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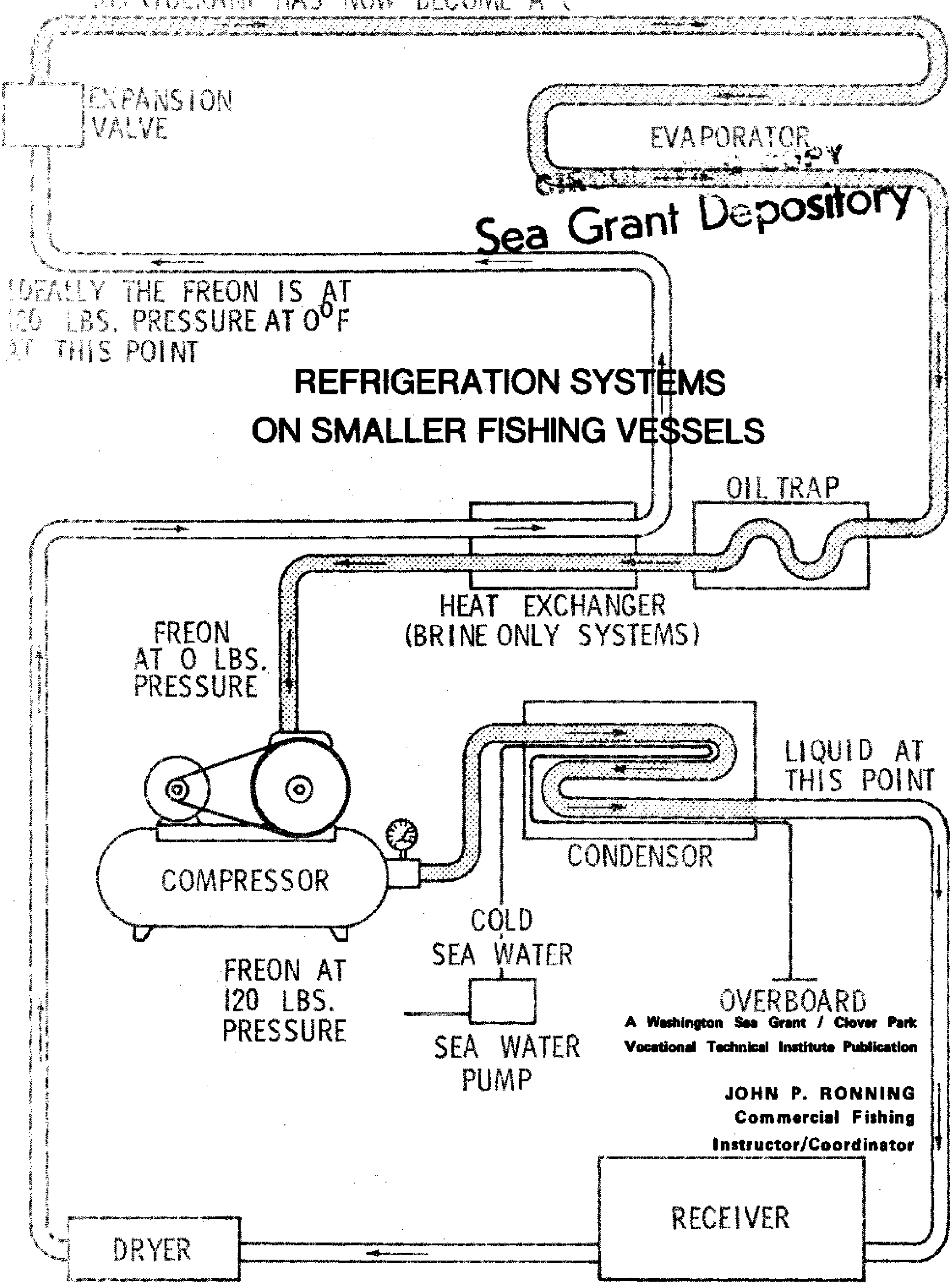
REFRIGERATION SYSTEMS ON SMALLER FISHING VESSELS



A Washington Sea Grant / Clover Park Vocational Technical Institute Publication

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FIGURE 1. TYPICAL REFRIGERATION SYSTEM

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I — INTRODUCTION - FISHING VESSEL REFRIGERATION

This publication is intended to assist North Pacific commercial fishermen to a better understanding of the suitability and use of refrigeration equipment to hold and freeze the catch. It is not intended to provide detailed technical information, but to present some general information and useful guide lines. In this way the fisherman can be better prepared to take advantage of other available information and to discuss his interests or needs for refrigeration equipment with other fishermen or with the suppliers. Although we have had refrigeration systems on fishing vessels for sometime, they have been mostly on larger vessels such as tuna purse seine boats. Only in recent years we have seen refrigeration used on smaller vessels. It is this class of vessel that makes up the biggest part of the North Pacific commercial fishing fleet and to which this bulletin is intended to be the most useful.

The main reasons for considering a refrigeration system are to maintain high product quality, conserve ice, extend fishing trip length and decrease labor. Pacific Coast fishermen land catches of high ex-vessel value and know of the need to give such fish the best possible handling and care to bring the best price. Some fishermen seem to always bring in better quality fish than others and are always welcome to the buyer.

Those who don't always bring in the best quality product need to see how they can improve the quality and at the same time increase their profit returns. Another important factor is that the buying public is now more aware of the overall need for improved quality measures throughout the fishing industry. Proposed Federal legislation dealing with Mandatory Product Sanitation is now being drafted. New regulations that will affect the processing and wholesale plants will also be extended to affect fishing vessels and make them subject to some new regulations in the near future.

Another consideration is that there is an increasing trend to dual purpose fishing operations. For example, some vessels will fish for salmon part of the season and then fish for albacore tuna. The albacore trips are much longer than the average salmon trip and require some extra ice holding capability or other form of refrigeration. Other vessels may fish for salmon, albacore, and crab all in one season and require one or more type of refrigeration equipment to get the best quality product in each operation.

Also important is the fact that some fishermen are making trips farther from ports and need to reduce running time costs, or have some additional protection for the catch quality preservation when driven from the fishing grounds by weather. The halibut fisherman certainly needs to stay on the grounds to get a full trip and in some instances even the small troller or gillnetter will require more than one day to make a trip pay.

The trend in recent years has shown increased attention by the fishermen to a more productive situation by a combination of better quality, and increased production with reduced costs wherever possible. Just as the adoption of high-speed engines, hydraulics, automatic steering, and electronics have been shown to be to the fisherman's advantage, the proper selection of refrigeration equipment can be a way to more fishing time, higher profits and greater return on investment to the operator.

This bulletin covers a general consideration of the selection and use of fishing vessel refrigeration systems and describes the basic kinds of equipment that is available and that has been used in various fishing operations. Some advantages and disadvantages of the systems are presented and compared as to equipment costs, installations, maintenance, and effectiveness for different fishing operations. Sources of information such as refrigeration equipment suppliers and installers, and fishery researchers are also presented for the fisherman who wants additional information for his interest or an intended application.

II — REFRIGERATION EQUIPMENT CONSIDERATIONS

Marine refrigeration equipment has been available for more than 50 years and on vessel freezing systems for more than 25 years. This came about because changes in fishing grounds or fish transport required traveling longer distances and ice was not always enough to hold a quality product for the time required. Development of this equipment thru modern refrigeration technology has reached a fairly high level for the larger vessels. It is considered in many of these installations that the refrigerated vessel is able to out-produce the ice-boat by 25 percent or more. However, it has only been in the last few years that any real number of the smaller vessels have been equipped with refrigeration for ice holding or freezing the catch, It is estimated that some 10 percent of North Pacific vessels are refrigerated and few of them are under 45 feet long. Some reasons for the slowness in adapting equipment for the smaller vessels include the custom made nature of installations, primarily from modifications of systems developed for larger vessels, or from the trucking industry. Some excessive overall costs result from the failure of the fisherman and the refrigeration supplier to get together on proper selection and installation of equipment. Refrigeration experts are not always familiar with details of the various fishing operations and the fisherman too often is unfamiliar with refrigeration equipment.

At least three basic things should be considered in selection and installation of such equipment, (A) the type of fishing operation and the product, (B) matching the vessel, the refrigeration equipment, and operating area (C) equipment installation operations and maintenance costs. The costs of a refrigeration system can vary from 10 percent to 25 percent of the vessel cost and failure to consider these fundamentals can result in excessive overall costs and unsatisfactory system performance.

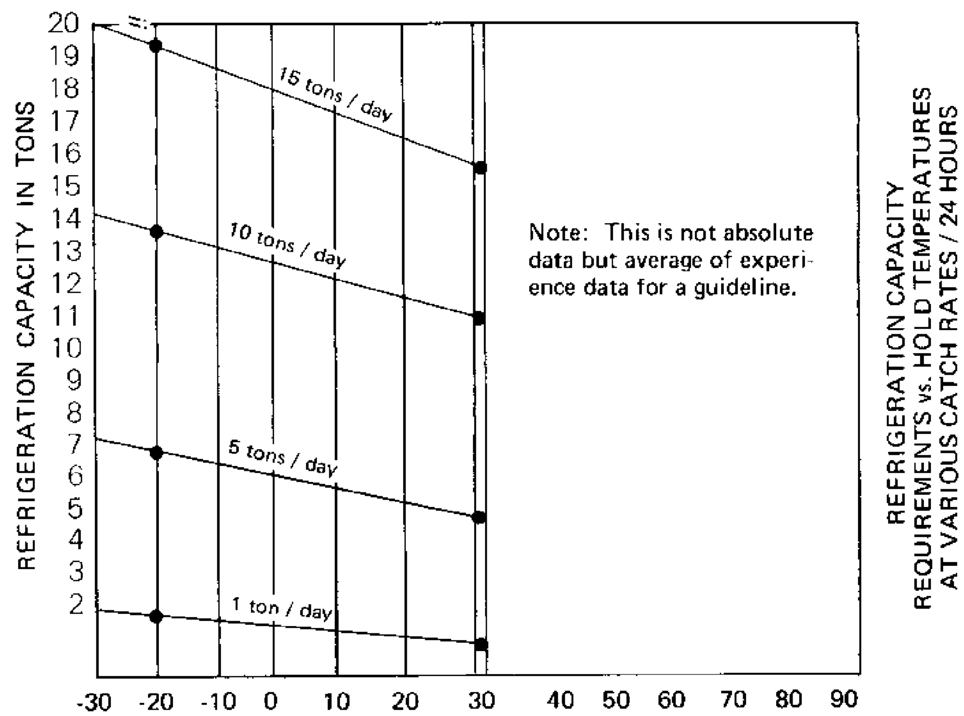
A - TYPE OF FISHING OPERATION AND PRODUCT

The catching, handling, and storage methods in different fishing operations vary widely. The nature of the product delivered may dictate the choice of the holding or freezing equipment to be used. The catch rate is certainly important in determining required refrigeration capacities. Fishermen may not agree on expected catch rates on a normal trip, but some estimates have been made for average catches as guidelines.

Average daily troll or gillnet salmon catches range from a few hundred pounds to 1500 pounds or more. Average daily salmon seining operations range from 5,000 to 15,000 pounds or more.

Average daily albacore catches range from 1,000 to 2,000 pounds and upward. The average daily halibut catch ranges from 1,500 to 6,000 pounds daily, but may go as high as 20,000 pounds. Average daily North Pacific bottom fish catches are about 10,000 to 12,000 pounds but have dropped off from former years catch levels. Pacific shrimp catches can vary quite widely being from 1,500 to 2,000 pounds daily in Washington and Oregon, to as high as 50,000 pounds or more in Alaska.

FIGURE I



Sizing the refrigeration equipment to always handle a maximum catch is not reasonable from the standpoint of the cost of equipment or finding enough space for it on the smaller vessel. As a guideline, one ton of fish requires about one ton of ice for holding at 32°F. Refrigeration for ice holding is often installed to permit ice holding with less than the usual ice load. As a rule of thumb, requirements for refrigeration equipment capacity to hold fish at 32°F range from 1 to 1¼ tons of refrigeration output per ton of fish per 24 hours. However, as freezing and holding temperatures drop to 28°F or below, refrigeration capacity needs to be doubled or more. As a guideline for freezing, most vessels will require as a minimum one-fifth to one-fourth of the hold tonnage capacity in refrigeration capacity for normal catch rates with a small built-in excess refrigeration capacity desireable.

In addition to sizing the catch the method of deck handling may require additional refrigeration equipment. Line caught fish such as salmon or tuna, may require holding tanks to keep fish in good condition while fishing continues or until the fish have been properly cleaned or dressed before going into the hold. The situation would be different in the case of bulk caught fish such as seine caught salmon or bottom fish or crabs which go directly into the hold or tanks in the hold.

An additional important consideration in selecting refrigeration equipment is the condition of the holding or freezing temperature the better the result. For example, dry or still air refrigeration systems such as pipe coils or plates relying on convection heat transfer are good ice holding systems, but are slower for freezing than air blast systems by a rate of about 1 to 3, or seawater/brine immersion systems by a rate of about 1 to 6. Quick freezing cannot imporve the quality of fish but can maintain the fish in about the same condition as it came out of the water. Quick freezing minimizes the size of ice crystals that form in the product. These ice crystals can change the texture and appearance of the fish when it is thawed. When the product is frozen more slowly, larger crystals from and can result in a lower quality product.

Proper ice holding temperatures for salmon, halibut, tuna, bottom fish and shrimp are considered 32°F (In a few instances shrimp are also held in chilled seawater at 29°F) Limits for ice holding these fish are considered to be as follows:

Salmon	10-12 days
Halibut	18-21 days
Tuna	15 days
Shrimp	3-5 days

Proper freezing temperatures for these species is considered to be 0°F or below for salmon, halibut, and bottom fish. Tuna must be held frozen at under 25°F (Shrimp are not in practice frozen at sea aboard North Pacific fishing vessels.) Limits for holding these products frozen range from 30 to 90 days, depending on condition of fish where caught, handling and vessel storage facilities. It is emphasized that an important factor in the selection of refrigeration equipment will be the buyers acceptance of the product.

B- MATCHING VESSEL EQUIPMENT, AND OPERATING AREA

One of the most important things to consider before selecting and sizing the refrigeration equipment to be used is knowledge of the operating area, such as air temperatures, water temperatures, weather, and so on, during the season to be fished. Water temperatures in extreme Northern Pacific waters may not exceed 45°F but in southern waters will exceed 75°F. Heat loads from outside air, engine heat and other machinery heat, as well as the temperature of fish will all affect the refrigeration system operation and are important in planning for an installation.

Probably the first thing to be considered is adequate insulation for the fish hold. It should be remembered that wooden vessels usually cannot easily accommodate insulation of a different kind than that required for ice holding, such as cork or styrene block. This is usually placed under the deck and on engine room and other bulkheads. Air space must be left between the hold and structural members to prevent dry-rot, and the corrosion of fastenings. Heat carrying pipes or any other equipment in the hold should also be insulated. As a guide line many wooden vessels will not be able to hold temperatures below

32°F and it is considered impractical and potentially detrimental to the vessel itself to try to get temperatures below 0°F in any wooden vessel.

The insulating of a steel vessel is quite different and a variety of satisfactory materials are available—styrene, urethanes, fiberglass, and others. The purpose here is to isolate the fish product from the entire hull metal with the insulation and a liner or vapor barrier. During the trip, shafting and bilge areas should be insulated and covered, but provided with access for drainage afterward. The basic hold insulation requirements also apply to a vessel with chilling tanks except that ventilation and hold lining should both be provided to prevent corrosion. Specifications covering insulation, hold arrangement and air circulation must be complete. These calculations should be prepared by an expert in refrigeration.

Particular attention must be given to the engine room for adequate space for additional ventilation for the refrigeration units, power plants, pumps, and accessories which generate considerable heat. Most smaller vessels, especially under 45 feet long, already have engine room space problems. Refrigeration equipment generally is continuously running on a trip and where normal engine room temperatures can get to 100°F or more they can rise considerably above this level when this extra equipment heat load is added. The situation can be worse in rough weather when hatches and doors are closed and fresh air intake is restricted. If adequate ventilation is not provided, the extra loads put on the vessel engine, generators, and other equipment can affect their normal performance. All engine room plumbing, pumps, heat exchangers, electrical equipment and so on must be carefully examined for ability to handle the extra heat load of the refrigeration equipment.

It should also be remembered that the refrigeration units themselves will contain fluids which may be able to withstand limited roll and pitch conditions at sea. Vibration caused by the main engine or auxiliaries could also affect the performance of the refrigeration units and they should be protected by isolation mount methods where necessary. Corrosion which is already a problem to fishing vessels is also a problem to some materials used in refrigeration units. This situation can be made worse by waste or decaying material from catches. This can also affect pumps, heat exchangers, or other equipment if they are common to the regular normal vessel machinery, and piping, and the refrigeration units.

C- OPERATIONS AND MAINTENANCE

One cannot place too much emphasis upon care in the operation and maintenance of the refrigeration system by the fishermen. Actually most basic modern refrigeration units are as simple and reliable as other mechanical equipment aboard and the things that require ordinary maintenance are repairable with ordinary tools. It most important that equipment, once correctly installed be operated properly. Adequate manuals are usually provided and additional information or instructions can be obtained from the supplier. It should be remembered that the equipment is designed to do a job and should not be neglected and then declared a failure when things go wrong.

It is an excellent idea to have both high and low temperature and pressure controls. With some experience these extra controls can be quite helpful in system operations. Manual controls and overrides should always be provided. Another thing to remember is that when at sea the hatch may be opened often and moisture from salt air can rapidly add salt-vapor to the hold and cause excessive frost build up.

From the standpoint of upkeep the most important thing is a preventive maintenance schedule just as is done with other vessel equipment. Such a schedule can hold breakdowns at a minimum while at sea. The hardest items to keep up are controls, compressors, condensers, and engines for refrigeration system power.

High temperature oil circulation, and close tolerances of moving parts in the refrigeration units will require more care than for the vessel main engine. The duty cycle for the refrigeration system may be twice as much in hours of operation. Replacement schedules should be set up and consideration given to replacing components when due, whether the item had failed or not. Small spare parts such as pump impellers, gaskets, filters and dryers should be kept on board. If space permits, it may be advisable to keep other items such as a spare compressor aboard. Spare refrigerant should always be kept aboard.

It is most important to consider ease of access for maintenance and replacement of equipment when installing the system.

III - FISHING VESSEL REFRIGERATION SYSTEMS

This section of the bulletin presents a general description of refrigeration systems that are in use on smaller vessels in North Pacific fisheries. General descriptive information presented on the systems and on costs, installation and maintenance. The suitability and efficiency of the systems, based on information about use from several fisheries sources is also discussed in general terms.

There is no singularly best refrigeration system. As mentioned before, the selection is usually made on the basis of the particular fishing operations and the fish product to be delivered.

There are five basic types of refrigeration systems to be discussed here. These are as follows:

A - Pipe Coils for Ice Holding and Freezing
B - Cold Plates for Ice Holding and Freezing
C - Air Blast for Ice Holding and Freezing
D - Seawater/Brine Chillers for Holding and Freezing
E - Brine Spray for Freezing

More than one of these systems may be used on different vessels in the same type of fishing operation. More than one type may also be used in some combination on the same vessel in a single fishery, or in dual purpose fishing operations. However, all of the systems have the same basic component units.

RECEIVER - a tank to store the charge of liquid refrigerant for the system.

EVAPORATOR - piping, usually steel or copper, to circulate the refrigerant in the refrigerated area—the hold, a cold plate, a chill tank, or air blast unit. In some cases as in seawater/brine chillers the evaporator may be located in a heat exchanger away from the hold tank.

COMPRESSOR - a pump to remove the refrigerant gas from the evaporator and to control evaporator pressure.

CONDENSER AND CONDENSER PUMP - a heat exchanger to cool the refrigerant and return it to liquid form in the receiver. The condenser is usually cooled by circulating seawater around the coil containing refrigerant.

ACCESSORIES - traps, drains, dryers, valves, guages, etc., to aid in operation and maintenance of the system.

CONTROLS - manual and automatic units to measure temperature and pressure to start and stop the system under changes in heat load. Automatic alarm, safety, and shut down devices are used to warn of excessive high or low temperature or pressure in the system units that could result in damage.

REFRIGERANT - substance that absorbs heat in circulating through the system by changing from liquid to gas under changes in pressure. Freon 12 and Freon 22 are the most common refrigerants used in smaller North Pacific fishing vessels and are used in all the systems described here. One reason for the popular choice is the lower initial costs of Freon refrigeration system in comparison with Ammonia systems. Freon is also non-flammable and for all practical purposes non-toxic. Freon systems are in wide use in other food industries, thus equipment service and supply is readily available. Freon 12 is commonly used to charge holding and freezing refrigeration systems working over a temperature range of 32°F to 0°F. For temperatures below this F is satisfactory for use to temperatures as low as -30°F.

Power to operate the refrigeration system is also an important item. The power system may be a seperate auxiliary engine. This is usually the case if the system is of larger size. This is quite desireable because the refrigeration system may run at times when the vessel is not running the main engine or auxiliaries. This is often considered the best power from the standpoint of cost since most vessels are designed without a lot of excess main engine power.

If the vessel already has enough electrical power from its own generators for the operation of a refrigeration system this may be the better way to power the system. If not, the most economical power choice may be a larger generator if the engine room is large enough. It should be noted that AC power is preferred to DC power since DC motors of comparable size H.P. are larger, more costly and often difficult to obtain replacement parts. In most of the above power drives, V-belts between power source and compressor have been the most satisfactory method used.

Another method is a power-take off from the main engine, but this may require a variable speed control to maintain the constant speed required for the refrigeration compressor, in the face of changing new engine speed.

If the vessel is already equipped with hydraulic system, hydraulic motor drive for the refrigeration units may be a good solution. However, this should be given careful consideration because of possible drawbacks. For example, if hydraulic winches are used, the combination of winch and refrigeration power may at times be more than the hydraulic system can handle. A variation in the available hydraulic power can cause variable power to the refrigeration system. Since the compressor load is fairly constant, it may be more economical to use direct or belt-driven power units sized to refrigeration equipment needs. Whatever the power used, in terms of refrigeration system requirements, 1 ton of refrigeration capacity (12,000 B.T. U.'s per hour) can require from 1 to almost 3 H.P. depending on the holding or freezing temperatures desired. It is usually desireable to provide a small excess of power for the system.

The overall cost to install a refrigeration system in the North Pacific fishing vessels can vary from about $900 per ton of refrigeration to $1700 per ton. It is always easier and more economical to design a refrigeration system into a new vessel than to put it into an older one. Except for some fleet installations, more than 90 percent of refrigeration systems installed aboard fishing vessels have been custom designed which usually costs more. Installation in a smaller vessel, for example less than 45 feet, may cost proportionately more due to difficulties in finding adequate space to place the refrigeration units and the resulting higher labor costs to do the job. It is noted here that refrigeration systems have been installed at reasonable cost in new vessels as small as 35 feet in length because the vessels were designed to accomodate the refrigeration units required for the intended fishing operation.

The cost of installing a refrigeration system can in part be reduced if the fisherman can do some of the work himself. This has been the case in several instances and done satisfactorily if the fisherman had the particular skills required. If he does he should proceed only after complete and accurate system design and specifications have been made. The fisherman and the refrigeration installer or supplier must have a complete understanding. If the fisherman does not have the necessary mechanical and electrical skills, he should rely upon the expertise of the refrigeration supplier and shipyard. This procedure can result in the lowest cost in the long term for the vessel refrigeration system.

TABLE I

The following information was developed in cooperation with the various information sources which contributed data for this bulletin. It is not intended to be absolute data, rather average data to indicate in a general way typical service life and cost effectiveness over a ten year period for the five refrigeration systems discussed.

SERVICE LIFE RATING-TYPICAL

1. Cold Plate System
2. Air Blast System
3. Pipe Coil System
4. Brine Spary/System
5. Seawater/Brine System

COST EFFECTIVENESS RATING-TYPICAL

1. Air Blast System
2. Cold Plate System
3. Pipe Coil System
4. Brine Spray/system
5. Seawater/Brine System

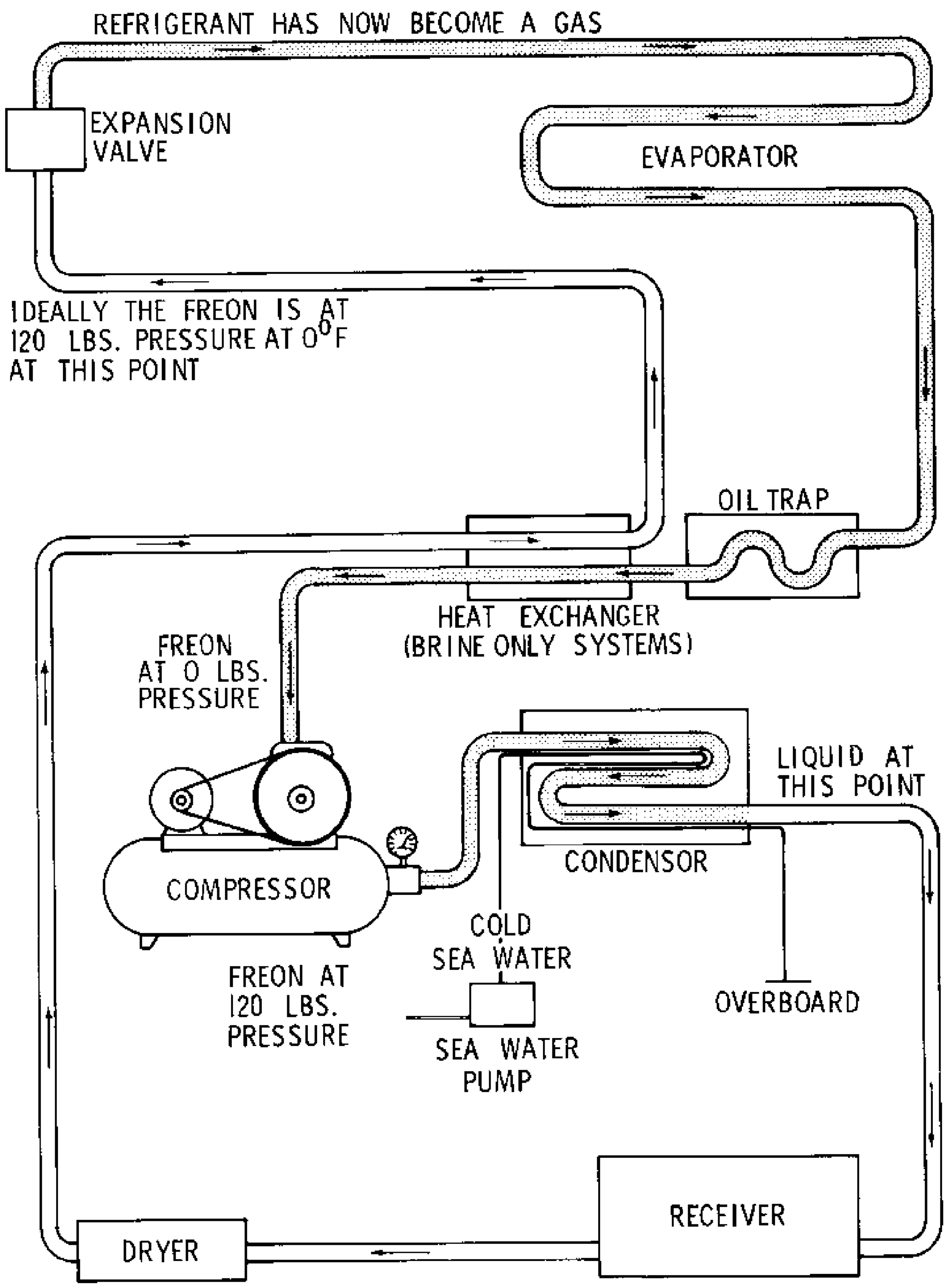


FIGURE 1. TYPICAL REFRIGERATION SYSTEM

A - PIPE COILS FOR HOLDING AND FREEZING:

DESCRIPTION:

The most common method of refrigeration on North Pacific fishing vessels is the pipecoil grid which has been in use more than 35 years. Its principal use has been as an ice-saver by reducing the hold temperature below outside temperatures. While dry still air freezing is a well known process, the amount of pipe coil and refrigeration equipment required to quick-freeze is prohibitive by both cost and space on the class of vessels discussed here.

The pipe coil system consists of the basic refrigeration units previously described. Usually all units except the evaporator will be mounted on the engine-room floor or bulkheads. The evaporator is a pipe coil grid of 1 to 1¼ inch black or galvanized steel pipe or hard-drawn copper tubing usually 5/8 to 7/8 inch in size. The steel pipe joints are welded or clamped. Copper joints and fittings are sweated or brazed. This is a job for the skilled refrigeration installer whereas the fisherman may be able to install and repair some of the other refrigeration units.

The pipe coils are installed under the deck, on bulkheads and sometimes on the sides of the hold down to the bilge line. Overhead coils are usually separate circuits. The pipe is placed on hangers, from close up to a few inches away from deck and bulkhead, to give some air-space behind the coils and keep hold insulation dry. Hanging should be secure to minimize vibration of coils. Lost hold space may be more than with other ice-saving systems. Spacing of the pipe coils will vary as required for hold coverage. The pipe coils may also be divided into more than one circuit to keep the desired system operating pressure levels. For example a 5/8 inch copper pipe grid may be 150 feet long, a 7/8 inch pipe grid 200 feet long, and so on with larger size coil.

From the standpoint of cost, black or galvanized steel pipe coil is less expensive to install than copper tubing but more costly to repair. The service life of black steel coil is five to six years, for galvanized steel coil 10 to 20 years. Copper coil has the greater heat transfer and weight advantage, but is more easily damaged when working in the hold. Copper coil appears to be the choice for smaller boats where weight could be a problem, and steel pipe coil the choice for larger vessels of the class discussed here. Costs for a pipe coil refrigeration system for holding iced fish will range from $3500 up to $15,000 or more. Maintenance costs for the total system, refrigeration units, and evaporator can be expected to range from 5 to 10 percent of the cost of the system annually. Care must be taken when working in the hold if pipe coils are present, as these coils may crack if stepped on or subjected to severe stress.

OPERATION

The pipe coil system should be turned on before ice is taken aboard to cool the hold and keep the ice crisp and easy to handle. This can be done by keeping the temperature at 30°F or lower until fishing begins and then at 32°F. Temperature control is very important and the thermometer should be located in the hold air, not in the ice or near a hatch or a pipe coil. At least two thermometers or thermostats should be used. They must be sheltered against damage. Experience is required in a new installation to learn the best way of handling hold temperature, ice and fish, to keep ice at the best melting rate and maintain some air convection in the hold. It is a good idea to check temperatures periodically, and advisable to have both a high and low temperature control to avoid freezing the fish. Hatches to the hold should be opened only when necessary to load fish during the trip. Pipe coils will drip during period of shut down and can cause freezing of the ice on the outside, or lumps in the ice making it difficult to work. Frost will build up and the coils will stop dripping, but excessive frost can act as insulation and overwork the refrigeration system.

The pipe coil system is of the most use in the trip out and during the fishing operations. At the end of the trip, it may be shut off to let the ice do the work, depending on how much ice is remaining. A rapid defrost system is desireable to make cleaning of the hold easier. Extreme care should be taken not to damage the coils when unloading the catch.

EFFICIENCY OF SYSTEM AND QUALITY OF PRODUCT

Pipe coil grid is probably the most common method of fish hold refrigeration, but not necessarily the most efficient. Still or slow moving air results in slower and poorer heat transfers. The system is regarded as an ice-saver and at the extreme can reduce normal trip ice costs up to one-half. Care must be taken to keep the fish from touching the coils because the refrigerant temperature is several degrees lower than the ice and the fish. This could result in partially frozen fish, dehydration, and loss of quality. Extreme care must be taken when unloading the catch so as not to damage the coils, because even small holes in the coils can result in refrigerant loss, rust and corrosion and shorten the pipe service life drastically. Care must be taken in cleaning the fish hold to be sure that all pieces of fish or debris are removed from around the coils. The coils should then be brushed and cleaned. Coils are regarded as more of a sanitary problem than cold plates or air blast systems for ice holding.

The pipe coil refrigeration system should not be regarded as a substitute for ice. In all cases good handling, cleaning, and storage of fish is just as important as if there were no refrigeration aboard. The biggest problem with the pipe coil grid is to find and keep the right temeprature balance to keep the ice melting at just the proper rate and thereby maintain top product quality. Good results for pipe coil ice holding systems have been experienced with round and dressed salmon, dressed halibut, tuna, shrimp, and bottom fish.

A recent modification of the pipe coil grid type of refrigeration system has been the incorporation of a deck mounted brine immersion tank for sharp freezing into the overall system.

This sharp freeze tank is usually made of wood, lined with pipe coils and operated from a separate refrigeration circuit. The coils in the tank are located very close together and the operating temperature of the system is much colder than the pipe coil system within the hold.

Brine is added to the deck tank prior to the beginning of the fishing operation. This brine is then lowered to an operating temperature of 0 degrees F or less. As the fish are caught, they are batch frozen in the brine tank. The amount of fish frozen at any one time is determined by the size of the brine tank.

After the fish have been frozen in the deck tank, they are transferred to the hold for storage. The pipe coil system in the hold is maintained at a holding temperature of 10 degrees F-15 degrees F. Due to low dehydration from this type of holding system, the product is kept in excellent condition for prolonged periods of time and retains excellent quality upon thawing and sale.

Many of the smaller albacore tuna jig vessels have adopted this method of refrigeration in recent years. The advantages are that more fish may be frozen over a given period of time due to the greater efficiency of the brine immersion deck tank and the lessening of labor to freeze the fish. Once the fish have been transferred from the deck tank to the storage hold and stacked there, the fisherman is finished with them until time to unload the trip.

This type of system has been found to work well with round salmon as well as albacore tuna and could be used for glazing dressed salmon as well.

B - COLD PLATES FOR HOLDING AND FREEZING:

DESCRIPTION:

Cold plates, also called holding plates, were introduced as an alternate to pipe coil systems about 20 years ago and have been used in North Pacific vessels since then. The principal use today is the same as for pipe coil system, as an ice saver. There are also some cold plate installations used in smaller vessels for contact quick-freezing. These are usually in combination with some other type of refrigeration equipment for holding the frozen fish. Like the pipe coil system, contact plate freezing is a still or slow moving air process. It should be remembered that the plates come in both ice holding and freezing types and that the moderate and low temperature types are not interchangeable. The cold plates are filled with a so called "eutectic" or cold holding solution which aids in maintaining a more even temperature.

The cold plate system consists of the basic refrigeration units previously described. Just as in the coil system, all units except the evaporator will be installed on the engine-room floor or bulkheads as available space dictates. The evaporator is one or more cold plates, about 1 inch thick, fabricated of steel and containing copper coil grid. High temperature plates are usually zinc plated and low temperature or freezing plates are laquer coated. The plates are readily available in standard sizes from several regional suppliers.

An important consideration for a small boat is whether the plate installation under the deck could or would endanger the stability of the vessel.

For ice holding, the plates are fastened under the deck beams.

One of the advantages of the plate system is that less total space is usually required than for a coil system in order to achieve the same amount of refrigeration capacity. Spacing is, as in pipe coil systems, to cover the entire hold. The plates are seldom mounted on bulkhead or sides—so bulkhead insulation may need to be heavier than with the coil system. As in the coil system the vessel hold should be adequately insulated for ice holding. The fisherman may be able to do the installing of the cold plates, if he has the necessary mechanical skills, just as with wome of the other refrigeration units. For contact freezing, cold plates are usually installed like shelves in each side bin and may be adjustable in spacing for fish sizes. When frozen, the fish are transferred to separate bins for holding. This requires another compressor unit for the different operating temperature in the sharp freeze unit.

Maintenance on the cold plates is usually less than a pipe coil system because they are less subject to damage and thus less affected by corrosion. However, if a leak in a plate does happen it is a job for the refrigeration expert and will probably require removing the plate from the vessel to a repair shop. Maintenance to the other system units is the same as for the coil system.

From the standpoint of cost, the cold plate system ice holding is about equal to the pipe coil system. The original cost for the cold plate evaporators may be more, and sometimes more plate refrigerating capacity than the equivalent in pipe coils may be required, but this is usually offset by some savings in the installation labor costs. Overall installation costs, for a cold plate refrigeration system can range from $3,500 to $15,000 or more depending on whether ice holding plates or freezing plates or both are required. Maintenance costs will range from 5 to 10 percent of the total refrigeration system cost annually.

EFFICIENCY OF SYSTEM AND QUALITY OF PRODUCT

Cold-holding plates like pipe coils are primarily an ice-saver and are used in the same way. The heat transfer is slow in still or slow moving air. The plates are perhaps more efficient from the space standpoint. This could make for more efficiency in a small boat where the size catch may be limited by the size of the hold. The cold-holding plates are also rated ahead of pipe coils for service life and cost effectiveness. Since the plates are usually installed under the deck there is less chance of fish coming into contact with the plates and freezing or dehydrating. There is also less chance of damaging the plates in unloading or cleaning up the hold and there is less of a sanitation problem than with pipe coils. Fish should never be placed on top of the plates. As with pipe coils; with good handling, cleaning, and storage practices, good results have been experienced with cold-holding plates and ice with dressed salmon, dressed halibut, tuna, shrimp, and bottom fish.

Recently several smaller vessels have installed contact freezing cold plates. Because the practice is relatively new, reaction by the buyers has been mixed. The freezing method is not as versatile as air blast freezing, but, takes a little less power to operate the system. One drawback has been a problem of distortion of the fish on the cold plate. However, experience has shown that with correct handling practices prior to freezing, good results have been obtained for dressed salmon, dressed halibut and tuna. One possible disadvantage is that there is some extra handling required in freezing, glazing and storage. This method of freezing is not recommended for a low cost product or bulk catches.

C - AIR BLAST FOR HOLDING AND FREEZING:

DESCRIPTION:

Air blast freezing has been in use on larger fishing vessels for more than 20 years. On smaller vessels, Gulf of Mexico shrimpers for example, it has been in use for about 15 years. However, it has been only in the last 4 or 5 years that it has been used on smaller North Pacific fishing vessels. It is now considered a dual purpose system being suitable for both ice holding and freezing of fish, even on the same vessel. Unlike coil and plate systems the air blast system moves air in the hold and in ice holding usage the chances of dry-rot and corrosion in a wooden vessel may be reduced.

The air blast system consists of the same basic refrigeration units previously described. These systems can be available in combination units consisting of engine/compressor/condenser sections, and control panel sections. They are available with diesel powered or electric drive units. The evaporator is one or more evaporator/blower units similar to an air conditioning unit that has been specially designed for marine use. Air blast systems are readily available from several local suppliers.

As in pipe coil and plate systems, all air blast refrigeration units except the evaporators are usually installed in the engine room. If there is sufficient space it is best to install the units in the combination sections described above. If space in the engine room is not suitable for this, the units may be separately installed on the floor or bulkheads. In some smaller ice holding installations the engine/compressor/condenser units have been installed on deck. A standby compressor is also recommended. The hold evaporators are bulkhead mounted with shock mountings to minimize vibration of the units.

When the air blast system is used as a freezer system, deck mounted brine freezing tanks are usually installed to freeze the fish prior to a batch storing operation. The air blast system can be a greater hold space saver than either pipe coils or plate systems. Because of the relative simplicity of the air blast system the mechanically inclined fisherman may be able to do more of the installation work or maintenance than with coil or plate systems.

From the cost standpoint, air blast refrigeration equipment is comparable or slightly less in cost than coil grid or cold plate systems. The ease in evaporator installation and more freedom from maintenance give them another cost advantage. The cost of an air blast system can range from $3,000 to $20,000 or more depending on use for ice holding or freezing and whether deck mounted chill tanks are used. Maintenance cost will range from less than 5 to about 10 percent of the total refrigeration system cost annually, something less than pipe coil or plate systems.

EFFICIENCY OF SYSTEM AND QUALITY OF PRODUCT:

The air blast refrigeration system has been shown to be most cost effective and is rated second in service life. The air is in movement in the hold and can keep more even ice holding temperatures than either pipe coil or plates. There is also less of a quality control problem with iced dressed fish because the fish cannot easily come in contact with the evaporator. There is also less of a sanitation problem in hold clean-up. The air blast system is not necessarily a substitute for ice, but with air in movement, dry and crisp ice can be kept in better condition until fishing begins. With good handling, cleaning and storage practices, air blast ice holding has experienced good results with round and dressed salmon, dressed halibut, and tuna.

The system is dual purpose and may be used as a freezer unit. Freezing rates are about twice as long as immersion freezing but more rapid than plate freezing. There is relatively no trouble with deformation, providing sufficient time has been allowed for Rigor Mortis to pass. However, care must be taken to minimize dehydration and dressed fish must be glazed as soon as possible after freezing. A recommended practice is storage of dressed fish in plastic bags to reduce dehydration in storage at low temperatures. With proper handling, cleaning and storage some very good results have been experienced with air blast freezing for dressed salmon, dressed halibut and tuna. Because of the extra handling required, it is not recommended for low cost products or bulk catches.

More recently air blast freezer systems have been installed on several smaller vessels. There has been varying success in product acceptance from the buyers. Promise for the future is indicated as onboard fish handling and storage methods are improved.

D - SEA WATER/BRINE IMMERSION CHILLERS FOR HOLDING AND FREEZING:

DESCRIPTION:

Immersion type chilling and freezing systems have been in use in North Pacific fishing vessels for more than 30 years, most notably in larger California tuna vessels. Seawater chilling systems have been used with success in Northern waters on salmon packers for the past 15 years, but it has only been in the last 10 years that they have been used to any degree on smaller fishing vessels. Satisfactory seawater chilling units have now been installed on salmon trollers and gillnetters in the 35 foot size. Extreme care should be taken in considering trim and stability for small vessel installation because the tanks must be full when the system is in operation. If designed with adequate capacity the same refrigerating system can usually be used for both holding fish in chilled seawater at 29°F as a substitute for ice, and for freezing fish.

The seawater chilling-brine freezing refrigeration system consists of the same basic units as previously described, plus seawater holding tanks with plumbing for water circulation.

There are two basic types of tank chilling systems in use. One type uses refrigerated pipe coils around the interior of the seawater filled tanks. This has been described earlier in section A. The other type uses the shell and tube heat-exchangers in which the refrigerant is circulated in the tubes, and the chill tank water circulated around the tubes.

In this second type of system the evaporator is located in the heat exchanger away from the tanks in the hold. Tubes are commonly made of copper, copper nickel, or stainless steel. Shell pipe for the tank water is of the same materials or of plastic pipe. Chillers are available in a variety of sizes from several suppliers and entire chiller systems are available with diesel, electric or hydraulic drive features. They may be installed as a single large unit or as a bank of smaller units. If there is not enough space in the vessel engine room the chiller unit may be bulkhead or deck mounted or mounted within the fish tank itself. Fundamentally the chiller system is larger and takes more space than other systems because of extra pumps, piping, filters, tanks and so on.

This entire system, particularly the chiller heat/exchanger unit should be installed with a view toward access for maintenance. This is usually a job for the refrigeration expert not the fisherman. The basic requirements for the tanks in the hold are that they be watertight, easy to clean, corrosion resistant, and do not absorb moisture. Tanks of wood, plywood, aluminum, fiberglass and coated steel have been used. It is easier to build tanks into a new vessel than an old one. Since the tanks are full during fishing operations, particular importance should be given to vessel trim and stability.

In a wooden vessel, the space between the tank and the hull is left open for ventilation and possible leak repair and need not be insulated. In a steel vessel where there is insulation, the insulation must be sealed with concrete or fiberglass, and tanks must be absolutely watertight to avoid contamination. Tanks are constructed in various sizes and partitioned to prevent excess movement of water and fish, and will usually have a narrow hatch opening.

Water in the chill tanks is circulated by pumps with circulation usually from bottom to top to permit removal of floating debris. Screens and strainers are installed on the suction side of the circulating system to stop debris and prevent fish from blocking the tank circulation. Two or more tanks are required for proper handling of chilled seawater or brine. Tank installations are usually a shipyard job instead of the fishermen's, because of stresses and vibrations on the vessel structure requiring careful installation work. Just as the fisherman may maintain some or all the other refrigeration units, he may maintain the immersion system if he has the mechanical skills.

Costs for a seawater chilling or brine freezing refrigeration system can range from slightly higher than other systems per ton to double the amounts per ton. The range can be from about $6,000 to $25,000 depending on the size and installation difficulties. Maintenance costs can be expected to range from 10 to 20 percent annually of the total refrigeration system, thus somewhat higher than the other holding and freezing systems.

EFFICIENCY OF SYSTEM AND QUALITY OF PRODUCT

Immersion chilling or freezing is about six times as fast as in still air and about twice as fast as air blast freezing. The most important advantage over icing is the reduced handling and storage time and saving of labor. On the other hand, pumps, piping and heat exchangers can easily become contaminated, and require considerable maintenance. Seawater chillers and brine freezers are rated lowest in service life and cost-effectiveness. If the system uses refrigerated coils in the tanks cleaning and sanitation can be a problem, because the coils are usually close-up to the outside of the tanks. Chilling of the fish must be accomplished as rapidly as possible to avoid spoilage. Blood, slime, and bacteria are circulated in a relatively small volume of water and any spoilage could cause rejection of the entire catch.

One disadvantage to immersion freezing in brine is salt up-take by absorption by the fish and it is more severe with dressed salmon, particularly small fish. The salt up-take is not as severe in halibut or tuna. The salt up-take may also accelerate oxidation and rancidity in later dry storage of salmon. If salmon have been feeding heavily, holding for more than a few days can cause belly burn and there may be discoloration of the body or the flesh during the canning process.

The salt up-take in tuna does not penetrate the inner layers of flesh, but may be quite high in the outer layer of flesh. Good quality tuna have been left at sea for periods up to 30 days at 29° F and much longer if frozen at 25° F or below.

Quality shrimp have been landed after short storage in chilled seawater, but tend to suffer a smaller rate of meat recovery per pound of whole shrimp in processing. It is not a practice to brine freeze shrimp in the North Pacific fishery. This is also true of bottom fish where storage in chilled seawater or brine freezing tends to produce fish that are distorted, or are too soft to fillet easily and are of poorer texture. The industry here is not geared to brine-frozen or sea water chilled bottom fish processing.

E - BRINE SPRAY FOR FREEZING:

DESCRIPTION:

Brine spray refrigeration systems are a modification of the seawater/brine immersion chiller systems described in section D. They are open systems and do not need to use tanks in the hold or refrigerated circulating coils unless they are already in. Brine spray systems have been in use in North Pacific fishing vessels, primarily California tuna seiners, for about 15 years, and on smaller vessels in northern waters for about 10 years. These systems have been installed on new vessels essentially for use in the tuna fishery and on some older vessels that are usually engaged in other fisheries, but which fish tuna part of the season. One possible modification used on the seawater chilling/brine immersion system is the use of a stepped compressor which can provide closer control of refrigeration capacity with continued operation as the freezing load decreases during fishing operations and the catch reaches lower temperatures.

The brine spray circulating system is "open" with four or more distributor headers or plastic pipe running under the deck the length of the hold. The spray is provided by drilling small discharge holes at intervals along the distribution headers. Circuits are valved and can be directed to different parts of the hold to control freezing. Brine intakes are located on either side of the shaft alley with a cross connection to keep the water or brine level even. The intakes are screened the length of the hold to eliminate take-up of debris from the catch. As in the case of the seawater/brine immersion units the installation of refrigeration units is usually a job for the refrigeration expert. However the simplified nature of the brine distribution system, makes it one that the fisherman, particularly on a small vessel, can do with relative ease.

The hold for brine spray freezing in a wooden vessel must be lined with plywood, insulated, and sealed completely watertight with fiberglass or other materials. Insulation is required for fishing tuna and the hold may be "jacketed" in a larger vessel to permit storage without the use of the usual holding refrigeration pipe coils. Equipment for cooling the "jacket" may be a separate compressor and fan. The hold lining and sealing procedures for a steel vessel would be the same as for the seawater/brine immersion system described in section D.

The brine spray refrigeration system can be a less costly system to install than the usual seawater/brine chilling system with tanks or circulating pipe coils. Costs by comparison are estimated to be from two-thirds to three-fourths as much and can range from about $7,000 to $15,000 or more. Maintenance costs can be expected to be from 10 to 20 percent annually of the total refrigeration system costs, or comparable with seawater/brine immersion systems.

EFFECTIVENESS OF SYSTEM AND QUALITY OF PRODUCT

Brine spray refrigeration has the advantage of simplicity and lower costs of installation as compared to immersion brine systems. However, like immersion systems, brine spray systems are rated low in service life and cost-effectiveness. Headers, piping and heat-exchangers can become contaminated and require considerable maintenance. Operation of the system requires good judgement of salt content of the brine. The absence of coils or tanks in the hold makes cleaning and disinfecting somewhat easier and saves hold space. The brine spray gives a good heat transfer rate, though not as fast as immersion freezing. About one-third less fish can be taken in the same space as an immersion system freezer.

While considered an efficient freezing system, brine spray is really suited only for tuna fishing. There are the same problems of salt penetration and fish discoloration as with brine immersion freezing and the system has been used with salmon and halibut but is not recommended. Brine spray tends to build up salt deposits on fish faster than immersion and this makes the fish harder to glaze. As in immersion freezing, brine frozen fish may suffer from some dehydration and tend to accelerate oxidation and rancidity in cold storage. Brine spray freezing also tends to result in some distortion of the product, but this is not too great a disadvantage with tuna.

Summary Table of Comparison

Efficiency of System
Including Quality of Product

Type of Equiptment	Salmon		Halibut	Tuna	Shrimp	Bottom Fish
	Round	Dressed	Dressed	Round	Whole	Round
Pipe Coils Holding 32°F	Good	Good	Good	Good	Good	Good
Freezing 0°F or below	NR	NR	NR	NR	NR	NR
Cold Plates Holding 32°F	Good	Good	Good	Good	Good	Good
Freezing 0°F or below	NR	Good	Good	Good	NR	NR
Air Blast Holding 32°F	Good	Good	Good	Good	NR	NR
Freezing 0°F or below	Good	Good	Good	Good	NR	NR
Seawater/Brine Holding 29°F	Good	NR	Fair	Good	Good	NR
Freezing 25°F or below	NR	NR	NR	Good	NR	NR
Brine Spray						
Brine Spray Freezing 25°F or below	NR	NR	NR	Good	NR	NR

GOOD = good quality product can be produced
FAIR = product is of lesser quality but acceptable
NR = not recommended or not industry practice

In summary, the type of refrigeration system used aboard a vessel will depend essentially upon the following factors:

Vessel size and engine room space.

Fishery or fisheries the system will be used in.

Available capital for installation of the system.

If the vessel to be refrigerated is used in the salmon troll, tuna jig and dungeness crab industry the preferred systems would be:

1. Pipe coil and deck mounted brine immersion sharp freeze tank
2. Pipe coil and freezing plate
3. Air blast
4. Spray brine

In older vessels to be refrigerated for the salmon and tuna troll/dungeness crab fishery, the pipe coil and freezing plate system is most commonly used. This will be closely followed by the air blast systems and the third choice is the spray brine system.

The pipe coil/freezing plate system can be installed and used with a minimum of insulation. If insulation is applied under the deck of the vessel and the engine room/fish hold bulkead is insulated, the skin of the fish hold will act as insulation along the outer surface of the fish hold. This is an important consideration. If the hold of an older vessel is insulated completely rot in the hull will surely ensue. By allowing "breathing" space between the outer hull and the inner "skin" this rot and dead air space is minimized.

When insulating uder t the deck of an older boat, it is recommended that insulating blocks be inserted between the deck beams and a small air space be left around each beam. These insulation blocks are either cork or styrofoam material. They are held in place with lath battens and may be removed during periods of non-use of the boat. Their removal will permit air circulation and thus retard rot.

Insulation may be applied directly to the engine room bulkhead, if the engine room side of the bulkhead is left unpainted. This bulkhead will then breathe from the engine room side.

The air blast refrigeration system may be successfully used with insulation similar to that of the pipe coil/freezing plate system. It is recommended that the rear bulkhead of the fish hold be insulated also when using an air blast system.

The air blast system will tend to dehydrate the hatch of the vessel, by freezing the moisture from the air. It is recommended that the bilge and shaft alley be insulated to prevent freezing of the bilge water and possible problems from ice drawing the caulking out of the planks in the bilge area. The insulation of the bilge area will also permit bilge water to flow to the bilge pump sections and allow the entire stern of the vessel to be pumped at regular intervals.

The spray brine refrigeration system is the most costly to install in an older, wooden vessel. The hatch of the vessel must be made water tight and then insulated completely to achieve the best results with spray brine. This type of installation is certain to require a considerable amount of shipyard expense. There is also a considerable amount of plumbing necessary for spray brine refrigeration. In order to fish for salmon or other iced fish with a spray brine equipped boat, the refrigeration system is not used and the product is merely held in ice within the insulated hold but without refrigeration.

If a vessel is to be used primarily in an "ice" fishery, such as salmon or halibut, where the dressed fish is held on ice during a trip and is not frozen, the cold plate refrigeration system is adequate. The sole function of a cold plate system is to slow the rate of ice melting and lessen the amount of ice necessary to make a trip of a given length.

The cold plate system for ice holding has several advantages as stated earlier in this manual. The biggest advantage of this system is that it takes a minimum of space in the hold and if installed under the deck, the space is not premium space. The maintenance factor for a cold plate system will tend to be lower than that of other systems used in the same manner. If cold plates are properly hung from the overhead of the hatch and care is used when working around these plates, they will operate very well for many years without major maintenance.

In the event a vessel is to be used for salmon packing, the refrigerated seawater immersion system is the best system to install. Through adequate planning and proper component selection an immersion system may also be used as a spray brine system if the need arises. It is, therefore, very important to give sufficient attention to all phases of the system when installing it.Compressor size and capacity become extremely important in this type of installation.

There are several integrated refrigeration units being marketed at this time. These units combine the auxiliary diesel engine, refrigeration compressor and refrigerant receivers into one compace unit for shipboard installation. Some of these units also have an auxiliary A-C or D-C alternator mounted on the opposite end of the diesel auxiliary engine as an added feature. These power units are very compact and lend themselves well to installation aboard vessels with a minimum of engine room space. The refrigeration control panel with suitable automatic and manual operating controls may also be incorporated into the integrated unit package.

It is highly recommended that a second compressor-receiver unit be installed when the refrigeration system is purchased. The second compressor should be driven by the main engine of the vessel. This installation will offer added refrigeration capacity as well as providing a back-up system in the event the auxiliary engine breaks down while the vessel is on the fishing grounds. There is a considerable added expense for this extra unit, but there is also a considerable cost to the fisherman due to lost fishing time if an auxiliary engine malfunctions.

An additional feature of the brine spray system is that it may be used to "chill" dungeness crabs. This system is used to bring the seawater in the hold down to about 36 degrees Fahrenheit. This will tend to retard movement and activity of the dungeness crabs in the hold. The net effect is that the crabs can be held in the tank much longer by recirculating the refrigerated water. Boats have held dungeness crabs for as long as 10 days by using this system.

VI - SOURCES OF INFORMATION

The following is a listing of the sources of information that contributed to this bulletin.

A - REFRIGERATION EQUIPMENT SUPPLIERS

Freezer Fabricators, Stanwood, Washington

Marine Construction and Design Co.,
Seattle Washington

Marine Refrigeration Co.,
Seattle Washington

Puget Sound Engineering, Inc.
Seattle, Washington

Sure-Freeze, Inc.,
Seattle Washington

Thermal Supply Co.,
Seattle Washington

Thermo-King, Corp.,
Seattle Washington

Transport Equipment Co.,
Seattle, Washington

W. E. Stone Co., Inc.,
Seattle, Washington

B - INSTITUTIONS

Fisheries Research Board of Canada,
Vancouver, B. C.

Fishermen's Cooperative Association,
Bellingham, Washington

Halibut Producers Cooperative,
Bellingham, Washington

International Pacific Halibut Commission
Seattle, Washington

National Marine Fisheries Service,
Technological Laboratory and Gear Research Unit,
Seattle, Washington

University of Washington, College of Fisheries,
Seattle, Washington

C - BULLETINS, PERIODICALS

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Chilling and Freezing Salmon and Tuna in Refrigerated Seawater, S. W. Roach, H.L.A. Tarr, N. Tomlinson J. S.M. Harrisson, Fisheries Research Board of Canada, Ottowa, 1967

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