INDIA

A CHILLED SEAWATER (CSW) SYSTEM FOR FISHING AND CARRIER VESSELS ENGAGED IN THE SMALL PELAGIC SPECIES FISHERY OF SOUTHWEST INDIA

A report prepared for the Pelagic Fishery Investigation on the Southwest Coast Phase II – Project

by

Stewart W. Roach
Refrigeration Engineer Consultant

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1980
This is one of a series of reports prepared during the course of the FAO/UNDP project identified on the title page. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.

The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the United Nations or the Food and Agriculture Organization of the United Nations concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers.
ACKNOWLEDGEMENTS

This is one of a series of field documents prepared and issued by the project (Phase II) and is based on the work of:

Stewart W. Roach - Refrigeration Engineer Consultant
R. Ravikumar - Naval Architect

Special recognition is due to the Karnataka Fisheries Development Corporation (KFDC) for collaboration and assistance in providing the vessel and local components, to Mr K. Venkatesh, Director, and Mr Ramesh Jeppu, Manager (Fishing), for their cooperation and supervision. Thanks are also due to the Integrated Fisheries Project and Central Institute of Fisheries, Cochin for providing the drawings.

Comments are welcome and should be addressed to:

The Director
Pelagic Fishery Project
P.O. Box 1791
Cochin 682016
INDIA
# TABLE OF CONTENTS

1. INTRODUCTION
   1.1 Terms of Reference 1
   1.2 Background Information 1
   1.3 General Description of Small Pelagic Fisheries in Southwest India 2
   1.4 Purse Seining 2
   1.5 Present Fish Handling Practices 3

2. THE DEMONSTRATION CSW INSTALLATION
   2.1 Proposals Considered 4
   2.2 Conversion of 32-ft Shrimp Trawler 5
      2.2.1 Modifications 5
      2.2.2 Stability Data 6
      2.2.3 Description of a CSW System 7
      2.2.4 CSW System Specifications 7

3. OPERATIONAL ASPECTS 9
   3.1 Capacity and Chilling Calculations 9
   3.2 Ice Requirements - Completely Insulated Fish Hold 10
   3.3 Ice Requirements - Bulkhead and Deckhead Insulation Only 10
   3.4 Operating and Conversion Costs 11
      3.4.1 Operating Advantages 11
      3.4.2 Conversion Costs 12
   3.5 Operating Performance 13

4. CONCLUSIONS AND RECOMMENDATIONS 14
   4.1 Follow-up Programme 15
      4.1.1 The Research and Development Programme 15
      4.1.2 Kerala Fisheries Corporation 15
      4.1.3 Government Assistance 16
      4.1.4 Manufacturing of Blowers in India 16

Appendix 1 CHILLED SEAWATER SYSTEM - DATA SHEET 17
## LIST OF PHOTOGRAPHS

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>KFDC-5 with 3.0 t of CSW fish aboard</td>
<td>19</td>
</tr>
<tr>
<td>2.</td>
<td>SUTORBILT 3HVB blower with water pump on lift and power take-off clutch on right</td>
<td>19</td>
</tr>
<tr>
<td>3.</td>
<td>Unloading CSW fish from KFDC-5</td>
<td>20</td>
</tr>
<tr>
<td>4.</td>
<td>Fish hold of KFDC-5 showing installation of air pipes, upright screens on bulkhead, and 2 sets of shifting boards</td>
<td>20</td>
</tr>
</tbody>
</table>

## LIST OF FIGURES

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chilled seawater system: piping layout</td>
<td>21</td>
</tr>
<tr>
<td>2.</td>
<td>Typical schematic construction of reinforced plastic lining in wooden vessels</td>
<td>22</td>
</tr>
<tr>
<td>3.</td>
<td>Ice-air-seawater chilling of Pacific herring</td>
<td>23</td>
</tr>
<tr>
<td>4.</td>
<td>SUTORBILT 3HVB air blower: typical performance standard inlet conditions</td>
<td>24</td>
</tr>
<tr>
<td>5.</td>
<td>32 ft (9.75 m) trawler Mk IV: before modification</td>
<td>25</td>
</tr>
<tr>
<td>6.</td>
<td>32 ft (9.75 m) trawler Mk IV: modified for CSW system</td>
<td>26</td>
</tr>
<tr>
<td>7.</td>
<td>43 1/2 ft trawler/purse seiner: original plan and first modifications for CSW system</td>
<td>27</td>
</tr>
<tr>
<td>8.</td>
<td>43 1/2 ft trawler/purse seiner: details of modifications for CSW system</td>
<td>28</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

1.1 TERMS OF REFERENCE

The Government of India, assisted by the United Nations Development Programme and the Food and Agriculture Organization of the United Nations, have been engaged in the Pelagic Fishing Investigations on the Southwest Coast - Phase II - Project (IND/75/038), whose main purpose is estimating the characteristics, size and location of the pelagic fishery resources, determining the most efficient gear and methods for efficient and economic exploitation, and determining for industrial application the most economic ways of processing and marketing pelagic fish.

The project was operational from 1 January 1976 to 30 March 1979.

As part of the project operation FAO assigned Mr Stewart W. Roach, Refrigeration Engineer Consultant, from 6 November to 19 December 1978 with the following terms of reference:

- to demonstrate a chilled seawater system suitable for storage of catches of small pelagic fish;
- to adapt this system to the small vessels of the Indian fleet;
- to consider and design handling systems including loading and unloading for small pelagic species;
- to prepare experimental and demonstrational activities which can be carried out in technological institutes.

1.2 BACKGROUND INFORMATION

Chilled seawater systems are a comparatively recent innovation. The Consultant was familiar with progress made on the Pacific coast of Canada where the development of systems for salmon and herring transport and storage has been intensive and CSW systems are now the most common method for short-term preservation of fish.

Several attempts were made to introduce the handling of sardine and mackerel in shallow plastic boxes, which is the standard procedure in the Mediterranean sardine industry, and quality results were excellent. This method of handling did not, however, prove practical for commercial use since the fishermen are used to handling in bulk and on deck. Moreover, refrigerated seawater systems were unfeasible not only as the capital cost was prohibitive for installation in the small vessels (30-45 ft), but also because they presented technical problems of maintenance and operation beyond the capabilities of the fishermen. Thus, it appeared that a chilled seawater system would ideally suit the present conditions of the growing purse seine industry of southwest India due to its:

- low capital cost
- simplicity of operation
- ease of bulk handling to load and offload
- completely sanitary nature
1.3 GENERAL DESCRIPTION OF SMALL PELAGIC FISHERIES IN SOUTHWEST INDIA

The underexploited small pelagic species, mainly sardines (both oil sardines, Sardinella longiceps, and lesser sardines, mainly Sardinella fimbriata) and Indian mackerel (Rastrelliger kanagurta), constitute a traditional artisanal shore fishery, forming the bulk of the landings in the states of Karnataka and Kerala, and the Union territory of Goa. These species have consistently dominated the catch in the above areas as follows:

**MARINE LANDINGS - KARNATAKA, KERALA AND GOA**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sardine/mackerels Total in t</th>
<th>Total marine Landings in t</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>321 692</td>
<td>424 835</td>
<td>75</td>
</tr>
<tr>
<td>1970</td>
<td>351 487</td>
<td>528 821</td>
<td>66</td>
</tr>
<tr>
<td>1975</td>
<td>229 919</td>
<td>537 500</td>
<td>43</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>60</td>
</tr>
</tbody>
</table>

The traditional gears used have changed very little in the last few decades and, apart from gillnets which had limited mobility as they were fished from non-mechanized canoes, the main methods used were several types of beach seines (rampani) and fixed types of shoreline gear (lifnets, traps, weirs, etc.). The fishery was immobile, catches being limited to waiting for the inshore movement of schools, and consequently it was extremely seasonal and localized to within 3 km of the shore, making for erratic landings in some areas, and a short peak season.

1.4 PURSE SEINING

Purse-seine fishing methods were introduced from Portugal to Goa on the southwest coast of India in 1957. In 1958 the Indo-Norwegian Fishery Project based its headquarters in Cochin with fishing stations throughout Kerala, Karnataka, and southern Tamil Nadu. It was in the mid-sixties that Goa introduced what are the typical purse-seine methods of today by rigging two departmental vessels. Similarly, in the same period, greater emphasis was also placed by IFF on purse seining. However, it took several years to become a popular fishing method for a number of reasons: in Goa, sardines and mackerels had wide annual and seasonal fluctuations, creating operating and economic problems for purse seining which required a considerable capital outlay compared to traditional fishing methods; in Kerala and Karnataka, the main reason, apart from financing, was probably the insistence of the non-mechanized fishermen on their "traditional rights" to harvest the mackerels and sardines and these social implications demanded traditional methods rather than development of new catching techniques.

Purse seining remained stagnant in India, with up to 12 units in Goa between 1965 and 1974, and a few demonstration and exploratory purse seine units of the Indo-Norwegian Project. In 1975, the Government of Karnataka undertook a fishery development scheme, similar to that for shrimp trawlers, whereby the capital costs of purse-seine vessels and nets were subsidized 25 percent. The State Department of Fisheries rigged two demonstration units, and two privately owned vessels also were commissioned. These vessels proved so successful that 20 more vessels were built in the following year, another 30 in 1977-78; and further construction had
increased the purse-seine fleet to a total of 180 vessels by early 1979. Goa has a fluctuating fleet with 40 vessels equipped to purse seine. The subsidy programme was cut back in 1977, being limited at present to groups of shore seine (rampāni) fishermen who collectively own the boat; and others receive a 20 percent subsidy toward the cost of the purse seine only. However, construction continues, funds being readily available from banks and financial institutions as the loan repayments and earning records of purse-seine vessels have been outstanding. In only three fishing seasons, the purse-seine catch in Karnataka rose from less than 4 to 26 percent of the total marine landings, which represents a tenfold increase by purse seiners from 3,200 t in the 1975-76 season, to over 30,000 t in the 1977-78 season. Karnataka is the first State in India whose landings from mechanized boats exceed those from the traditional non-mechanized sector.

In Karnataka State the introduction of purse seining with mechanized vessels been accomplished without conflict with the pre-existing artisanal fishermen, and this improved fishing technology has benefitted the fishery industry as a whole without harming the traditional sector. There have been no major problems in absorbing and applying a new fishing technology, but the infrastructure for handling, distribution and marketing has shown limitations in its flexibility to absorb some increase for traditional distribution. In the Mangalore-Nalpe area of Karnataka, the infrastructure is incapable of coping with landings during peak periods and as a result there are surplus catches which cannot be properly handled and utilized.

Expansion of fishing effort has therefore exceeded the capacity of the infrastructure, giving less than optimum returns from the catches to the fishermen. There is a critical need to introduce improved methods of catch handling afloat and for additional investments in mechanical refrigeration and handling equipment on shore. Discussions with managers both in industry and government showed that the fishery is proving very profitable to all concerned including the fishermen, vessel owners, shore workers, freezing and canning companies, brokers of fresh fish, truckers, ice plants and other components of the infrastructure; economic returns could, however, be increased if the infrastructure could cope with the increased landings. It can thus be concluded that if the fishery is to continue to prosper, the primary concern of industry and government should be focused on further infrastructure development and that this should now take precedence over further expansion of catching effort.

Improved handling and preservation methods are urgently needed to reduce deterioration and waste of raw material at sea on the carrier vessels, at landing, and in transport to the processing plants and markets.

1.5 PRESENT FISH HANDLING PRACTICES

The current fish handling practices are unique since they evolved through the need to adapt existing units to cope with the explosive and unprecedented increase in catch rates which followed the introduction of mechanized seiners. These new vessels, built from the 43 1/2 ft design of the Indo-Norwegian Project, were modified to handle the purse seine, as had been done in Goa using a Portuguese-type deck layout. These seiners have no fish hold, and although there is an empty space forward of the engine, they carry the catch in bulk on deck when carrier vessels are not provided. In the Karnataka fishery, numerous small 32 ft shrimp trawlers are readily available during the off-season for shrimp and are used to transport the catch from the purse seiner to the landing site. Two carrier vessels are usually assigned to one purse seiner, or several carriers work in a pool with several seiners for flexibility. If a carrier is not used, the purse seiner puts the catch on deck and returns to port. From the deck of the carrier or purse seiner, the fish is shovelled
into baskets and carried by head-bearers to the trucks for transportation to the plants or to more distant markets. The better quality fish destined for canneries, freezing plants or distant markets is heavily iced in bulk during loading into open trucks.

The small shrimp trawler/carriers have no provision for storing bulk quantities below deck and the maximum carrying capacity of the vessel is loaded on deck. The seiners and small carriers are greatly lacking in stability when carrying a deckload of bulk fish. The State Fisheries Organization alerts the fleet to storm warnings so that fishing operations are normally carried out in calm waters but the safety factor is at best rather limited.

Purse seining is presently carried out in fairly close proximity to landing sites. From the moment the seine catch is brailed by the seiner crew onto the deck of the carriers and delivered to the landing site for unloading, the time elapsed varies from 2 to 4 hours, depending on whether or not the carrier waits for the seiner to make another set. The quality of the catch delivered to the landings varies greatly and depends on such factors as delays, time of day, ambient temperatures, wind and relative humidity. The best quality comes from small loads landed early in the morning or late in the evening when sun and wind effects are least damaging. Depending on the supply and demand conditions, these landings will fetch a premium price on the auction market. However, market prices vary greatly and are directly related to the available supply of fish and not only to the quality. Fish for canning, freezing, and shipment to distant markets must be fresh, undamaged and of sufficiently high quality to ensure a further safe storage life when chilled and stored in crushed ice for up to 2 days. During the peak season, mackerel is in greatest demand with prices for good quality fish reported to range from Rs. 1,000 to 1,500/t. Similarly, sardine prices were reported to range from Rs. 400 to as low as Rs. 50/t. Sardines are delicate with a shorter fresh storage life than mackerel and thus large quantities are destined for fish meal and fertilizers since they must be disposed of immediately after landing.

Ice is used liberally to chill and preserve premium quality fish for the canneries, freezing plants and distant fish markets, but much is wasted due to lack of insulated shipping and storage containers, chill rooms and insulated and/or refrigerated trucks. Moreover, its value decreases when applied after quality deterioration has commenced. Ice production in the Mangalore area is limited and there is a lack of ice storage space, but the major problem is misuse and consequent wastage of the available supplies.

2. THE DEMONSTRATION CSW INSTALLATION

2.1 PROPOSALS CONSIDERED

Several proposals were examined in order to demonstrate the value and operation of a CSW system. Prior to deciding on the 32-footer conversion, consideration was given to:

- R/V SARDINELLA: a 54-ft fibreglass combination vessel operated by the Pelagic Fishery Project. Although it handles both purse-seine and trawl gear, its capability is limited as the underdeck hold space is used for dry storage; the catch is stowed on deck in a very unsatisfactory manner and seriously limits the fishing capability. With a purse-seine on deck, the installation of a CSW system in the fish hold would seriously affect the trim and stability of the vessel so this proposal was rejected.
- F/V NORIND 2: an Integrated Fisheries Project vessel of wooden construction, 57 ft m length, built in India from plans of a typical double-rigged Gulf of Mexico shrimp trawler. This vessel had a suitable layout and no stability or trim problems, but could not be out of commission for the time required for the installation.

It was then decided to go to the State of Karnataka, since this was the hub of the purse-seine activity, and to assess the following alternatives:

- a 32-ft fibreglass trawler attached to the College of Fisheries, Mangalore;
- State fisheries vessels - 32 or 43 1/2 footers;
- new construction in the private sector, either a 45-ft purse seiner or a carrier of specified size;

A 32-ft ex-shrimp trawler owned by the Karnataka Fisheries Development Corporation (KFDC) in Mangalore was the final choice. It was selected because:

- the vessel was immediately available;
- the KFDC had approved funds to provide locally incurred costs;
- the KFDC had infrastructure necessary to provide services, such as ice, offloading and processing facilities;
- the KFDC was developing both domestic and export markets for frozen mackerel, but had experienced quality problems with purse-seine caught fish due to deterioration in the short time from catching to landing.

2.2 CONVERSION OF 32-ft SHRIMP TRAWLER

The Consultant set out the design parameters for a small CSW unit suitable for chilling small pelagics in tropical waters, based on the CSW system in use on fishing vessels on the Pacific coast of Canada (see Appendix 1 for details). In September 1978, R. Ravikumar carried out basic design and stability calculations on the FAO Mark IV, design No. 25-04 (see Fig. 5) which is the basic hull design of most 32-ft shrimp trawlers in South India. The vessel to be converted KFDC No. 5, was essentially built to this plan, except that the engine was located aft of the original position shown in the plan.

2.2.1 Modifications

On examining the 32-ft vessel KFDC No. 5 hauled out at Mangalore, the following modifications were decided:

- remove existing deckhouse, shift engine forward by 28", and relocate deckhouse accordingly;
- extend intermediate shaft and relocate line bearings to permit access to after bearing and coupling through a removable portion of the shaft alley cover, and relocate the forward bearing in the engine space;
- erect bulkheads to give an inside dimension of 120", excluding insulation. Position the inside of the after bulkhead on top of heavy cross timber over end of shaft log, as shown in FAO Mark IV design No. 25-04;
- construct shaft alley with 2" timber sides, and 3/4" plywood top;
- line hull surfaces with 1" planking;
- apply 3" thickness of rigid polyurethane foam insulation to all inner surfaces of fishhold using 2 oz mat and resin to bond to wood;
- finished surface to be 3 x 2 oz mat plus 1 layer 1 1/2 oz mat plus surface tissue; for the dickhead surface, 1 x 2 oz and 1 x 1 1/2 oz mat plus surface tissue is sufficient;
- install shifting boards of 1" thickness, removable in the hatch section, but fixed otherwise, spaced longitudinally to divide the free surface about equally in thirds when half-loaded;
- extend deck carlings to provide a hatch 6' long x 5' wide inside dimensions, 2 1/2" thickness by 16" high; locate approximately equidistant from each bulkhead;
- install power take-off, air blower, water pump, piping, screens, etc. /All work according to Fig. 6/.

2.2.2 Stability Data

The following stability data were obtained after the vessel was converted and in operating condition, based on lines plans of the FAO Mark IV design No. 25-04 from which the vessel was reportedly built:

(a) a check was made as to the maximum payload the vessel could carry and the corresponding full load displacement estimated at 10.66 t beyond which the vessel's safety may be affected
(b) the standard MK IV has a light displacement of 7.3 t
(c) the vessel when modified as a carrier would also have a light displacement of 7.3 t, the winch, mast and rigging being replaced by the GRP hold lining weight
(d) the payload (ice + fish + seawater) that the vessel can carry is 3.82 t, corresponding to a hold capacity of 135 ft³ (3.82 m³)
(e) the existing hold when lined and insulated gave a volume of 135 ft³, not including the hatch coaming
(f) stability and trim were calculated for a displacement of 10.55 t (3.25 t of fish, ice and seawater) and showed that the vessel would trim by the aft giving a minimum freeboard of 12", a G.M. corrected for free surface of 1.23 ft, and a roll period of 3.35 seconds
(g) actual tests on 26 March with a payload of 4 t (ice + fish + seawater) showed a minimum freeboard of 9" and a roll period of 3 seconds
(h) measurements carried out on 10 April showed that the volume of the hold was 135 ft³, light displacement from measured drafts corresponded to 7.3 t and roll periods for light and loaded conditions were 3 seconds
(i) it is recommended that the free surface when loaded should be at the bottom of the hatch coaming to ensure that the loaded displacement does not exceed 10.66 t and no further catch is kept on deck.
2.2.3 Description of a CSW System

Although fish may be stored in CSW in a simple tank using only ice and manually circulating seawater, this arrangement creates several problems. It is a simple matter to calculate the ice requirement of such a system, but it is mandatory that the ice melt rapidly enough to quickly lower the temperature to 0°C and maintain the temperature uniformly, as shown in Fig. 3. Circulation must be sufficiently rapid to ensure that no temperature stratification occurs, since the ice tends to float on the surface and specific gravity differences between fresh water near the melting ice and the seawater tend to increase this stratification. In the new CSW systems employed on the Canadian west coast, fish are chilled in a mixture of seawater and ice which is vigorously agitated by compressed air injection. This has proved to be an excellent method for chilling fish, and cooling is much more rapid and complete compared with simple icing. The main function of the air is to agitate the seawater-ice mixture so that the water temperature is maintained uniformly in the 1°C to 0°C range and to ensure that no localized warm "pockets" exist in the tank. Secondly, agitation of the mixture enhances the heat transfer rate between the fish and the slush ice so that the fish is rapidly chilled down to the optimum temperature. The air pressure required depends primarily on the depth of the tank (the submergence) and to a lesser degree on pressure losses in the supply lines from the air compressor or "blower".

This system is ideally suited for the preservation of seine-caught fish in tropical waters. The sudden heat load imposed under such conditions cannot conveniently be dealt with one small carrier vessels in any other way. Ice provides an immediate, unlimited refrigeration effect, vigorous air agitation of the CSW provides high heat transfer, and the buoyancy of fish in seawater ensures rapid circulation of the constantly chilled seawater through the mass of fish.

2.2.4 CSW System Specifications

The minimum air flow rate is 0.5 cfm per square foot of deckhead area.

The air pipes on or in the tank floor are spaced on a maximum of 3 ft centres and within 6 inches of vertical bulkheads. Each pipe is drilled with sufficient equally-spaced holes that the total area of the holes equals the internal cross-sectional area of the blower-delivery air pipe. To minimize pressure drop in the air grid, the full air delivery pipe diameter is maintained into the tank. The grid pipes are sized so that the total of the cross-sectional area of the branch pipes equals the area of the delivery pipe.

Air Blower

SUTORBILT 3HVB rotary positive displacement model 3HVB which has the following specifications:

<table>
<thead>
<tr>
<th>rpm</th>
<th>7 psi</th>
<th>cfm</th>
<th>hp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 500</td>
<td>28</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>2 000</td>
<td>50</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>2 500</td>
<td>73</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>3 000</td>
<td>95</td>
<td>4.5</td>
<td></td>
</tr>
</tbody>
</table>
The performance curves and hp requirements are shown in Fig. 4. When selecting blowers which are to be driven mechanically from the main engine, the speed range of the engine must be carefully considered. All blowers have maximum and minimum speed limits and should not be operated above maximum speed or below minimum speed. Since compressor capacity varies directly with speed, the other components of the system must be able to compensate for variations in capacity. Since the speed range of the main engine of the 32-footer is from 650-1 300 rpm the blower output will vary from approximately 28-95 cfm depending on the engine speed. A blower speed of 2 000 rpm is recommended to provide the required air-flow rate for this application, when the vessel is operated at normal running speeds. Care should be exercised when running the air blower at lower speeds for extended periods of time, which can result in abnormal heating of the air blower.

Several inquiries were made to procure a blower manufactured in India. Nothing of this size was found, but quotes were received as follows:

SLN Maneklal Ind. Ltd., Bombay - Type P 40 watercooled, 73 cfm, 8 psic, Rs. 21 320
Bombay Ammonia (Madras) Pvt. Ltd., twin lobe, 50 cfm, 8 psic, Rs. 11 700

Mechanical Drive Components

A V-belt drive from the front end of the ship's engine to a "Little Flower" multi disc power take-off clutch from which both the blower and the water pump are driven by V-belts. Pulleys were selected to provide the desired speeds for both the blower and water pump. The water pump was provided with a disconnecting clutch as it need not be run when the air blower is operating.

Piping (Please refer to Figs. 1 and 6 for details)

Air - galvanized steel in the engine room, PVC plastic or aluminium in the tank,
- 1 1/4 inch inlet and outlet piping through the bulkhead into the tank for the floor piping-grid header
- floor grid to consist of four 1/2-inch pipes on 2 1/2-ft centres with each pipe drilled with 25 equally spaced 1/8-inch holes facing upward
- a 1 1/4-inch check valve and/or a vertical loop in the air delivery line above the tank top to prevent CSW siphoning back to the blower when not in operation
- a 1 1/4-inch pressure relief valve in the air delivery line
- a pressure gauge to monitor blower discharge pressure

Water - 1 1/2-inch galvanized steel piping for suction and delivery lines
- suction from a sea valve and from sumps in the fish hold with a non-return check valve
- discharge line to hose on deck for filling the hold, discharging overboard, and cleaning
- a centrifugal or positive displacement pump to supply seawater to the tank from a sea cock and for pumping out the tank, of about 60 gpm capacity.

2.2.5 Operation Instructions

(1) At the dock, one ton of crushed ice should be evenly spread over the floor of the tank;
(2) The carrier travels to sea to rendez-vous with the seiner;
(3) Approximately one ton of fish should be brailed into the tank so that the ice is covered by a layer of fish;

(4) Seawater is pumped into the tank until the seawater-ice-fish mixture becomes liquid

(5) Stop adding sea water and commence air agitation;

(6) Continue loading fish;

(7) If sufficient fish is available to fill the tank, loading continues until the seawater-ice-fish mixture rises into the hatch coaming. If there is ice floating on the surface, excess CSW should be pumped overboard, otherwise the excess may be allowed to spill from the hatch;

(8) Air agitation should continue throughout the loading operations;

(9) The tank should be considered fully loaded when fish remain in the water near the surface. The tank should not be overloaded by pumping out chilled water and allowing the fish to settle. All the fish should be covered by the CSW;

(10) Foaming may prove bothersome but is unavoidable;

(11) After loading, the hatch covers should be replaced and fastened down;

(12) The carrier then will return to the landing dock;

(13) Air agitation may be discontinued, when temperatures are uniform and the ice is used up. For this installation of under 4 t capacity, agitation should be from 30 to 60 min;

(14) Unloading should preferably be done by brailing but if necessary the CSW may be pumped from the tank and unloading done manually;

(15) If the fish are to be held on board overnight or longer, more ice can be placed in the hatch coaming and air agitation carried out periodically for brief periods. The amount of ice will depend on the temperatures required, and the length of time the fish is to be stored;

(16) After unloading, the tank should be washed and the air pipes drained.

3. OPERATIONAL ASPECTS

3.1 CAPACITY AND CHILLING CALCULATIONS

The fish-carrying capacity of the CSW demonstration tank is approximately 2.75 t. A more viable and suitably sized CSW carrier for this application should accommodate 5-10 t in two tanks below deck. Plans for a 40-45 ft, roundbidge fibreglass hull for this purpose are in preparation and will be available from the Pelagic Fishery Project through FAO during the first half of 1980 (included in field document 12, in preparation). For immediate use, the Pelagic Fishery Project, in collaboration with the Central Institute of Fishery Technology, produced a G.A. plan showing modifications to the 43 1/2-ft Indo-Norwegian Project 3 design. This will permit the vessel to carry a purse seine and have a CSW system of 15.6-m³ capacity or approximately 12 t total, or 8-10 t fish only in CSW (see Figs. 7 and 8).
3.2 ICE REQUIREMENTS - COMPLETELY INSULATED FISH HOLD

Assuming the following:

- Temperature of sea water and fish: $85^\circ F$
- Cubic capacity of the CSW tank: 3.5 t
- Fish carrying capacity: 2.75 t
- Specific heat of fish: 0.7 BTU/°F/lb
- Latent heat of one (metric) ton of ice: 316 800 BTU

The fish cooling load = $2.75 (2 \times 200) (0.7) (85-30)$
= 232 925 BTU

The sea water cooling load = $\frac{(3.5-2.75) (2 \times 200) (1.0) (85-30)}{2}$
Total = 45 375 BTU

Ice requirement to chill fish and sea water = $\frac{278 300}{316 800} = 0.88$ t.

Allowing for heat leakage and infiltration into system and CSW spillage, the ice requirement for 2 3/4 t of fish is one ton. This assumes that the amount of sea water used is 0.38 t ($3 \times \frac{5}{2}$) since there is a rapid initial melting of ice in tropical conditions which minimizes the amount of seawater required.

3.3 ICE REQUIREMENTS - BULKHEAD AND DECKHEAD INSULATION ONLY

Elimination of the hull insulation and of the fibreglass tank lining would reduce the total costs for a CSW system to an acceptable level. The refrigeration load imposed by heat infiltration is comparatively small related to the chilling load, and the cost of providing a fibreglass tank lining to prevent contamination and leakage could be eliminated if the wooden construction can be made watertight. The deckhead can easily be insulated as can the two bulkheads, the latter by applying conventional insulation on the warm side.

The thermal inertia of the mass of fish, ice and water is large in relation to the heat infiltration so that in practice there will be no significant temperature rise at holding temperature. For the prevailing conditions, the quantity of ice needed to offset heat infiltration will determine the viability of this approach in accordance with the following calculations:

Assumed conditions - seawater temperature = $85^\circ F$
- wooden hull thickness = 2"
- air space between ribs = 3"
- wooden tank lining thickness = 1 1/2"
- $K$ (thermal conductivity of dense wood = 0.1 BTU/h/ft $^2\circ F$)

Calculated solution - overall conductance $J = 0.267$ BTU/h/ft $^2\circ F$
- heat flux $q = 14.7$ BTU/h/ft $^2\circ F$
- the total heat transferred through the hull of the 32-ft demonstration vessel (surface area = approximately 113 ft $^2$)
$Q = qA = (14.7) (113)$
= 1 662 BTU/h

or in terms of ice meltage $= \frac{1 662}{144} = 11.6$ lb/h extra
Conclusion

The additional quantity of ice required to offset that heat leakage through an uninsulated wooden hull is an acceptable added cost, under conditions where the holding time is relatively short, say up to 48 hours.

3.4 OPERATING AND CONVERSION COSTS

3.4.1 Operating Advantages

As mentioned briefly in 3.1, the demonstration unit is neither an ideal nor optimum size from both operating and initial investment viewpoints. First, a vessel of slightly larger dimensions (length, breadth, depth) can give a much greater cubic capacity without proportionately increasing the cost of the hull. Similarly, the same engine, blower, pump, piping etc. would have the capacity to adequately chill and store fish in a hold of 50 percent more deckhead area (120 ft², as against 80 ft²) and up to three times the present depth (average 3 ft requiring about 1.5 psi as against blower capacity of 8 psi). A vessel with a hold capacity of five times the demonstration unit, or 15 t fish, could use the same equipment.

Similarly, since a 15-t capacity vessel could operate with the same hp engine (possibly speed will be forsaken so consumption of fuel for a round trip will increase slightly) and the same crew complement, so the operating costs in total per trip will be similar, but on a unit of cargo will be proportionately reduced according to the carrying capacity of the vessel. Under present fishing conditions, typical catch rates per purse-seine set are probably averaging between 0.5 and 2.5 t. Unless the seiner (or another seiner) can fill the carrier to capacity in a short time after the partial load comes aboard, then the carrier is forced to leave for the landing site with only a partial load thus increasing the unit cost of transportation still further.

The cost of ice (Rs. 100/t) is an additional pre-market cost, but is more than recoverable in many ways. Since time did not permit a factual cost analysis, this can be done over a period but for purposes of this paper, the cost of ice is considered to be recoverable in total plus providing additional revenue for the following reasons:

- shrinkage in CSW is negligible compared to the losses of weight from compaction of fish stowed in bulk, since the fish remain buoyant in the CSW
- loss due to quality (both weight and value) is non-existent for the brief periods required when held in CSW
- since the fish is pre-chilled prior to shipping overland, the land carrier can have a greater ratio of payload to ice, thereby making a saving to the consumer both because less ice is used and freight costs per net weight of product are lower
- obvious advantages directly related to quality such as price, and preference when supply exceeds demand
- using the CSW system as storage for further processing, awaiting transport, holding for the next day's market, etc.

No attempt is made here to give an economic analysis of this demonstration unit or proposed units of larger capacity, but it is suggested that the College of Fisheries, Mangalore, and CIPT, Cochin, could collaborate on such studies, as there is an urgent need to demonstrate to the industry the necessity for and benefits to be accrued from improved handling methods.
3.4.2 Conversion Costs

- Actual costs for the demonstration unit

Although a detailed list follows for the actual costs incurred, these should not be taken for future estimation purposes because:

- many items were imported duty-free from Singapore. The invoice price is therefore much lower since there is a high rate of taxation on chemicals and petro-chemical materials, this is partially offset by the cost of airfreight in most instances, but was necessary to obtain delivery on time, as both surface shipment and Indian suppliers required considerable lead time

- quantities ordered were in excess of requirements in order to ensure against running short if work had to be redone, etc.

- fibreglass specifications were intentionally made excessively strong, as the fitting of the inner lining and bulkheads in the vessel could not be done as well as had they been an integral part of a newly constructed vessel.

Separate capital cost estimates are therefore given to indicate the costs involved to effect conversion with locally available materials.

### ACTUAL COSTS INCURRED BY THE PELAGIC FISHERY PROJECT

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
<th>Purchased</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>450 kg</td>
<td>Isophthalic resin</td>
<td>13 456</td>
<td>10 465</td>
</tr>
<tr>
<td>1</td>
<td>SUTORBILT air blower No. HVB 3</td>
<td>730</td>
<td>5 913</td>
</tr>
<tr>
<td>450 ft²</td>
<td>Polyurethane foam 3 x 2.5 lb/ft</td>
<td>4 022</td>
<td>15 364</td>
</tr>
<tr>
<td></td>
<td>density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 kg</td>
<td>Fibreglass - 140 kg E 600 &amp; 450</td>
<td>1 330</td>
<td>5 080</td>
</tr>
<tr>
<td></td>
<td>Catalyst and accelerator aerosol</td>
<td>822</td>
<td>3 140</td>
</tr>
<tr>
<td>1</td>
<td>&quot;Little Flower&quot; multi-disc power take-off</td>
<td>2 912</td>
<td>2 912</td>
</tr>
<tr>
<td>1</td>
<td>1 1/4 bronze gear pump with dog clutch</td>
<td>1 600</td>
<td>1 600</td>
</tr>
<tr>
<td></td>
<td>(donated by IFP, so price estimated for centrifugal pump of 60 gpm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rs. 47 465 | Rs. 37 890

Equivalent to US$ 5 860 | 4 680

### ACTUAL COSTS INCURRED BY THE KARNATAKA FISHERIES DEVELOPMENT CORPORATION

<table>
<thead>
<tr>
<th>Description</th>
<th>Purchased</th>
<th>Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber and stores items</td>
<td>6 465</td>
<td></td>
</tr>
<tr>
<td>Workshop - fabrication of shaft extension install engine, mechanical, piping, screens, etc.</td>
<td>1 730</td>
<td></td>
</tr>
<tr>
<td>Labour - fibreglassing</td>
<td>2 565</td>
<td></td>
</tr>
<tr>
<td>- carpenters</td>
<td>4 677</td>
<td></td>
</tr>
</tbody>
</table>

Total cost of conversion  Rs. 53 327 | Equivalent to US$ 6 600

Note: Rate of exchange US$ 1.00 = Rs. 6.1
## ESTIMATED CONVERSION/ADDITION NEW BUILDING COSTS

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit cost</th>
<th>32 footer</th>
<th>43 1/2 footer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit</td>
<td>Value (Rs.)</td>
<td>Unit</td>
</tr>
<tr>
<td>Wood work: lining, bulkheads hatch, shifting boards, etc.</td>
<td>3</td>
<td>000</td>
<td>4</td>
</tr>
<tr>
<td>Fully insulated: 2&quot; x 2 1/2&quot; density</td>
<td>28 m²</td>
<td>5 880</td>
<td>45 m²</td>
</tr>
<tr>
<td>(includes application labour)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibreglass lining: (includes application labour)</td>
<td>9 380</td>
<td></td>
<td>15 075</td>
</tr>
<tr>
<td>Air blower</td>
<td>6</td>
<td>000</td>
<td>6</td>
</tr>
<tr>
<td>- piping</td>
<td>1</td>
<td>000</td>
<td>1</td>
</tr>
<tr>
<td>Power take-off</td>
<td>3</td>
<td>000</td>
<td>3</td>
</tr>
<tr>
<td>Water pump</td>
<td>1</td>
<td>000</td>
<td>1</td>
</tr>
<tr>
<td>- piping and screens</td>
<td>2</td>
<td>000</td>
<td>2</td>
</tr>
<tr>
<td>Labour - woodwork</td>
<td>3</td>
<td>000</td>
<td>4</td>
</tr>
<tr>
<td>- mechanical</td>
<td>1</td>
<td>000</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total: fully insulated and fibreglassed</strong></td>
<td>37 360</td>
<td></td>
<td>49 725</td>
</tr>
<tr>
<td>Delete - insulation of aft bulkhead and hull - fibreglass</td>
<td>16 m²</td>
<td>(3 360)</td>
<td>25 m²</td>
</tr>
<tr>
<td>Present cost - hull complete with copper sheathing, engine Ruston 4YDAM</td>
<td>56 000</td>
<td></td>
<td>185 000</td>
</tr>
<tr>
<td>Cost of carrier with CSW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- fully insulated and fibreglassed</td>
<td>169 360</td>
<td></td>
<td>378 225</td>
</tr>
<tr>
<td>- partially insulated and no fibreglass lining</td>
<td>156 620</td>
<td></td>
<td>357 900</td>
</tr>
<tr>
<td>Fish-carrying capacity</td>
<td>3 t</td>
<td></td>
<td>8-10 t</td>
</tr>
</tbody>
</table>

### 3.5 OPERATING PERFORMANCE

Due to delays in construction, the vessel did not become operational until 10 March. It was planned to conduct sea trials on 12-14 March, but many small details required completion before the hold could be hydrostatically tested and the equipment checked out. By 24 March, the vessel had undertaken harbour trials and equipment had been run. The fishhold was filled with water, the blower run for a short time, and the water pumped out. All went smoothly, and sea trials to take fish on board were scheduled for 26 March. The sea trial took place as planned, without incident and with results that were extremely successful as chronologically outlined below.
Although temperatures were not as low as expected, the quality was excellent the following morning; the flesh was firm, the eyes bright and no bleaching of the gills or loss of scales had taken place. The theoretical temperatures had not been reached but this was probably due to the loading of an inaccurate quantity of ice.

**Air temperature 29°C**
**Water temperature 80°C**

<table>
<thead>
<tr>
<th>26 March 1979</th>
<th>Temperature readings in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>each corner and centre of the hatch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hours</th>
<th>Activity</th>
<th>Corner</th>
<th>Corner</th>
<th>Corner</th>
<th>Corner</th>
<th>Centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.30</td>
<td>loaded 1 t crushed ice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.30</td>
<td>loaded 1 250 kg sardines and started blower, added about 200 l water</td>
<td>+5</td>
<td>+2</td>
<td>+1</td>
<td>+4</td>
<td>+4</td>
</tr>
<tr>
<td>14.00</td>
<td>temperature readings</td>
<td>+5</td>
<td>+2</td>
<td>+1</td>
<td>+4</td>
<td>+4</td>
</tr>
<tr>
<td>14.15</td>
<td>reached dock-stopped blower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.45</td>
<td>returned to sea, started blower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.15</td>
<td>stopped blower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.30</td>
<td>loaded 750 kg sardines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.30</td>
<td>loaded 1 000 kg sardines, blower on</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.00</td>
<td>returned to dock, blower off</td>
<td>+7</td>
<td>+8</td>
<td>+8</td>
<td>+8</td>
<td>+7</td>
</tr>
</tbody>
</table>

**27 March 1979**

<table>
<thead>
<tr>
<th>Hours</th>
<th>Activity</th>
<th>Corner</th>
<th>Corner</th>
<th>Corner</th>
<th>Corner</th>
<th>Centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>08.00</td>
<td>temperature readings</td>
<td>+7</td>
<td>+9</td>
<td>+9</td>
<td>+7</td>
<td>+8</td>
</tr>
<tr>
<td>09.00</td>
<td>started unloading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09.45</td>
<td>finished unloading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.15</td>
<td>loaded 450 kg ice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.30</td>
<td>returned to sea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.00</td>
<td>returned to dock - no catches</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**4. CONCLUSIONS AND RECOMMENDATIONS**

Bacterial growth is the most serious single cause of loss of quality and of spoilage in fresh fish. It causes the bad odours, flavours, flesh softening and discolouration associated with spoiling fish. The rate of bacterial growth is dependent on temperature and on the initial number of bacteria present on the fish.

Delays in handling fish on deck at sea can seriously affect the quality of the landed catch. It can be shown that for every hour fish are left on deck the equivalent of one day's shelf life in ice is lost. All fishing boats, even those only out for one day, should chill the catch. Chilling should preferably commence immediately after the fish is caught, using ice or some equivalent technique.
The importance of rapid and complete chilling of the catch cannot be overemphasized and it is important to remember that the rate at which spoilage occurs accelerates with time, which means that the loss in quality caused by delay in chilling becomes more serious the longer the period of storage continues. In the context of a tropical fishery, with ambient temperatures continually exceeding 30°C, the spoilage rates for unchilled fish are extremely high and fish will continue to spoil at these high rates until adequately chilled.

In southern India, a modern pelagic fishery is rapidly developing with landings of resources previously exploited by only the artisanal sector. This new fishery has quickly expanded yet is unable to take advantage of new markets and new product forms. It is thus mainly dependent on traditional markets, and heavy landings often have negative effects on this market, to the detriment of the traditional and purse-seine fishermen. A serious constraint on the development of this new fishery at present is the relatively small quantity of high quality fish in the total landings. The CSW demonstration unit can be utilized to show the value of rapid chilling for upgrading the general quality level of landings.

4.1 FOLLOW-UP PROGRAMME

A follow-up programme should be carried out by the Government of Karnataka State and of India. The Karnataka Fisheries Development Corporation, the Kerala Fisheries Corporation, the College of Fisheries in Mangalore, and the Central Institute of Fisheries Technology in Ernakulam are now familiar with the CSW carrier concept and are prepared to participate in the follow-up development work.

4.1.1 The Research and Development Programme - which should include:

(a) supervision and operation of the equipment during sea trials

(b) engineering studies of ice consumption, chilling rates and uniformity of CSW tank temperatures

(c) fish storage tests to determine the effects of delays in chilling on:
   - further iced storage life
   - quality of canned products
   - storage life of frozen products

(d) storage and field trials to examine the feasibility and economics of shipping fish chilled by CSW system in insulated containers or in containers in insulated trucks to distant markets.

A simple improvement for shipping CSW fish would be to use the present system of fish in bulk, but preferably in baskets or, better, in shallow boxes on the typical stake-type open truck and then covering with an insulated tarpaulin.

4.1.2 Kerala Fisheries Corporation

The Pelagic Fishery Project has imported two SUTORBILT 3HVB air blowers, to be used in purse-seine or carrier vessels currently under construction. In collaboration with CIPT, modifications have been made to the 43 1/2 ft Indo-Norwegian plan in order to incorporate the use of CSW systems in the fish holds, and the other six purse seiners can readily have equipment installed when blowers become available (see Figs. 7 and 8).
4.1.3 Government Assistance

The subsidy programme made available by the Government of Karnataka was instrumental in the rapid development of the purse-seine fishery, and recent additions to the fleet have continued without subsidization, being privately financed because of the good earning records of operating vessels. It is now evident that in order to optimize the returns from the purse-seine caught fish, large investments are required to provide necessary infrastructures, such as:

- CSW or other types of fish handling and preservation systems
- ice supply and storage
- off-loading and shipping facilities at landing sites
- insulated road and rail transport
- processing facilities - freezing, canning, curing, etc.

As mentioned earlier, the prime requisite for quality is the rapid chilling of fish as soon as caught. When the landing of prime quality fish becomes routine, the new markets, new products and raising of capital for better utilization of the raw material become closer to reality.

The Central and State Governments are aware of these needs, and should assist the industry in attaining a goal of improved quality. Serious consideration should be given to a programme to subsidize or make funds available at a reasonable cost to finance proven ways to improve quality. The obvious starting point is at the place and the time of catch, and the CSW demonstration unit will prove the value of popularizing this handling system.

4.1.4 Manufacturing of Blowers in India

The SUTORBILT 3HVB series B blower is available in the USA ex-factory for less than US$ 500 or Rs. 4 050. The price in India for a blower of similar capacity was Rs 11 700 plus duties and levies as applicable. The possibilities of having a local machine shop make a lot of 20-50 units should be pursued by industry and government.
Appendix 1

CHILLED SEAWATER SYSTEM - DATA SHEET

Description
- Fish are chilled in a mixture of seawater and ice which is agitated by air (see the piping layout schematic drawing, Fig. 2)

Advantages
- Simple system - low initial cost
- Does not require skilled operators as do mechanical refrigeration systems
- No danger of plugging chillers or strainers (e.g., with herring scales or roe)
- Does not have "iceberg" or circulation problems of normal slush ice system using a pump

Disadvantages
- Requires reliable ice supply
- Cost of ice over a few years operation could amount to price of mechanical CSW system
- Extensive foaming in the tank will occur because of the aeration of the protein in the water

Equipment
- Air blower (low pressure, high capacity) connected to a grid of pipes on the floor of the tank. Blower is sized to give a minimum of 0.5 cubic feet/min (cfm) per square foot of deckhead area at a pressure sufficient to overcome the head of water in the tank (each 10 ft of seawater requires 4.4 psi) plus the pressure drop in the piping. A pressure rating of 5-7 psi is usually adequate for most installations

Piping Grid
- The pipes on the floor of the tank should be on a maximum of 3-ft centres and no more than half that distance for bulkheads (see Fig. 1). Each pipe should be drilled with sufficient equally-spaced holes so that the total area of the holes equals the internal cross sectional area of the pipe (see following table for examples). Note that the length of the pipe makes no difference to the total number of holes required. It only means the longer the pipe, the longer the distance between holes.

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Number of Holes</th>
<th>1/2&quot;</th>
<th>3/4&quot;</th>
<th>1&quot;</th>
<th>1 1/2&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8&quot; hole size</td>
<td>25</td>
<td>43</td>
<td>70</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>3/16&quot; hole size</td>
<td>11</td>
<td>19</td>
<td>31</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>

Design Tips
- Provide blower with cool air supply and use metal pipes to connect to it
- Vent the tanks
- Install a check valve and/or a vertical loop in the air line above the top of the tank to prevent flooding back to the blower when not in operation. Systems should also have pressure relief valve

Compiled by: Environment Canada, Fisheries and Marine, Vancouver Laboratory, Vancouver B.C.
- The system will need a pump to supply water to the tanks from the sea valve and to pump out at the end of the trip.
- In a multi-tanked boat shut-off valves are installed on the lines to each tank and the pipes are usually sized to carry the full output of the blower on one tank at a time. The full outlet pipe diameter is maintained into the tank where the grid pipes are sized so that the total of the cross sectional area of the branch pipes equals the area of the main pipe.

Operating Tips
- Ice can be carried dry to the fishing grounds or 'slushed' before departure, but the latter is not recommended for tropical conditions.
- The starting mixture should have at least enough water to float the ice and permit adequate heat transfer.
- The air is normally bubbled into one tank at a time. The pre-chilling time required for the water is only 10-20'/tank.
- It is only necessary to bubble air into the tank continuously while fish are being loaded and for a few hours after. The air need be only turned on for a few minutes every few hours to prevent stratification of the mixture once the fish are chilled.

How Much Ice?
- The amount of ice required depends on the initial temperature of the water and the fish, the size of the tank and the quality of its insulation and the length of the trip. In some cases, for stability, the tanks will have to be completely filled at the beginning of the trip and the excess water spilled as fish are added. This will require extra ice to chill the wasted water. For typical applications in British Columbia waters the approximate amount of ice to use in each tank can be estimated as follows:

\[
\text{Tons of ice} = \frac{W + F + D}{6}
\]

Where:
- \(W\) = Tons of water to be chilled
- \(F\) = Tons of fish to be chilled
- \(D\) = Days duration of the trip

Note: If no water is wasted \(W + F\) = simply the capacity of the tank in tons.

This formula will give a conservative amount of ice to ensure there will not be a shortage. With this start, experience will soon indicate the right amount to take for each tank.

Examples
- A 20-t tank on a 6-day trip with no water being spilled would require

\[
\frac{20 + 6}{6} = 4 1/3 \text{ t of ice}
\]

- If the same tank is filled with 20 t of water and 13 t of fish is added, the excess water spilled it will require

\[
\frac{20 + 13 + 6}{6} = 6 1/2 \text{ t of ice}
\]

Therefore, the more water used, the more ice is required. In tropical conditions, both the availability and the cost of ice will probably dictate that the CSW system be operated with a minimal amount of seawater.
Photograph 1 – KFDC–5 with 3.0 t of CSW fish aboard

Photograph 2 – SUTORBIT3 HVB blower with water pump on lift and power take–off clutch on right
Photograph 3 — Unloading CSW fish from KFDC-5

Photograph 4 — Fish hold of KFDC-5 showing installation of air pipes, upright screens on bulkhead, and 2 sets of shifting boards
Fig. 1 - Chilled seawater system: Piping layout
Fig. 2 - Typical schematic construction of reinforced plastic lining in wooden vessels
Location of probes in a typical CSW fish hold

For fish of 2.5 cm thickness the temperature of the centre falls from 13°C to 0°C in one hour

Fig. 3 - Ice-air-seawater chilling of Pacific herring
Fig. 4 - SUTORBILT 3HVB air blower: typical performance standard inlet conditions
Fig. 5 - 32-ft (9.75 m) trawler Mk IV: before modification
AIR PIPING SCHEMATIC

WATER PIPING SCHEMATIC

BULK HEAD SECTIONS

SUMP AND SCREEN DETAILS

SECTION B-B

STANCHION DETAILS

LOCATION OF HATCH AND SHIFTING
BOARDS IN RELATION TO BULKHEAD

PELAGIC FISHERY PROJECT
COCHIN-16

CHILLED SEAWATER
CONVERSION OF
32 FT. MK IV
SHRIMP TRAWLER

DETAILS OF AIR PIPING

SECTION B-B

DETAILS OF WATER PIPING

AND REMOVABLE SHIP AXLE COVERS

PELAGIC FISHERY PROJECT
COCHIN-16
AN EQUIPMENT ARE NOT FIXED.

NOTE: DIMENSIONS OF HULL, BOOM, AND WASTE MOUTH AND EQUIPMENT ARE NOT TRUE.

THEY SHOULD BE CHANGED ACCORDING TO MOUNT OF EQUIPMENT AND CONSTRUCTION OF SHIP IN.cb.

See alsoCHECK INSTALLATION.

1. SEE DRAWING 132G-CSW-3 FOR DETAILS OF INSTALLATION, FIBERGLASS AND CSW EQUIPMENT INSTALLATION

2. BULKHEADS RETOLOCATED AND STRENGTHENED

3. SHIP ENGINE FORWARD

4. HATCH ENLARGED

MODIFICATION DRAWN BY C.A.T. COCHIN

PELAGIC FISHERY PROJECT, COCHIN 16-
MODIFICATIONS TO INCORPORATE
CHILLED SEA WATER SYSTEM

I. SEE DRAWING 132G-CSW-3 FOR DETAILS OF INSTALLATION, FIBERGLASS AND CSW EQUIPMENT INSTALLATION

II. BULKHEADS RETOLOCATED AND STRENGTHENED

III. SHIP ENGINE FORWARD

IV. HATCH ENLARGED

MODIFICATION DRAWN BY C.A.T. COCHIN

45°-6° TRAWLER WEST COAST TYPE
Fig. 8 - 43 1/2 ft trawler/purse seiner: details of modifications for CSM system