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CHILLED SEAWATER SYSTEMS

Installation and Operation on Alaskan Vessels

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INTRODUCTION

The best way to protect the quality of fish is rapid chilling to 32°F immediately after catch. Cooling slows bacterial spoilage and enzymatic deterioration, the two most important causes of quality loss.

Rapid cooling is achieved by a number of different methods. Some are simple, such as the use of flake ice, while others such as refrigerated seawater (RSW) systems use mechanical chilling units. A popular system today, chilled seawater (CSW) lies somewhere between ice and RSW in complexity.

The term 'chilled seawater' can refer to two systems of refrigeration. One is slush ice, a simple mixture of seawater and ice, which has been used for many years on the West Coast with good success. The second and more recent development in CSW is the 'champagne' system. This is a slush ice system incorporating a grid of pipes on the floor of the fish hold. Air bubbles into the seawater/ice mixture through perforations in the pipes. The bubbles circulate the cold water through the load of fish. The champagne system chills large quantities of fish faster than either slush or flake ice. The champagne system is of increasing interest to fishermen and tender operators.

This publication discusses installation and operation of a champagne system, as well as pitfalls that can be avoided by careful planning and operation.

SYSTEM CONSIDERATIONS

The two most important components of an effective champagne system are equipment and design. The following are general recommendations:

EQUIPMENT

A champagne system requires minimal equipment. The tank must be watertight, corrosion resistant and easily cleanable. A pump connected to a seacock is needed to add seawater to the tank. The water pump and seacock should be sized so that the tank can be filled as quickly as possible. Minimizing fill times can be important for the safety of the vessel. A slow fill time might cause stability problems especially in open waters. Frequently, a large pump will not supply its rated flow because the seacock is too small. The water pump also should be connected to an overboard discharge for emptying the tank.

The air delivery system consists of a piping grid on the bottom of the tank connected to an air pump. The piping grid within the tank should be constructed of corrosion-proof material, usually aluminium. The diameter of the distribution pipe depends on the size of the air pump to be used. It should be a low pressure, high capacity pump, sized to provide a minimum air flow of 0.5 cfm per ft^2 of deckhead area at a sufficient pressure to overcome the head of water in the hold plus the pressure drop in the distribution pipes. For example, a tank that is 10 ft wide, 20 ft long and 10 ft deep will have 200 ft^2 of deck head area and a 10 ft head of seawater that exerts 4.4 psi. So, the air pump for this tank must provide a minimum flow of 100 cfm (0.5 cfm x 200 ft^2 = 100). And to overcome head pressure, a rating of 5 to 7 psi is needed and usually adequate for most installations.

DESIGN

Most designs for a champagne system focus on the air delivery system. The following recommendations result from Canadian experiences with the system. These design considerations help assure that a champagne system can be properly installed in ways that prevent surprises during operation.

The piping grid in the tank must be spaced to achieve adequate circulation. Air pipes on the tank floor should be spaced on a maximum of 3 ft centers and 6 in. from any vertical bulkhead (See Figure 1). Holes are drilled in the distribution pipes to allow unrestricted airflow into the tank. Each distribution pipe in the system should be drilled with equally spaced holes. The total area of the holes should equal the cross-sectional area of the pipe (See Table 1).

The holes in the pipes should be drilled in the top 90° of the pipe for proper circulation. The preferred drilling method is to alternate the holes at 45° from the perpendicular as shown in Figure 2.

The pipe size from the air pump to the tank pipe grid is critical in minimizing pressure drop, which can cause inefficient circulation. The delivery pipe diameter should be the same all the way into the tank. In addition, the grid pipes should be sized so that the total cross-sectional area of the branch pipes will equal the cross-sectional area of the delivery pipe (See Table 2).

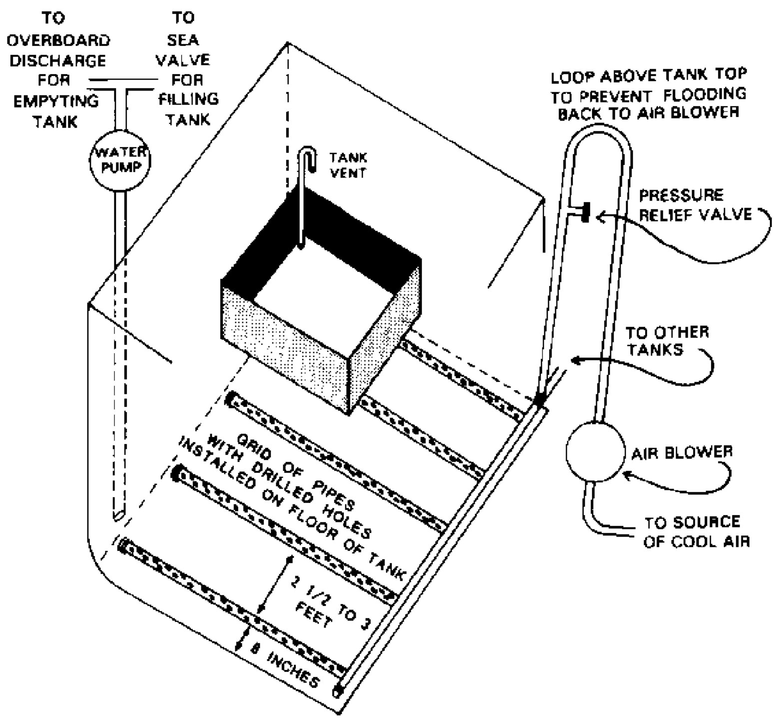

Figure 1. Diagram of chilled seawater system (CSW). Air is bubbled through the holes in the grid of pipes on the floor of the tank to agitate the ice-fish-sea-water mixture.

Table 1
Hole Requirements for Distribution Pipes
Pipe Size (Sch. 40)

Hole Size	1/2 in.	3/4 in.	1 in.	1-1/2 in.
1/8 in.	25	43	70	165
3/16 in.	11	19	31	74
	(Number of Holes Needed)			

Source: Gibbard, *et al*. (1979).

Table 2
Sizing Distribution Pipes for Various
Sizes of Air Delivery Pipes

Distribution	Size of Air Delivery Pipe			
Pipe Size	2 in.	2-1/2 in.	3 in.	4 in.
1 in.	4	5	8	14
1-1/4 in.	2	3	5	9
1 1/2 in.	-	2	4	6
	(Number of Pipes Needed)			

1. Holes drilled in top 90° section of pipe.

2. Holes drilled on alternating sides.

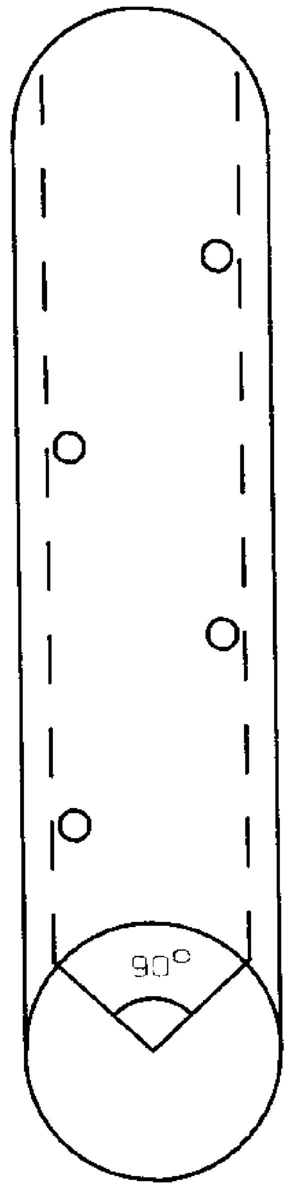

Figure 2. Example of hole placement in CSW distribution pipes.

The air intake of the pump is also important. It should have a constant source of cool air. Putting the air pump in the engine room adds heat by introducing warm air into the ice/water mixture. This extra heat makes quick chilling and proper operation more difficult.

A check valve and a vertical loop should be installed in the air line above the top of the tank to prevent water from flooding back to the air pump when it is not in operation. Both are recommended since check valves can stick or freeze. A pressure relief valve also should be installed in the system in case of blockages in the lines.

A means of draining and cleaning the piping system is critical. Air lines that are difficult to clean let bacteria grow and contaminate fish in the system. (See page 17.) Clean-out plugs should be installed in the piping where convenient to aid in easy cleaning.

The fish holds must be vented to provide pressure relief when the system is operating. A closed system can create a positive pressure against tank sides and hatch covers. Eventually enough pressure is created that a hatch cover may blow off.

When a champagne system is installed on a multi-tank vessel, it is important to treat each hold as a separate system. This is done by installing shut off valves on the main air lines and sizing these air lines to carry the full output of the blower to each tank. During operation, the air system is used on only one tank at a time, since each tank requires only 10 to 20 minutes per hour of operation to maintain constant temperature. (See page 12.)

CSW OPERATION

Operating a champagne system is simple once the particular system is understood. The objective is to chill the fish as rapidly as possible to the 31°F to 32°F range.

DETERMINING ICE NEEDS

First decide the amount of ice needed for proper operation. This is not a simple task. There are many factors to be considered, especially system operating strategy and physical parameters of the boat.

SYSTEM OPERATING STRATEGY

There are three strategies for operating a champagne system:

1. Fill/spill
2. Fill/no-spill and
3. No-fill/no-spill

They differ only in the amount of water that is added to the ice to make the slush mixture.

Fill/spill

The tank is flooded to the top with water to ensure vessel stablility while operating in the open sea before fish are loaded aboard. As the fish are loaded aboard, excess water from the tank is spilled. This option requires the greatest amount of ice because it must include a quantity to chill water that will be spilled during operation.

Fill/no-spill

Water is initially added to the level of the ice to create a slush. If the tank is not full after fish are added, more water is added to fill the tank. This strategy is used by many tenders and fishing vessels in protected waters. This strategy uses a partially filled tank while the fish are being added, so there is a potential for stability problems. As such, the fill/no-spill strategy is not recommended for open waters.

No-fill/no-spill

This option is rarely used because it creates a situation of traveling with a partially filled tank. After traveling, water is added to the level of the ice to create the slush, then fish are added. No additional water is added to fill the tank. This method may be used by vessels tied at a dock or by anchored processors.

PHYSICAL PARAMETERS

The physical parameters of a boat also affect ice requirements for the champagne system. Specifically, the amount of hold insulation determines the amount of heat entering the system from such outside sources as the engine room, hot weather, and shaft alleys. These extra heat sources compete with the added fish for the available chilling capacity. They slow the chilling rate and can cause temperature fluctuation in the system.

Minimum recommended insulation for CSW systems is 4 to 5 in. of urethane-type material completely insulating the hold. It is important that there be no pathways for heat to find its way into the hold. The diagrams in Figure 3 illustrate various types of construction and hold insulation. The top two diagrams are examples of poor insulation design. The top figure illustrates construction using an enclosed air space as the insulating material. Air, however, is a good conductor of heat and provides little insulating capacity. Consequently, it does not prevent heat from entering the hold. The thermal resistance of this type of construction is low and indicates that heat can enter the hold easily. The second diagram shows similar construction except that urethane foam has replaced the air space. While it has better insulating characteristics (the thermal resistance is higher), heat can penetrate the hold through the steel frame connecting the hold walls to the outer skin of the boat. Even though urethane foam is used, it does not

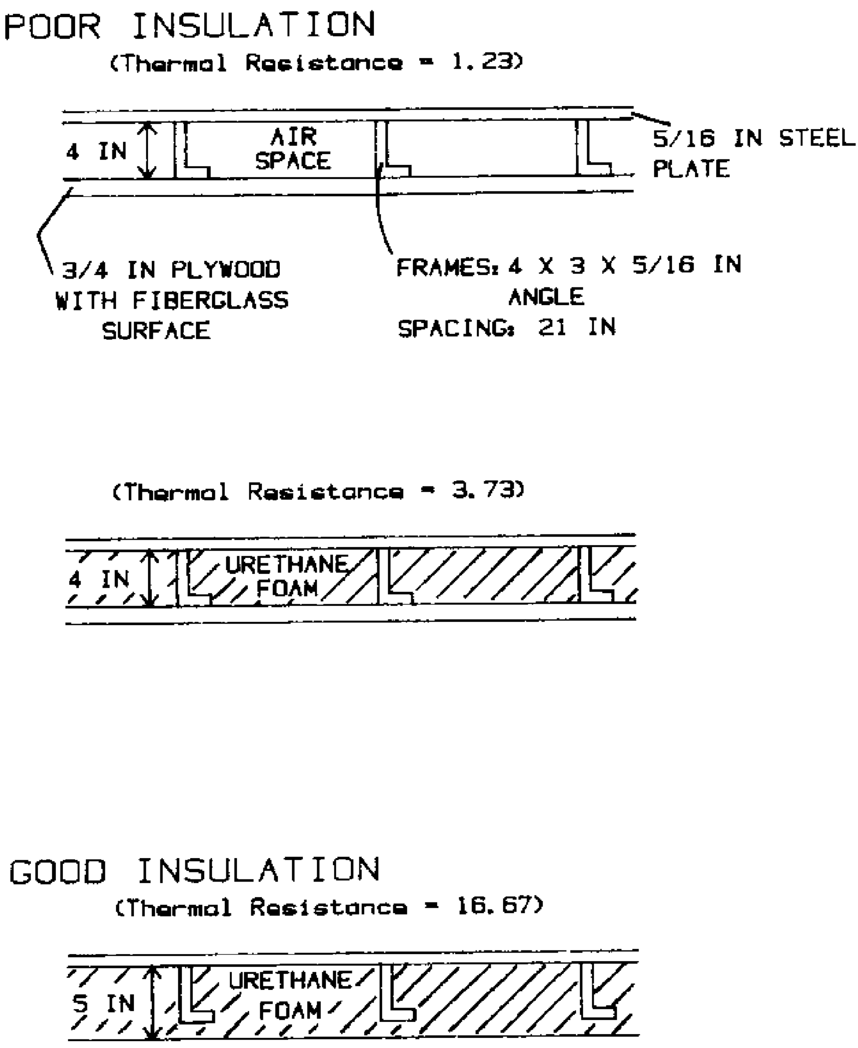

Figure 3. Examples of hold construction and insulation levels. (Kolbe, Crapo, and Hilderbrand, in press.)

provide adequate insulating capacity becuse there are other pathways for heat to penetrate the hold. The final figure shows a properly insulated hold. Urethane foam is used as the insulating material and surrounds the steel frames so that there are no pathways for heat to enter. The thermal resistance is very high indicating that little heat penetrates the hold.

In short, CSW tanks should have as much insulation as possible to simplify the operation and allow the system to perform to optimum capability.

While the factors affecting the ice requirements of a champagne system are complex, determining how much ice is required is simple. The Canadian Department of Fisheries and Oceans has suggested a formula to aid in loading the correct amount of ice at the beginning of a trip. The formula is based on the fill/spill strategy and good insulation, but can be used for all the operating strategies:

$$\text{Tons of Ice Needed} = \frac{W + F + D}{6}$$

where
- W = tons of water to be chilled
- F = tons of fish to be chilled
- D = number of days during trip

Note: If no water is wasted, then
W + F = capacity of the tank in tons.

The Canadian formula is a conservative estimate of ice needs for typical British Columbia conditions. It does not consider the effect of hold insulation and may not be totally applicable to conditions in Alaska. However, with adjustments, the formula has proven adequate.

A computer program also is available to calculate ice requirements involving more factors than the Canadian formula. This program, which accurately estimates ice needs for any situation, was developed at Oregon State University. It requests information on hold size, seawater temperature, bubbling time, hold insulation, fish to be loaded and operating strategy from the user. Based on the information received, the program calculates how much ice is needed. A sample output is shown on Figure 4. Copies of the program are available from the University of Alaska Marine Advisory Program, Pouch K, Kodiak, AK 99615.

The difference between a poor and a good CSW system is illustrated in Figures 5 and 6. A poorly designed CSW system (Figure 5) exhibits considerable temperature fluctuation. The water temperature does not achieve the 32°F necessary for proper chilling. Instead, the temperature fluctuates greatly. The fish added to this system are chilled slowly, taking longer than two hours, and do not maintain a stable temperature. Consequently, fish added to such a system will never be well chilled and their quality will suffer. Good CSW systems with proper installation and operation (Figure 6) exhibit little temperature fluctuation and maintain close to the desired 32°F. The water is chilled quickly and the temperature is steady. The fish are chilled rapidly and are held with little temperature fluctuation.

GENERAL OPERATING PRACTICES

The following procedure generally is accepted as being the way to operate a 'champagne' system.

1. Load sufficient ice into the hold and spread evenly over the bottom for uniform chilling. In the event that the surface freezes up, a thin sheet of ice is easier to break up than large chunks.

2. When possible, the ice should be carried dry to the fishing grounds unless stability considerations during pumping will not permit this. Carrying ice dry saves chilling capacity that would be lost if

Figure 4
Sample Printout of Computer Program

```
THIS IS 'SLUSH', A PROGRAM TO CALCULATE ICE REQUIRE-
MENTS FOR CSW TANKED SYSTEMS.

     CASE 2    FILL/NO-SPILL

                    *********
     EXTRA WATER HAS BEEN ADDED TO FILL THE TANK
                    *********

     INITIAL TEMPERATURE                     55 F
     TANK VOLUME                           1000 CUBIC FT
     FISH TO BE LOADED                     14.0 TONS
     NUMBER OF DAYS TO BE HELD                6 DAYS
     HOURS PER DAY AIR BUBBLING             2.0 HOURS
     ASSUMED INSULATION LEVEL               MED
     ICE MELT FROM FISH                     2.0 TONS
     ICE MELT FROM HEAT LEAK                2.3 TONS
     ICE MELT FROM BUBBLED AIR              0.3 TONS
     ICE MELT FOR WATER ADDED               1.8 TONS
     TOTAL ICE REQUIRED                     6.4 TONS
     APPROX PERCENTAGE OF TANK
          OCCUPIED BY DRY
          BULK LOADED ICE                   43
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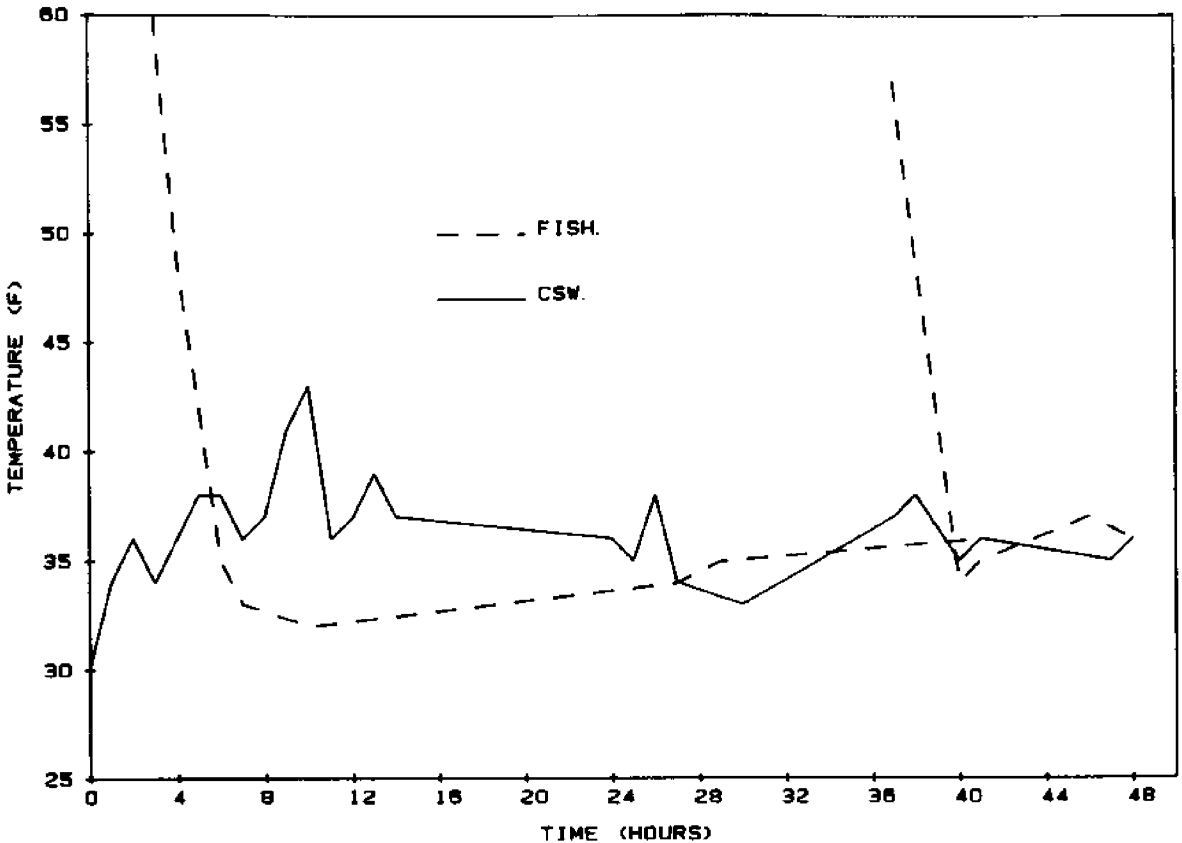

Figure 5. Temperature profile of a poor CSW system.

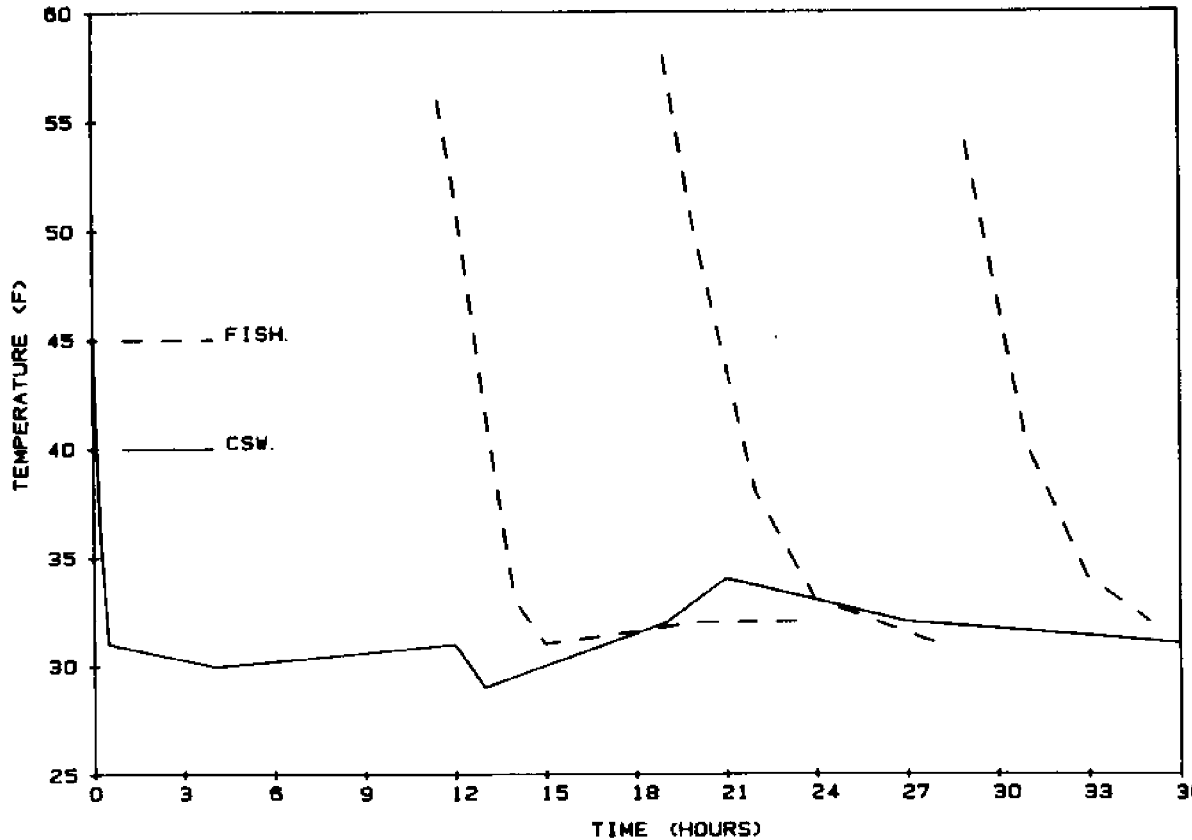

Figure 6. Temperature profile of a good CSW system.

water was added at the beginning of the trip.

3. At the fishing grounds, use shovels to break up any top crust of ice that has formed so the slush can form evenly without large chunks of ice.

4. Add water according to the prescribed method that is being followed. Only clean water should be added. Using harbor water can contaminate the system with bacteria. When using the fill/no-spill strategy, enough water should be added to 'float' the ice.

5. Begin adding fish and start air agitation schedule. Agitation should be used whenever fish are being added to the tank. Experience on insulated Alaskan vessels has shown that agitation of 10 to 20 minutes per hour is adequate.

6. Packing density of fish should not exceed 42 to 45 lb per cf of hold space. Higher loading density will slow the circulation and chilling rate, possibly creating hot spots.

7. When loading is complete, a final agitation should be done to assure that all fish are chilled. There is considerable discussion on the optimum length of agitation time, with up to 6 hours recommended by the Canadians. However, experience with insulated vessels has shown that if you agitate every time fish are being added to the tank, then the final agitation need take only slightly longer than normal, usually 15 to 30 minutes.

8. Once the fish are chilled, only periodic agitation is needed to prevent temperature stratification within the tank. Ex-

perience with Alaskan vessels suggests that agitation of 10 to 20 minutes is needed every 3 or 4 hours.

PITFALLS IN 'CHAMPAGNE' OPERATION

As with any refrigeration system, problems can occur that result in the loss of fish and discouragement with the system. These problems are the result of poor system installation and/or poor operating procedures. The most common problems with the 'champagne' system are:

- Circulation problems
- Temperature control problems
- Loading problems
- Contamination problems
- Foaming

Circulation problems are among the biggest problems with 'champagne' systems. Although the air delivery system should provide circulation, poor design can eliminate its benefits. System design flaws such as oversized distribution pipes or an undersized blower can lead to inadequate air flow into the tanks. Piping layout is also critical. Air pipes placed too close to bulkheads (within 6 in.) can restrict the circulation patterns resulting in localized hot spots.

Poor temperature control poses a serious problem for CSW systems. Ideally, a system with good insulation and adequate ice is capable of maintaining 32°F for both the ice/water mixture and the stored fish. Temperature fluctuation can be caused by a number of design and operation problems. Poor circulation is a major reason for poor temperature control. Lack of adequate hold insulation dramatically affects the ability to maintain desired temperatures. Operational factors causing fluctuating temperatures include inadequate ice and such things as removing large hatch covers during hot days.

Loading problems can also cause CSW systems to fail. If fish sometimes are loaded into the hold through a single hatch, they can pile up in one part of the hold. Large amounts of fish loaded in short periods, can accumulate a large mass of fish in one corner and make quick chilling very difficult. A common misconception is that the fish will slide around the tank and even out. This does not occur in all cases. Rather than relying on chance, it is better to use several hatches to even out the loading pattern. If there is only one hatch on the deck, chutes or slides should be used to distribute fish into the hold. Loading fish beyond 42 to 45 lb/cf of hold space is a common problem which restricts circulation and slows or even stops chilling. Holds should be sized and loading limits established that do not exceed 45 lb/cf.

Contamination due to poor system cleaning can be another pitfall to CSW operation. After each delivery, the entire system, especially the air pipes in the hold, should be thoroughly cleaned and sanitized. The following procedure is recommended:

1. Rinse the tank with fresh or salt water after unloading and physically remove all large particles.

2. Clean the tanks with a warm solution of detergent using scrub brushes on all surfaces. Use enough water to cover the bottom of the tank and the air pipes.

3. Rinse detergent from the walls using fresh water or clean salt water.

4. Rinse the hold with a sanitizing solution using enough to cover the air piping system.

Finally, foaming caused by air agitation is a nuisance for all CSW tanks. The air whips up the fish slime in the water and creates the foam. Great volumes of foam can be generated from short periods of agitation. While this is a nuisance, it does no harm to the fish or the system.

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