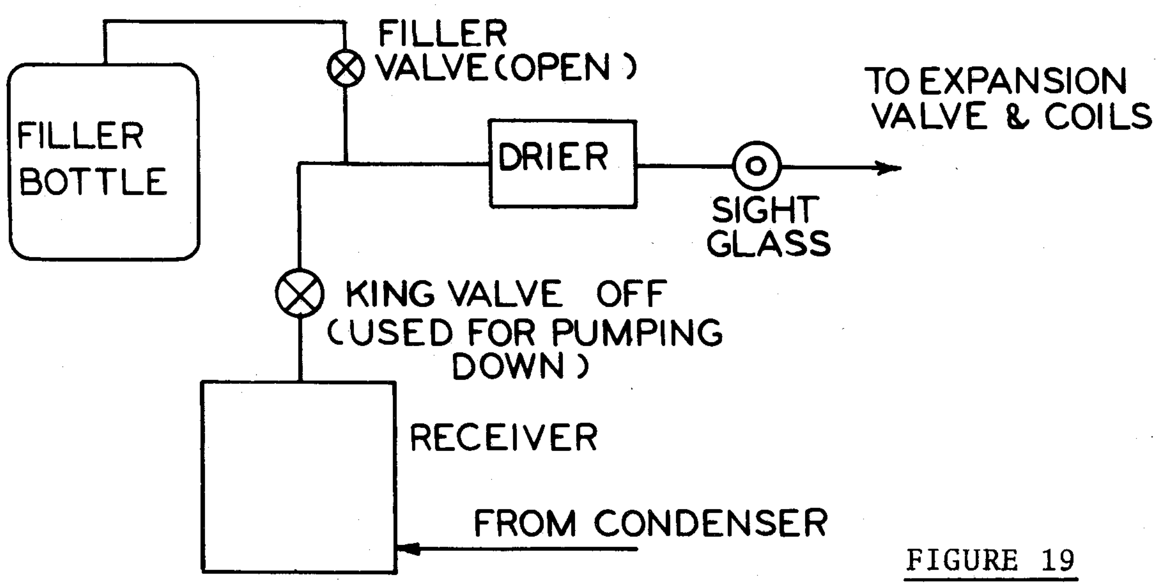


FIGURE 19

valve (used for pumping down) is turned (or it could remain right-side up, filling the system with refrigerant gas). As you're filling, watch the sight glass; you should see a steady flow of bubbles. If you have a system that holds, for example, 50-75 pounds of refrigerant and you're pouring in a slug from a 25-pound bottle, it's probably o.k. to put the entire 25 pounds in if the receiver is of an adequate size. But as discussed previously, spare refrigerant should be kept in the spare bottle and not in the system.

C. Component Servicing

Compressor

One of the difficulties with refrigeration systems on fishing vessels in this area is that they may be used only about 60 days out of the year. Such long periods of down-time are hard on systems. In the compressor, watch out for seals going bad as a results--especially mechanical seals made out of neoprene and carbon face.*

Adequate lubrication obviously is very important. Keep in mind, once again, that a system which is low on refrigerant can run the risk of losing proper lubrication for the compressor--movement of the refrigerant is necessary to keep the oil circulating. Most compressors have sight glasses showing the level of oil; if you can see the oil anywhere in the sight glass, it's probably o.k. On a splash lubrication system, the oil needs to be only deep enough so the dippers hit. Oil pressure gauges are frequently used to measure the health of a pressurized lubrication system. The thing to watch out for is that these gauges don't stay accurate very long.

It's easy to blame one component, such as the compressor, for a problem that might be caused by something else in the system. For example, a head pressure that is too high might have any one of several causes: a restriction in the condenser water flow, an increase in the cooling water temperature, air in the system, or even a bad high-side pressure gauge (check to see that it goes to zero when the pressure is released).

What <u>should</u> the head pressure be?** For R-12, pressure should be in the range of 105-125 psig, with discharge temperatures around 140-160 °F. For R-22, pressures should be in the range of 200-215 psig, discharge temperatures in the area of 200 °F. Temperature of the hot gas line from the compressor

---

*This is a frequent problem in automotive air conditioning systems, too.

**Head pressure switches are frequently used to shut down when the head pressure gets too high. These switches <u>very seldom</u> fail. Generally, adjusting or changing a pressure switch (or thermostat) is a crutch, not a cure.

will usually be too hot to allow you to hold your hand against it. However, the line should be below 212 °F. Check this by splashing water or spitting on it. If the water sizzles, causing steam, the line is over 212° and you have compressor problems. A possible cause is that the discharge valve isn't closing tightly. Therefore, gas would be sucked back in, causing too much to be compressed during the compression cycle, resulting in discharge gas which is too hot.

It's also possible to check for bad valves by slowly closing off the suction line. The compressor should be able to pump a good vacuum fairly rapidly--the* low side gauge should go down to around 22-28 inches of vacuum. Following this, stop the machine--the vacuum should hold. If it comes right back up, there is a compressor problem--probably broken suction or discharge valves.**

Try to maintain even head pressures, because these affect the rating of the expansion valve. For example, if you bought a 5-ton valve for R-12 and ran it at 75 psi instead of 120, you'd have a 2-1/2 ton valve. This is because the rating of the valve depends on the <u>pressure drop</u> across the valve. One solution to uneven head pressures is to install a water regulator to control water flow rate through the condenser.

For a similar reason, one occasionally sees refrigerant liquid slugging back to the compressor, especially with R-12. One cause of this is a sudden increase in head pressure (possibly due to operating in warmer temperature water). If the head pressure were to jump from, say, 120 to 180 psi, the pressure drop across the open expansion valve is suddenly higher, causing a greater volume of refrigerant to be pushed through the system. Thus, for a short time, the capacity of the system is increased; all of the refrigerant is not evaporated in the coils; and some flows past the control bulb into the compressor.

Expansion Valve

There shouldn't be any servicing at all done on expansion valves. First of all, buy <u>good</u> valves.*** Then, once the expansion valve is set and adjusted, walk away from it and <u>leave</u>

---

*A gauge which measures both pressure and vacuum will almost always show units of "psi" for pressure above ambient, and "inches of mercury" for "vacuums" below ambient. A true, absolute vacuum (if it were attainable) would show up on the gauge as 29.92 inches.

**Broken suction or discharge valves in the compressor can frequently cause loss of oil as well. Oil can be blown out of the compressor within 15 minutes if one of these failures occurs.

***One fisherman that had a habit of buying surplus expansion valves for a dollar apiece ended up losing 100 tons of fish in two trips.

it alone. If, for some reason, the valve doesn't hold its adjustment, it should go back to the factory. There is no reason to take the cap off. If you occasionally detect inadequate flow through the valve, the difficulty is usually elsewhere. This is especially true of a valve that has been working for six months or more. There might be dirt or moisture causing a problem, but it's not the valve's fault. Very few valves fail.

As stated previously, expansion valves sense temperature difference, that is, the amount of superheat. So in order to check that the valve is operating properly, it's necessary to use two temperature sensors (or a temperature sensor and a pressure gauge).* Expansion valves are usually set for about 7° superheat. If frost is seen on the compressor, it means that the expansion valve is either set wrong or it's bad.** The general solution to this problem is to buy a new valve. If you are using a Sporlen or Alco valve, you can merely change the seat or the inside of the valve.

Condenser

Discussion above has shown the importance of good water flow through the condenser. Take the access plate off periodically and clean out debris and fouling. For a shell-and-tube, or double pipe, do this during lay-up or off-season. For a keel cooler, you can take care of it when you haul out.

What happens if a condenser fails and water runs into the refrigerant circuit? This is a real mess that's going to take a considerable amount of time to fix up. The following describes the general procedure:

1. Assuming it is the condenser that has failed, remove it, clean and repair it, or throw it away and install a new one.
2. Remove the compressor, overhaul and clean it, and put it back.
3. It is difficult to clean the sludge out of the receiver. The best and probably cheapest solution is to throw it away and install a new one. At this point, the compressor, condenser, and receiver are clean and ready to go.
4. Remove the expansion valve and blow the refrigerant lines clean with dry nitrogen. Then, with lines disconnected from the coils (or "chiller," or "evaporator") blow the bulk of the water out of the coils with nitrogen. You're now ready to work on the final drying of the coils. For this a "system cleaner" is needed.

---

*Note that if you are attempting to measure the temperature of the gas by measuring the outside pipe wall temperature, remember that the wall will be warmer than the gas. For a copper pipe, the wall will be about 1/2 °F warmer; through a steel wall pipe, the drop will be around 6-7 °F.

**It is possible to have the compressor frost over for a short period of time (for example, if the brine pump shuts off) and this doesn't indicate a bad expansion valve. But it shouldn't happen as a permanent thing.

5. A system cleaner is essentially a distiller. One type commonly used is made by York, is about 10 inches in diameter and 4 feet high, and contains screening and about 6 pounds of chemicals--either silica gel or activated alumina. Hook it up between the coils and compressor according to the diagram in Figure 20.
6. If the refrigerant used was R-22, change to R-12 while using the system cleaner. The reason for this is that water will float on R-12 better than on R-22. Thus, removal of water from the coils and separation in the cleaner will be more efficient with R-12.*
7. It takes sometimes 16 to 24 hours of running to clean out and separate all the water in the system. Sight glasses on the side of the cleaner indicate water or refrigerant levels. Heat applied to the cleaner will cause refrigerant to vaporize and flow to the compressor. Chemicals (silica gel or activated alumina) must be changed frequently. The procedure is long and difficult, but it is better than the alternative, which is to run a vacuum pump for a few weeks, a technique which still may not completely dry the system.

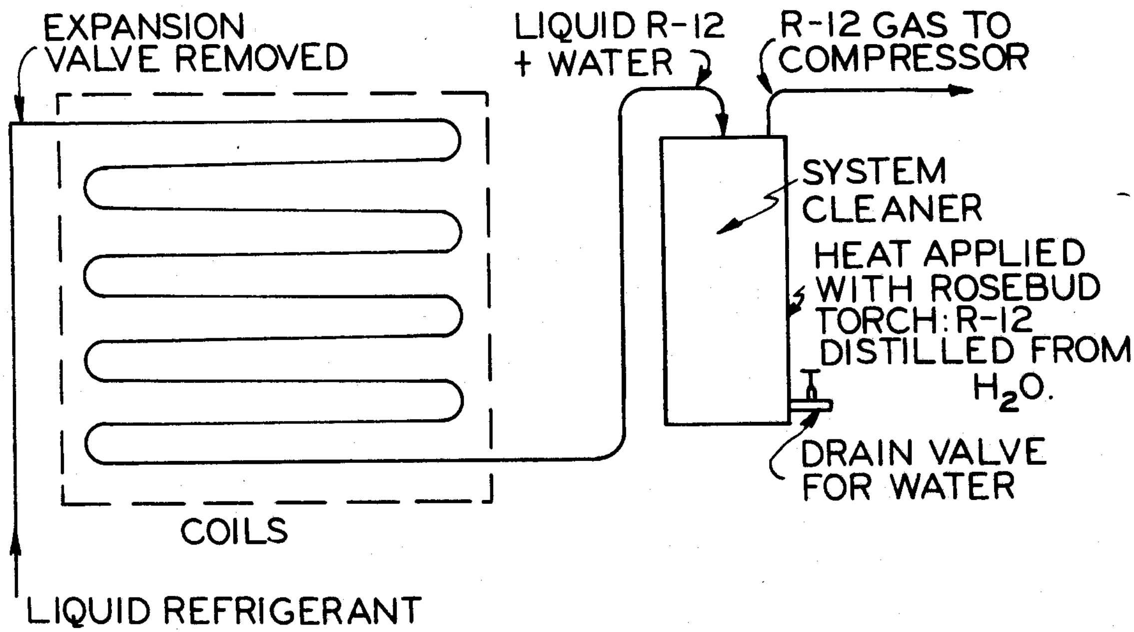


FIGURE 20

*Occasionally, R-11 is used for this kind of job because it is slightly cheaper. However, the advantage of R-12 is that the refrigerant is recycled and, in many cases, left in the system when the cleaning is completed.

Filters/Driers

Use a sight glass with a moisture indicator to continually show the condition of the drier. Install it downstream of the drier so that dirt or darkened refrigerant won't cloud the indicator on initial start-up. The moisture indicator is actually a piece of litmus paper--usually green when it's dry, yellow in the presence of moisture. These indicators are 100% dependable. If the one on your system turns color, or if you open up the piping to do work, change both the drier and the indicator. Because indicators are dependable and because a refrigeration system should be completely sealed, you should never have to <u>routinely</u> change a drier or indicator.

Occasionally a filter or drier may become clogged with dirt. Any restriction in a liquid refrigerant line will be accompanied by a temperature drop. Obviously, a built-in, intentional restriction is the expansion valve. However, when the restriction is a drier or filter that is plugged or perhaps undersized, the device acts somewhat like the expansion valve--the pressure drops over this restriction and some of the refrigerant is evaporated, thus decreasing the temperature. You can detect this by grabbing the tubing on either side. It might be, for example, 80° on the upstream side and 70° on the downstream side. The result of this pre-evaporation is to rob the last evaporator coils of refrigerant, causing a decrease in capacity and an accumulation of oil in these last coils.

Receiver

Occasionally the flow into the receiver appears to be intermittent, as seen through the top sight glass. That is, it appears to "rain" refrigerant for a while; it then stops and you can't see anything coming in; then once again, it commences to "rain." This actually represents slugging of liquid from the condenser into the receiver. The situation is not particularly harmful to the system; it is caused by heat from the engine room flowing into the line between the condenser and the receiver (Figure 21). For example, if the seawater cooling the condenser is 60° and the engine room is 90°, the liquid leaving the condenser may gassify and "slug" into the receiver. Due to this gas, a "false pressure" of around 1 psi is created in the condenser. A solution to this is to install an equalizer line (1/2- or 5/8-inch copper tubing) as diagrammed in Figure 21.

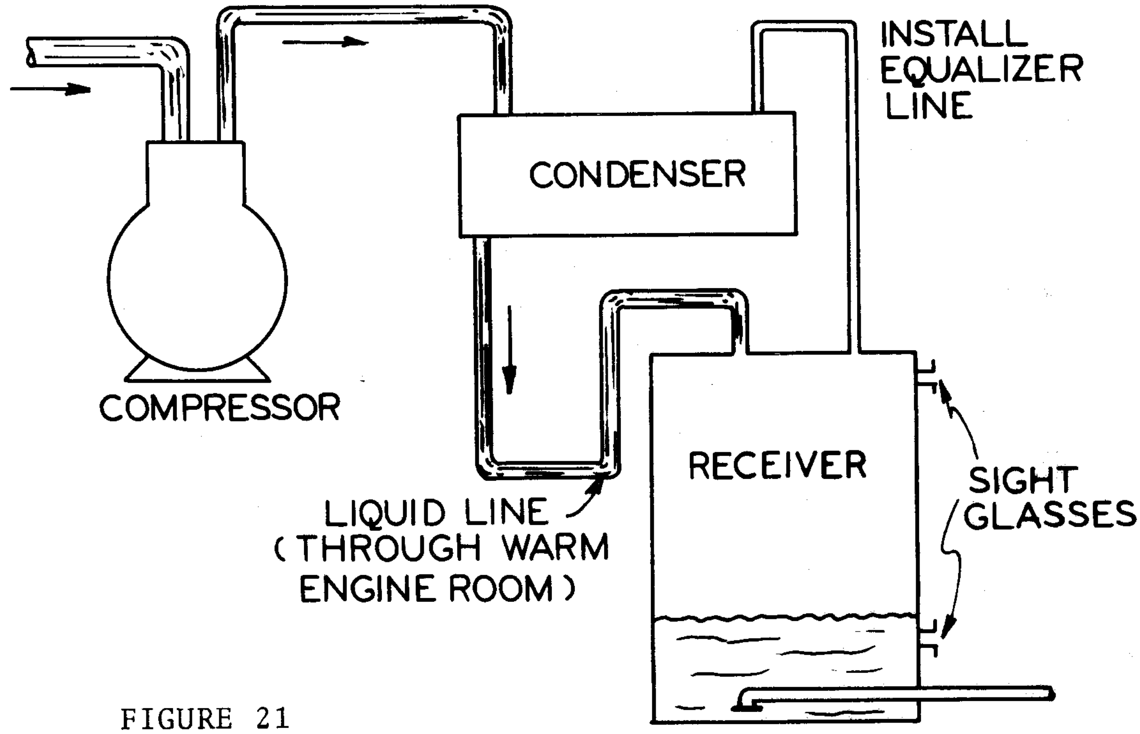


FIGURE 21

Chiller

The biggest problem with chillers is clogging with scales or salt. The result might be a decrease in flow rate, heat transfer rate, performance, and perhaps a freezing-up if the salt is not being properly dissolved.

INDEX

OREGON STATE UNIVERSITY
EXTENSION
SERVICE

Extension Service, Oregon State University, Corvallis, Henry A. Wadsworth, director. This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

Extension's Marine Advisory Program is supported in part by the Sea Grant Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Extension invites participation in its programs and offers them equally to all people, without discrimination. 6-77/1.5M