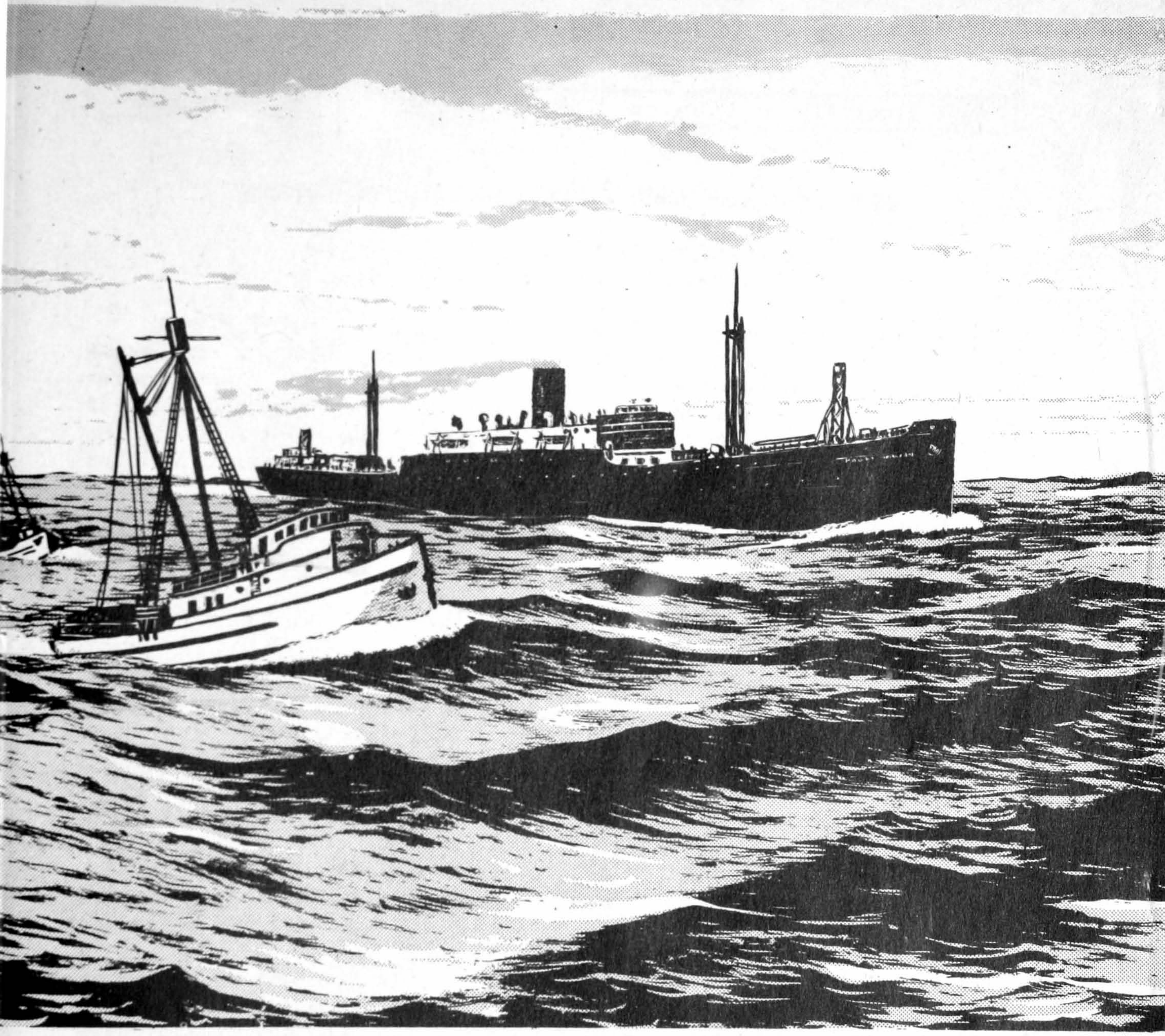
SUGGESTIONS FOR OPERATORS OF TUNA RECEIVING SHIPS



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SUGGESTIONS FOR OPERATORS OF TUNA RECEIVING SHIPS

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The Pacific Explorer, a factory ship equipped to dry freeze and store tuna returned in July 1947 to Astoria, Oregon, from Costa Rican waters with a near capacity cargo of 2,250 tons of tuna. This was the initial or "shakedown" trip for the converted vessel and, as was expected, many technical and operating problems became evident. A discussion of these problems, suggestions on good practice, and possible future techniques should be of interest to all who operate in tropical waters and, more particularly, those companies which as a result of the Pacific Explorer's trip are now actively engaged in fitting out vessels for a similar purpose.

SUGGESTIONS ON EQUIPMENT

The operation and maintenance of mechanical and electrical equipment in tropical harbors and seas was found to be much more of a problem than would be anticipated in northern waters. Operators of tuna receiving ships may find it necessary to make arrangements with fishing vessels which have not had previous tropical service. Observance of the following precautions will avoid many difficulties:

1. A fishing fleet comprised of both live bait boats and purse seiners is advisable to round out production. A receiving ship must have sustained and near capacity landings to prove profitable. The landings of fish on the Pacific Explorer were highly erratic in time and volume depending on the availability of bait and the fishermen's degree of good fortune. During certain periods when bait was available and the fish were biting, the bait boats were consistent producers. However, the purse seiners as a group and for their period of operation had a more consistent production record despite numerous difficulties regarding their legal status in Costa Rican waters.

2. Lost production time by the fishing vessels prolongs the voyage of the receiving ship and consequently it should concern the buyer as well as the fisherman. The operators of receiving ships should insist that the fishermen have proper equipment or else be prepared to face the

consequences of needlessly lost time and disharmony. Failures of electrical equipment were the greatest single class of operational difficulties on vessels fishing for the Pacific Explorer and these generally occurred on equipment having temperature rise and insulation ratings unsuited for prolonged service under moist tropical conditions. Marine type motors with a grade of waterproof enclosure to suit the location and with insulation of the highest caliber material rated at a 50 degree C. temperature rise in a 50 degree C. ambient temperature (surrounding temperature of 122 degrees F.) should be used. Since even this grade of insulation will not necessarily prevent moisture penetration, the motors and generators should be fitted with strip heaters which automatically become energized when the equipment is idle. In addition to spare mechanical parts, each fishing vessel should carry spare electrical parts such as armatures, field coils, brushes, and bearings for the smaller motors, and also the larger ones of questionable ratings. The loss of fishing time because of equipment failures is a tragic and expensive experience.

3. The refrigeration systems on fishing vessels not having previous tropical service must be subject to a careful analysis before venturing them into the southern tuna fishery. The condensers might well be of inadequate capacity in the tropics with the consequent cooling water of higher temperature. The compressor plant should be suited to maintain temperatures in the hold in the 0 to 10 degree F. range and spare equipment should be available in case of a breakdown. The system must have adequate capacity to freeze the fish and this condition must not be unduly affected by the addition of fresh, warm fish. It is advisable to have adequate capacity to reduce the temperature of the fish below 22 degrees F. in a few days' time. The fish holds should be fitted with a minimum of 1¼-inch diameter coils on 8-inch centers. While it is not common practice on ice boats, coils should be fitted to the athwartships fish pen partitions as well as the common arrangement of coils on the deck head, skin and floor of the holds to obtain more adequate refrigeration. In acquiring a fishing fleet, preference should be given to brine type boats, other factors being equal. If vessels having sub-standard refrigeration must be used, they should land fish at no longer than 10-day intervals. Unfrozen fish packed in ice can be more rapidly unloaded than frozen fish.

4. Bait vessels having a capacity of less than 1,000 scoops of bait will be limited in their operations; those carrying less than 600 scoops will be considerably handicapped; and boats carrying less than 300 scoops will have two strikes against them before even starting operations. Bait was unusually difficult to obtain in Costa Rican waters during the first half of 1947 but fortunately the opening of the Panama bait grounds eased the situation. Even if these grounds remain open during a proposed period of operations, it may be necessary for the vessels to run considerable distances before finding tuna. The most successful bait boat fishing for the Pacific Explorer expended an average of about 45 scoops of bait per ton of tuna. The best fishing encountered on any one trip required 23.5 scoops per ton of tuna with 9 men fishing. The fishermen frequently found it necessary to expend 200 scoops of their meager supply in test fishing of various schools before finding one that was worthwhile.

5. Many of the vessels fishing in more northern waters probably have insufficient bait-water pump capacity for southern tuna operations. Standard practice indicates that a complete change of water in the bait tanks at no longer than 10-minute intervals is necessary. This may be roughly checked by a calculation of the pump and tank capacities or determined by dumping a bottle of ink into the tanks and observing the time required for the color to disappear. If the pump capacity is inadequate, the quantity of live bait must be reduced under that possible in northern waters and the period of survival may be appreciably shortened. Northern vessel operators must remember that a scoop of the larger southern anchovitas contains a far smaller number of fish than a scoop of northern anchovies and will consequently afford less fishing. A spare bait pump is highly desirable, for the loss of a baiting due to failure of the equipment is a discouraging experience.

6. Adequate forced draft ventilation is mandatory in the engine rooms and highly desirable in the living spaces of fishing vessels intended for tropical service. A fan capacity and air ducts capable of effecting a complete change of air in the engine rooms at a maximum of 4-minute intervals are necessary. If an engineer is to be maintained on constant watch, a cooling air duct must be directed at his usual station.

7. Despite all precautions, breakdowns will occur on the fishing vessels and many of the small ones may not carry personnel of sufficient skill to make the necessary repairs without supervision or assistance. The receiving ship should carry an experienced electrician and a machinist among the crew to facilitate repairs. The electrician of the Pacific Explorer recommended that the following AC-DC testing and general equipment should be available:

- Ammeters with shunts to 300 amperes
- Clamp-on type ammeter
- Voltmeters
- Millivolt and ohm meter
- Growler for armature testing
- Test switchboard, AC-DC, 6 to 220 volts
- Pocket compass for checking polarity
- Battery charger
- Electrical spares for speed boats
- Presto-lite tank
- Assortment of electrician's tools

The usual assortment of machine tools such as a small lathe, drill press, press, welding equipment, and a shaper should also be carried to facilitate minor mechanical repairs.

8. The refrigeration and auxiliary capacity of the receiving ship should be at least 50 percent in excess of the maximum calculated requirements as atmosphere and water temperatures and other conditions may

necessitate operating the equipment below the anticipated performance levels. Also emergencies will arise and temporary handling of the fish by other than the regular method may be necessary. The capacity of the condensers will be reduced after a period of operations because of the accumulation of marine growths. It is thought that the condenser design should be based on a cooling water temperature in excess of 87 degrees F. and 50 percent of the estimated flow of water. Cleaning of the sea chests on the Pacific Explorer was necessary after a period of 4 months and fortunately a diver was available at Puntarenas, Costa Rica. Practical considerations prevented the cleaning of the condenser service lines. Initially the pressure of the supply water at the condenser was 80 pounds per square inch. This was gradually reduced to 30 pounds as marine growths accumulated but, upon cleaning of the sea chests, the water pressure rose to near its original reading.

9. The use of a brine rather than a dry freezing system may be more advantageous because a reserve of cold can be established during periods of low landings, a higher rate of heat transfer can be achieved, and greater quantities of fish can be frozen in a given space. Furthermore, the amount of labor required to stow fish in brine freezers should be far less than in the dry freezers on the Pacific Explorer. The cost of installing all brine wells on a receiving ship may be prohibitive and a combination of freezing wells and dry storage may prove more economical. A discussion of possible complications under the latter system is included at the end of this article.

10. It is obviously necessary to handle fish in the most economical manner. It will be advantageous to effect working agreements with the fishermen and allied unions as these groups are experienced in handling fish and will be more sympathetic with the purposes. If operating agreements will permit, the fish should be delivered to the deck of the receiving ship by the fishermen as is customary on shore installations. Inverted L type cranes or conveyors should be installed to avoid the need for a signal man to direct the winch operator of the conventional type of ships rigging. The fish should pass over a grading and marking table to facilitate adequate inspection and marking for subsequent identification of the fish. The fish may be weighed on a series of platform scales after grading or a dynamometer scale can be attached between the fish box and the unloading cable. A convenient system for distributing the fish to the freezers and eventually to the storage rooms should be arranged. A series of small loading hatches over the storage rooms may prove advantageous if a combined horizontal and vertical flow of fish is practical. The use of a portable belt and blade type of inclined conveyor may be advantageous for stacking fish at heights above a convenient working level. Such conveyors, to be effective, should have a restraining trough at least 10 inches in width.

11. Thoroughly frozen tuna preserved in ice aboard the fishing vessels can be quite roughly handled without undue external damage. Frozen tuna at a temperature of 0 degree F. were dropped for a distance of 20 feet as a temporary emergency measure; however, the use of chutes was far more

desirable. Tuna frozen in brine must be handled more gently than those preserved in ice on the fishing vessels because of salt penetration in the surface layers of the fish. Both fresh and frozen tuna were found to slide very well on inclined and smooth-surface sheet metal or wood chutes but a type of roller chute normally used for transporting case goods was not satisfactory. Frozen tuna dropped for the level of 1 deck (about 11 feet) on smooth chutes at an angle of about 30 degrees from horizontal were projected for distances of 30 to 40 feet inside the lower room from the starting point. The wooden chutes were made as an emergency measure and they were only useful for a short period of service. Any sheet metal chutes should be well reinforced with angle and bar iron as they will necessarily be subject to rough usage.

12. A system of air circulation must be provided if overhead coils are to be used in the storage rooms. This can be accomplished by stacking the fish on gratings and attaching battens to the side walls. A free air circulation space of 6 inches along the side walls and 4 inches under the gratings is thought to be adequate. Better practice, according to Mr. Otto Young of the Pacific Experimental Fishery Station at Vancouver, B. C., would be to install a solid baffle of some material such as plywood between the battens and the walls with air circulation spaces above and below the baffle. This would permit a rising column of air on the warm or hull side and a falling column of cooled air on the fish side. If cooling coils are used on all the storage room surfaces, air circulation should not be as pertinent a factor.

The observance of these precautions and the selection of otherwise suitable vessels manned with at least a portion of experienced southern tuna fishermen will materially reduce the operational problems of the receiving ships and the fishing vessels.

SUGGESTIONS FOR MAINTAINING QUALITY OF TUNA ON RECEIVING SHIPS

Quality control will be a significant factor in purchasing, freezing, storing and transporting tuna by receiving ships. Vessels selling fish to the Pacific Explorer demanded "cash on the barrel head." It was the responsibility of the buyer to ascertain that the fish were of good quality and to maintain them in good condition. Since tuna is a perishable product, it behooves the buyer to take adequate precautions. Observations and studies on the Pacific Explorer indicate that the following precautions should be taken:

1. From 1 to 3 quality control men, depending on the size of the operation, should be employed and it is necessary that they have no other duties than quality control. They should only be responsible to the management of the vessel and if differences arise which cannot be settled aboard the ship they should be referred to the home office. They should maintain a complete history on each lot of fish received, its routing through the

freezers and final destination in storage. Their records should include the daily catches of each vessel; the ratio of ice to fish used on the fishing vessel; condition of the fish in the hold, whether frozen or not; whether a surplus of ice is present or absent; internal temperatures from a random selection of the fish as landed; internal flesh and stomach cavity examinations of random fish for the degree of freshness; routing through the freezers; time of freezing; internal temperatures of the fish when removed from the freezers; adequacy of the glaze; and storage room temperatures. Test cores should be periodically taken from the stomach cavities of random fish in storage to determine their condition.

2. A data sheet on plant operation should be prepared each day and incorporated in the records of the management and the quality control men. The sheet should contain complete operational data on the refrigerating equipment and the power loads. Each watch in the compressor room should at 4-hour intervals record the significant operational data, such as temperatures and pressures of the refrigerant at the various stages, condenser data, machines operating, electrical power requirements, purging, lubrication, oil removal, shutdowns, and other pertinent factors. The records of the Diesel-electric plant should cover the machines operating, power and amperage output, voltage, any interruptions of service and their cause, and other routine operational data. A cold storage log should also be kept of the day's activities and the movements and condition of the fish. It is assumed that most operators of receiving ships may find it advantageous to insure the cargo and these records will facilitate the settlement of any claims. If the quality control men only reduce the spoilage by 1 percent their employment is a profitable arrangement.

3. The ice boats should use a quantity of ice at least equal to or in excess of half of the tonnage of fish landed. In the ice-mechanical refrigeration system, the function of the ice is to rapidly lower the temperature of the fish to the freezing point, while the dual function of the mechanical refrigeration is to preserve the ice, when en route to the fishing grounds, and then to hold and eventually freeze the catch. The heat of melting of ice is 144 BTU per pound and the temperature of freshly caught tuna is near or above that of the ocean. Thus 1 pound of melting ice under ideal conditions can only lower the temperature of approximately 2.6 pounds of fish from 87 to 32 degrees F. Considering the large size of the fish and the unequal distribution of ice, such ideal conditions cannot be attained and a surplus of ice must be used. Furthermore, the refrigerating coils must remove heat through a large volume of fish having a considerable resistance to heat transfer. There is a tendency among tuna fishermen to believe that the quantity of ice necessary when fishing for a local market is lower than for long range operations. This concept is untrue for the receiving ship is an equally long range operation and even a greater period of time may be involved.

4. "Marine bacteria can grow at lower temperatures than any other bacteria on record." 1/ Bacteriologists who have studied the spoilage of fish are in general agreement that the total number of bacteria continues to increase at temperatures above the range 18 to 22 degrees F. Within this range, the total number will remain relatively constant or be slow to change. Below this range, there is a tendency for the total number to decrease somewhat with prolonged storage but freezing and storage in the normal ranges will never kill all the bacteria which are present. "The bacterial decomposition and bacterial growth rate at 30 degrees F. is only about half of that at 36 degrees F." 2/ "It takes 6 days at 32 degrees F. for bacterial numbers to reach the same stage that they would at 68 degrees F. in one day." 3/ Thus, the internal temperatures and the period of time elapsing since the death of the fish are significant criteria in their acceptability. The quality control men should receive daily reports via radio on the activities of the vessels to establish the history of the fish.

5. The quality of any lots of fish having an internal temperature appreciably in excess of 32 degrees should be carefully investigated. If the fish are of recent capture, it may be granted that an insufficient period has elapsed to permit cooling the fish. If there is no surplus of ice, the grading efforts must be intensified. Durable dressed fish such as halibut undergo noticeable deterioration when stored in melting ice for periods of 12 to 16 days. A more serious situation can be expected in round tuna stored at similar temperatures.

6. Some minimum criteria must be established on the amount of preservative care or work which the refrigeration systems of the fishing vessels must perform. The temperature of any tuna should be below 20 degrees F. for suitable preservation. 4/ Any tuna more than a week out of water and having an internal temperature appreciably in excess of 25 degrees should be viewed with suspicion as to its quality until more information on grading aboard receiving ships has been accumulated. In freezing fish muscle, the greatest destruction of tissue occurs in the range of temperatures between 30 and 23 degrees F. and the temperature should be lowered through this range with the greatest possible speed, according to Mr. Otto Young of the Pacific Experimental Fisheries Station.

1/ Hess, Ernest. Cultural characteristics of marine bacteria in relation to low temperatures and freezing. Contr. Can. Biol. Fish., N. S. 8 459-474, 1933.

2/ Hess, Ernest. The influence of low temperatures above freezing upon the rate of autolytic and bacterial decomposition of haddock muscle. Contr. Can. Biol. Fish., N. S. 7, 149-163, 1932.

3/ Bedford, R. H. Ice for fishing vessels. Biol. Bd. Can., Progress Report Atlantic Stations, No. 6, 3-5.

4/ Conclusion and summary of detailed progress report no. 2 on the refrigeration of tuna. H. C. Godsil. State of California, Department of Natural Resources, Division of Fish and Game, California State Fisheries Lab.

7. Common practice dictates that tuna should not be left on the deck of fishing vessels for more than two hours before stowing in the holds. Even shorter periods of leaving the fish on deck are more desirable and should be adopted when conditions permit. No fish should be accepted which has not been iced or otherwise refrigerated, regardless of the period reported as elapsing since it was captured. "In one instance, 5 hour old fish put into an uniced hold had bacterial counts of 61,000,000; 30,000,000; 33,000,000; and 16,000,000 bacteria per ounce of skin. Another batch, properly cleaned, washed and iced in a clean hold had bacterial counts of 6,000 to 9,000 per ounce of skin, after 10 hours." 3/

8. The holds of ice boats should be thoroughly cleaned and disinfected after each discharge of cargo, and the bilges should be kept as dry as possible. "In two boats examined, one had 300,000,000 and another had 140,000,000 bacteria in each teaspoon full of bilge water. This is a serious source of contamination." 3/ The situation will probably be less serious in the case of brine boats where batches of brine are circulated through the fish. The wells should be thoroughly cleaned before a bait well is converted to fish storage and cooling brines exhibiting cloudiness should not be reused.

9. If brine vessels making frequent landings are used, the possibility of wet storage of the fish should be further investigated to facilitate unloading. An experimental quantity of tuna was held in one of the brine boats at a temperature of about 25 degrees F. for a period of nearly 2 weeks and these appeared to be of excellent quality judged by the color of the gills, clearness of eye and external sheen. The quality of fish preserved by this method should be carefully studied and the temperature should be maintained at less than 20 degrees F. for if the tuna are tightly packed in the wells, the brine may channelize and spaces with no circulation may develop at the skin and upper corner of the wells. Local spoilage may contaminate the contents of the well.

If brine purse seiners are used, experiments should be conducted along the lines of carrying ice in the wells to provide a refrigeration reserve to assist in the rapid cooling of the large catches involved. A pound of ice in sea water has the theoretical capacity of being able to cool 144 pounds of fish through 1 degree F. The theoretical cooling capacity of 7.2 tons of ice is sufficient to reduce the temperature of 20 tons of tuna from 87 to 35 degrees F. If sufficient ice is used to rapidly cool the fish to 40 or 45 degrees, an improvement in quality should result and the temperature of the entire catch can be more rapidly lowered to reasonably safe limits in a shorter time and with a smaller load on the mechanical refrigeration system.

10. Any soft fish, those having off colors externally or in the gill cavity and dull appearing eyes should be carefully checked for quality. Such fish may be found in the catches of either bait boats or purse seiners and may be the result of too great a period elapsing from killing to cooling, or inadequate refrigeration. A period of 8 to more than 10 hours may elapse

between setting and stowage of the last fish when catches of 50 tons and over are made by "ice boat" purse seiners. With an all brine boat, this period could be nearly cut in half. As time passes an increasing proportion of the fish remaining in the net will be dead and these will pass through the stage of rigor and eventually become soft. Fresh killed fish are firm but pliable, those in rigor are stiff and the fish progressing to the soft stage are also characterized by a deterioration of the external color. An observation on a purse seiner indicated that very few soft fish were encountered in brailing until a period of 6 to 8 hours had elapsed. After a period of 10 hours an appreciable proportion were still alive but it was estimated that 30 to 40 percent had reached the end of the stage of rigor. Since it appears possible to make large purse seine catches off Central America, "all brine" boats should be favored.

11. The fish should be landed on a grading table aboard the receiving ship, rather than on the deck or directly into the freezing chambers, to permit close observation of the individual tuna and enable the fishermen to mark their fish if such a scheme is adopted. Only firm or frozen fish with a known history should be accepted with a minimum of inspection. Periodic incisions should be made in the body cavity and the flesh of random fish and all those of questionable quality to ascertain the degree of freshness. Any traces of off or foul odors should place the fish in the classes of dubious or reject quality, and the possibility that off odors may be caused by certain types of feed should be exposed. These odors cannot be expected to decrease on freezing and a period of storage.

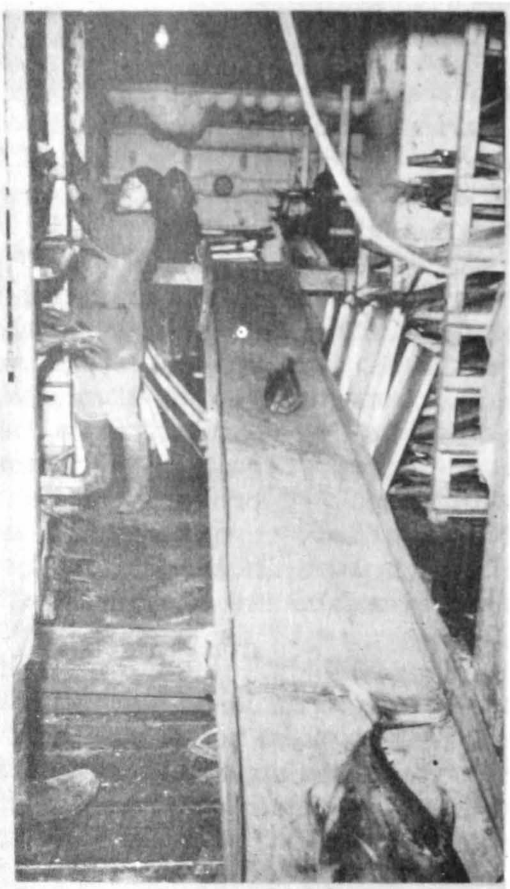
12. Split fish are thought to result as a purely physical phenomena and are not necessarily of poor quality. The freshly cooled external surface is probably under contractive stress as compared to the warmer interior, and local pressure may cause an extensive rupture of the skin as well as the underlying flesh. If the fish are to be dry frozen, the break is probably of little significance but a degree of salt penetration can be expected if the fish are to be frozen in brine. A broken back bone near the tail is not thought to have an adverse effect on quality but a break in the middle or upper portion of the spinal column indicates unduly rough handling and should be regarded with suspicion because of possible bruising and rupture of the body cavity.

13. While it is not common practice to wash tuna prior to storage in the fishing vessels, it is thought that the quality of the frozen fish could be improved by washing prior to freezing. Unfrozen tuna as landed have a considerable surface layer of slime and some loose scales which probably support extensive cultures of bacteria. Introducing these into brine freeze wells or the storage rooms is not expected to enhance the quality.

14. Some means of identifying the origin of the fish, which may be readily applied but will not be obliterated by rough handling, should be adopted to permit subsequent identification. Marks on the heads or tags may become ineffective but it was seldom that whole fins or tail sections were lost on the cargo of fish landed by the Pacific Explorer. A sufficient

number of variables should be possible by removing fins and tail sections to provide markings for an adequate fleet. Time and effort would be saved if the fishermen could be induced to pro-rate the losses on the basis of fish delivered to the ship. However, a system of marking will be of inestimable value in determining quality control measures for future application.

15. The charge in any freezer should not exceed the ability of the unit to lower the temperature of the fish to safe limits within a reasonable time. The accepted temperatures for storing fish are at zero degrees or lower. The internal temperature of tuna, frozen in properly operating shelf or blast freezers, should be lowered to zero in a period varying from 14 to 36 hours depending on the size of the fish. The maximum charge in any blast freezer must be carefully regulated or excessive defrosting problems will be encountered. A charge of 15 or more tons of tuna in a blast freezer,



LOADING TUNA IN THE BLAST FREEZER

having a cooling unit of approximately 930 feet of $1\frac{1}{4}$-inch diameter fin coils caused excessive defrost problems. Approximately 15 tons of tuna could be frozen on shelf coil units having a coil surface of about 5,800 feet of $1\frac{1}{4}$-inch diameter pipe. Shelf freezers mainly depend on direct contact and convection currents for their efficiency and fish placed on the floors of such rooms will not freeze as rapidly as those on the coils. The floor of a shelf freeze room may actually be a source of heat and is generally a warm surface as compared to the refrigerating coils. If emergency conditions render it necessary to overload such freezers, only the smallest fish should be placed on the floor and any fish so treated should be carefully checked to determine their rate of freezing. If the shelf freezers have adequate refrigeration capacity and it is necessary to increase their production, it would be more advisable to install circulating air fans to improve convection currents and only use the contact surfaces for freezing fish.

PILING FROZEN TUNA IN THE COLD STORAGE ROOM

16. Fish held in storage for prolonged periods should have a protective glaze of ice. A superior job could be done by individually glazing each fish but the process would be expensive. The tuna on the Pacific Explorer were glazed by periodically spraying either fresh or sea water, delivered by a common garden hoze and nozzle, over and through the fish as they were being stacked. As was expected, the glaze was not uniform but it was estimated to average about a sixteenth of an inch in thickness. While some small spots and areas of contact between the fish were probably inaccessible to the spray, there was no evidence of surface deterioration of the fish which could be attributed to a lack of glaze,

according to the cold storage workers at Astoria. The adequacy of the glaze should be periodically inspected as deterioration through oxidation and local dehydration of the flesh can be expected where the glaze is absent or insufficient.

17. Test cores should occasionally be bored from the stomach cavities of samples of tuna held in storage to ascertain their condition. The test cores should be examined for odor in the thawed state. Fish purchased in foreign waters, declared in foreign ports, or subject to duties by foreign governments will probably be classed as imports by our Customs Service and will be subject to inspection by the Food and Drug Administration, as was the case with the cargo of the Pacific Explorer. Essentially, their test of quality requires that there shall be no off odors from test cores and holes bored in the body cavity. Observations on the preliminary testing to segregate the fish into lots for Food and Drug Administration approval revealed that a sharp pungent odor was present in the rejects, while the cores from the fish thought to be acceptable had a sweet "fishy" odor. Fish which might be of questionable quality exhibited a slight off odor ranging from sour to that characteristic of salt fish. For future reference, the quality control men should make investigations to determine if particular types of off odors from the stomach are characteristically associated with certain types of feed. Experimental lots of fish should occasionally be dressed and frozen to determine if the value of the required labor will be returned in a better quality product and reduced spoilage.

The quality control men should have at least 6 metal shielded penetration thermometers and a dozen spare thermometer inserts for the frames, a thermocouple type of thermometer, and spare batteries, and several salometers if brine freezing is contemplated. A direct reading type thermocouple instrument is manufactured by the Leed Northrup Company. This and a heavy duty type of copper-constantan wire contained in a single, waterproof-enameled, and woven-fabric casing is recommended for use aboard ship. At least 500 feet of this wire should be purchased as it will be exposed to rough usage. If the machinery induces appreciable vibration in the hull, the thermocouple instrument should rest on a sponge rubber pad when readings are taken. The thermocouple system is an extremely valuable aid in determining the rates of freezing of fish, when they are frozen, and the temperature conditions of the fish in storage since the readings can be taken at a remote point. A small power drill is also necessary for taking test cores and inserting wires in thoroughly frozen fish. Other simple tools required are a hand type spring scale, an ice pick, a hammer, and a sharpened plastic-handle screw driver. The ice pick can be used as a rough index to determine if the fish are sufficiently frozen for stacking. Tuna at zero degrees are very resistant to penetration by an ice pick but they can be penetrated to some extent at a temperature of 15 degrees. The hammer and screw driver can be used for making holes in partially frozen fish for the insertion of thermocouple wire or penetration thermometers. A small retort should also be available to make test precooks of fish if suspicious circumstances appear.

The quality control men should be selected on the basis of scientific background and a knowledge of the tuna fishery. The senses of smell, touch and vision are now and probably will remain most effective for determining the quality of fish for some time to come. However, the scientific approach, a knowledge of the principles causing the deterioration of fish, how to spot lots needing more intensive grading, and how to detect possible future trouble are of extreme importance.

SUGGESTIONS ON BRINE FREEZING OF TUNA

Very little technical work has been done on brine freezing of fish and these remarks must be regarded as speculative. In the normal freezing operation on brine boats, the tuna are frozen and cooled in a medium of sodium chloride brine to a temperature range of 15 to 22 degrees, depending on conditions and then they are held in dry storage with the eventual reduction of the temperatures to the range of 5 to 15 degrees. The tuna become a solidly frozen mass and are difficult to remove without thawing or damage to the fish. The expense of removing fish in this condition from the freeze wells prior to storage in the conventional type of dry holding room may be prohibitive. It will be necessary to freeze the fish in dense brines and it may be necessary to avoid excessive packing to prevent the fish from freezing together. Table 1 lists the gravity and freezing properties of sodium chloride brines in the range of solutions which may be considered.

TABLE 1.--Gravity and Freezing Temperatures of Sodium Chloride Brines

Gravity			Freezing Point	Pounds NaCl	
Baume	Specific	Salometer	Degrees F.	Per cubic feet	Per gallon
13.6	1.103	52.6	13.9	9.63	1.29
14.5	1.111	56.8	12.0	10.40	1.39
15.4	1.118	60.0	10.2	11.17	1.49
16.3	1.126	64.0	8.2	11.95	1.60
17.2	1.134	68.0	6.1	12.74	1.71
18.1	1.142	71.7	4.0	13.55	1.81
19.0	1.150	75.2	1.8	14.36	1.92
19.9	1.158	79.1	-0.8	15.18	2.03
20.8	1.166	82.8	-3.0	16.02	2.14
21.7	1.175	86.8	-6.0	16.85	2.26
22.5	1.183	90.2	+3.8	17.71	2.37
23.4	1.191	94.0	+16.1	18.58	2.48

An inspection of Table 1 indicates that it should be theoretically possible to lower the temperature of the fish to 0 degrees F. in a cold brine solution. However, several practical difficulties may render this unfeasible. A brine with a freezing point of -6.0 degrees is near the "critical point" and a small amount of additional salt or a dilution from such a source as adherent moisture on the fish will cause a rise in the freezing point. The temperature of the refrigerant must be above the freezing point of the brine or the coils will become coated with ice, resulting in a pronounced lowering of their efficiency. A significant temperature differential must also exist between the brine and the fish if a reasonable rate of cooling is to be expected. Accordingly, it may not be practical to lower the temperature of the fish below the range of 10 to 15 degrees F. When operating the ice making tank of the Pacific Explorer, it was not feasible to maintain a brine temperature of less than 5 degrees F., despite the high velocity of the brine through the refrigerating coils.

The dense brine needed to freeze and cool the tuna will have a buoyant effect which may cause the fish to pack at the top of the conventional type of freezing well. Surface films of slime and water of low salt content may be expected on the fish. These circumstances may cause the fish to freeze together and further restrict the practical limit to which the tuna can be cooled. A high brine velocity or individual admittance of the fish to permit freezing of the surface films may avoid such difficulties if they occur.

If the tuna cannot be cooled to a temperature near zero other operational difficulties may be encountered. It may be necessary to cool the fish either on the floor of a storage room or after they are stacked. Tuna in the 15 to 20 degree temperature range are relatively soft by comparison with those at 0 degrees and will be more susceptible to injury from rough handling.

The temperature of the fish can be reduced by the holding room coils after stacking but the process will be slow because of the large mass. Successive additions of comparatively warm fish will disrupt the temperature of the holding rooms and cause unusual dehydration. If the tuna cannot be adequately cooled in the brine wells, a cooling room having considerably greater coil surface than a normal holding room should be considered. Forced air circulation will be advantageous under such conditions.