

8 to 10 in. on centers (6¼ to 8 in. for 1 in. pipe) above the water line, and from 12 to 18 in. centers (9 to 14 in. for 1 in. pipe) below. Coils for the forward and after bulkheads are also on from 8 to 10 in. centers for 1¼ in. pipe and from 6¼ to 8 in. for 1 in. pipe. The least heat through any area comes from the floor of the hold because of the insulating effect of the bilge, so this area is lined with coils on from 12 to 18 in. centers for 1¼ in. pipe and from 9 to 14 in. for 1 in. pipe. The shaft alley enclosure on the hold floor is similarly lined with coils. Another source of heat gain is through the hatch walls and cover. About all that can be done here is to put 1¼ in. coils on 6 to 8 in. centers (5 to 6¼ in. for 1 in. pipe) around all four faces of the hatch.

Most of the piping, except perhaps that under the deckhead will be immersed in ice and water, so a heat transfer coefficient, U , of 10 Btu per (hr) (sq ft pipe surface) (F deg td), may be assumed as average.

On Refrigerant 12 installations, steel pipe is preferred to hard drawn copper tubing coils because of the superior strength and resistance to abrasion and physical damage of the former in the severe hold service. Fig. 11 shows a typical coil and equipment layout for a single hold purse seiner. The direct-expansion cooling coils are normally divided into at least five circuits with a thermal expansion valve set for each circuit. Usually the overhead coils, including the hatch coils, are divided into 2 circuits. The forward and after bulkhead coils and the skin coils are divided into two more circuits. The floor and shaft alley coils make up the fifth circuit, and these are flanged and made removable for the sardining season.

Although standard marine type refrigerating equipment is sometimes used, the cramped quarters and odd sized spaces available for locating equipment usually require specially built or adapted components. Due to the severe service caused by using sea water for condensing, special consideration should be given the condenser and condenser water pump. For best corrosion resistance, Refrigerant 12 condensers should be provided with cupro-nickel tubes and tube sheets. However, for ammonia, the galvanized flat-type marine condenser and receiver combination is ideal for the smaller fishing boats as it is durable and easy to clean.

The small seiners frequently use Refrigerant 12 equipment,

whereas the large boats, especially those equipped with brine wells, generally use ammonia.

At the start of the cooling down operation, the loaded hold will be at approximately 32 F from the crushed ice in which the fish are stowed. The refrigeration compressor should be balanced against the evaporator surface at an evaporating temperature of about 15 F deg below the hold temperature. After the heavy cooling down load is taken care of, the evaporating temperature will gradually lower as the hold temperature gradually drops and the fish partially freeze. Under favorable conditions the hold will finally drop to about 20 F with the evaporating temperature from 10 to 12 F deg below the hold temperature.

Tuna Clippers

Typical California tuna clippers are outfitted for three or four months which is necessary for the round trip to the best tuna fishing waters. Some travel 2500 miles to the Galapagos Islands off the coast of Peru.

The hold of the tuna clipper is divided into steel wells or tanks arranged on both sides of the shaft alley. The wells have about 5 in. of insulation. On wooden vessels, the wells are constructed of five inch wooden planking except on the sides adjacent to the skin of the ship where only two inch planking is used. These wooden wells are uninsulated, but the combination wells for fuel oil as well as tuna are of steel and insulated. The shaft alley is used for pipe lines, control valves, brine pumps, and numerous other mechanical devices all tightly packed together in a very limited space. The tanks are lined with cooling coils and each is equipped with a brine circulating pump, sea water inlet and outlet, and connections to the brine transfer lines (Fig. 12).

Besides the regular fuel oil tanks, additional fuel oil is carried in some of the fish wells, as the permanent fuel tanks cannot carry enough fuel oil for the long trip. The remaining fish wells and bait tanks on deck all carry live bait. The bait is caught off the coast of Mexico, or near the fishing grounds, in coastal waters not far off shore. The bait must have constantly circulating fresh sea water to keep it alive. As the bait and fuel are used, they are replaced by the tuna.

The bait water circulating system lists high in importance to the successful operation of the tuna clipper. The whole fishing operation depends upon the live bait which is used to

attract the tuna. If the circulation of bait water stops for as little as 15 min., the bait will die. Enough sea water must be pumped to the bait wells and tanks to completely change the water five times each hour. Bait pumps are provided in duplicate, and each pump is capable of delivering the full volume required. The bait pump suction is taken from the sea chest, and fresh clean sea water is pumped to each of the wells and deck boxes where bait is carried. The bait water outlet from each well and tank discharges overboard.

The wells are prepared for receiving fish by filling with fresh sea water and chilling to 29 F with the refrigeration system. As sea water freezes at about 28 F, it is not practical to cool below 29 F in the preliminary chilling operation. Before the first well is completely full of fish, the second well is filled with fresh sea water, cooled down and made ready for loading. With the refrigeration operating and the brine recirculating, the fish are chilled down to 30 F internal temperature in 24 to 72 hr. This preliminary chilling time varies with the individual operator. Some desire to chill the fish as rapidly as possible. Others prefer a 3 day precooling period feeling that the longer time for chilling seals the pores of the fish better. This prevents an excessive salt penetration which may increase freezing time when dense brine is used in the later freezing process.

The next operation is to strengthen the brine so that the fish may be frozen at a lower temperature. This is accomplished by dumping salt (sodium chloride) directly into the well. It requires about 100 lb of salt for each ton fish capacity of the well. This makes dense brine of the sea water, the dense brine having a specific gravity of 1.126, a specific heat of 0.833, and a freezing point of 8.2 F. A cubic foot of the dense brine and fish mixture weighs 70.5 lb of which 50 lb is fish and 20.5 lb is brine.

In a matter of two or three days of operation with the dense brine and additional refrigeration, the internal temperature of the fish reaches 20 F or lower; as the brine temperature is maintained at about 18 F. The fish becomes rigid due to about 75 percent or more of their water content having become frozen. The dense brine solution is then pumped to another well for re-use, though in some cases it may be pumped overboard if badly contaminated with fish slime and blood. After brine freezing, the well is drained of dense brine and the temperature of the fish may be further reduced by the

refrigeration coils only. The fish are maintained in a dry frozen condition at 18 F or lower until port is almost reached. About one day from home, the circulation of sea water may be started through some of the wells so that the tuna will be sufficiently loosened from each other to start unloading. The fish must be thoroughly thawed before entering the cannery processing line. Steel buckets are lowered into the wells and the fish are manually thrown into the buckets. Power winches lift the buckets to the wharf. The fish are unloaded into flumes which carry them to the weighing tank and then into the cannery.

For this type of refrigeration duty, each tuna clipper generally has three or more refrigeration compressors driven by electric motors, and three different suction lines; one for 29 F brine, one for 18 F brine, and one for holding. Each fish well and tank is connected to each of the 3 suction lines, and the ammonia compressors are cross-connected so that any or all compressors may operate on any of the three different types of loads. Because of the desirability of parallel operation of compressors, ammonia is generally used as Refrigerant 12 compressors cannot be operated interconnected aboard ship because of oil problems.

Fig. 13 shows the general arrangement of a 105-ft tuna clipper. Three bait tanks, and one condenser tank forward of the bait tanks, are located on the after main deck.

Duplicate 10 in. bait pumps, each capable of delivering 2300 gpm of sea water against a 20 ft head and one 3 in. brine transfer pump capable of handling 300 gpm of sea water against a 50 ft head are provided. For emergency operation, the brine transfer pump may be cross-connected on the suction and discharge sides with the ship's general service pump.

Each brine tank, and each of the three bait tanks which are also arranged for freezing fish, are provided with a two inch brine circulating pump with shutoff valves on inlet and outlet. Each pump circulates 200 gpm of sea water against a 20 ft head. Pumps are mounted in the shaft alley. These pumps draw from the bottoms of the tanks and discharge into the hatches above the tanks through 2¼ in. galvanized piping. This circulation of the brine improves the heat transfer of the cooling coils and makes possible the rapid and uniform cooling and subsequent freezing of the fish.

A few clippers are provided with brine coolers in addition to cooling coils in the tanks. After the initial precooling of the

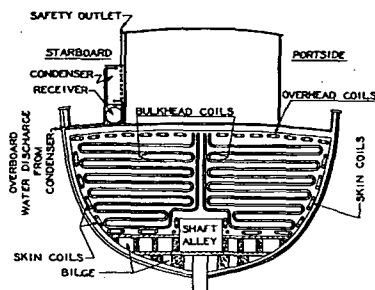


Fig. 11 Section Through Hold of Tuna Seiner Showing Piping

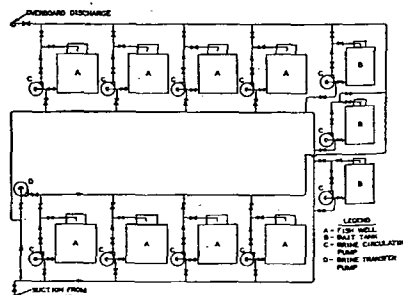


Fig. 12 Brine Piping for Tuna Clipper

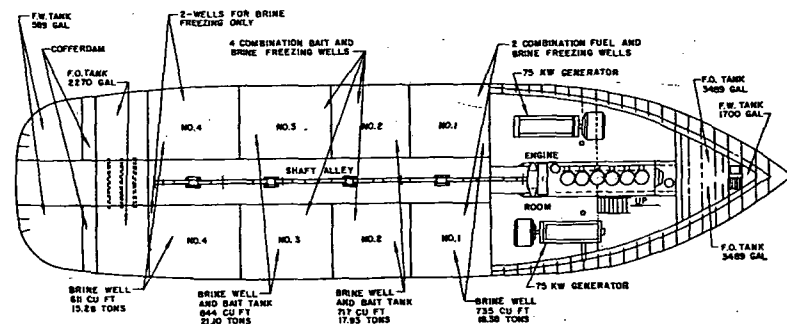


Fig. 13 Plan of Hold for 105-ft Tuna Clipper