rotating drums. Proper clearance between drum and bird is necessary to prevent excessive abrasion and beating of carcass.

Practically all poultry is now marketed in an eviscerated or ready-to-cook form, and New York dressed or uneviscerated poultry is of minor commercial importance. Evisceration immediately after feather removal is known as warm evisceration and is to be recommended because it speeds up subsequent chilling and completely prevents the development of visceral taints in the carcass.

It is desirable during the processing of poultry to emphasize good housekeeping. Ice, water and facilities used to chill poultry should be kept scrupulously clean. Because the housewife should be able to place the product as it comes from the store directly into the pan or oven, all precautions established for sanitary food processing should be observed.

Refrigeration in the Processing Plant

The internal temperature after being dressed in accordance with present commercial methods is approximately 100 F. The purpose of chilling is to retard deteriorative changes, and hence it becomes desirable to lower the temperature of birds as rapidly as possible. Inadequate chilling results in microbial growth leading to loss in quality and decrease in time that the product will remain salable. Poultry should be chilled to a temperature of approximately 35 F.

Two principal methods of chilling are commonplace in the industry at the present time. One method is chilling by means of direct contact with a cold liquid medium and the other is chilling in cold air. Only a minor fraction of all commercially processed poultry is air chilled at the present time. In general, air chilling will leave the skin rather dry with a 1 to 2 percent weight loss, whereas liquid chilling will leave the skin moist with a net weight gain. For air chilling, rooms are generally held at temperatures below 40 F and it is desirable to maintain temperatures as near 32 F as possible. Sweet and Stewart reported a method of chilling poultry in which stock was subjected to a brine spray for a short time. Before the birds in the test became completely chilled, they were transferred in some instances to a cooler and allowed to come to an internal temperature of 34 to 36 F. This was called the *cold-shock* method and, when a brine having a temperature of 20 F was used, chickens and turkeys were chilled in 25 to 35 percent of the time required in air at 35 F. Esselen *et al* studied the chilling and freezing rates of packaged and unpackaged ready-to-cook poultry in low temperature brines. Chilling in −20 F brine to freeze an outer shell of the bird, followed by holding in a 36 F room, was suggested as a rapid and effective method of removing body heat prior to freezing or marketing as a chilled product. Immersion times in −20 F brine for broilers, 12 lb turkeys and 22 to 27 lb turkeys were 6, 35 and 45 min, respectively. Connolly *et al* investigated cooling rates that could be produced by flowing cooled brine over or through the unpackaged eviscerated carcass. Cooling rates for eviscerated chickens by this method were considerably faster than those reported for air-agitated ice slush. Cooling with 25 F brine was not appreciably better than with 33 F brine. Cooling of eviscerated chickens by flowing brine required 15 to 60 min, while large eviscerated turkeys require 1 to 2½ hr.

Of the liquid chilling methods, the one most commonly employed involves the use of ice as the refrigerant. Poultry can be chilled in a very rapid manner in ice slush, in some cases at twice the rate that can be realized in air at the same temperature. Agitation of the ice slush with a stream of air results in an appreciable increase in rate of cooling. Adequate chilling rates are suggested by federal regulations which state that poultry carcasses weighing less than four pounds shall be chilled to 40 F or below in less than four hours; carcasses weighing four to eight pounds in less than six hours; and carcasses weighing more than eight pounds in less than eight hours. It has been pointed out by Bailey *et al* that cut-up chickens and eviscerated chickens, when ice is used, cool faster than dressed poultry. To cool poultry to 45 F, 112 min were required for dressed birds, 50 min for eviscerated birds and 25 min for disjoined or cut-up birds. The rapid chilling of poultry is advantageous in that it retards deteriorative changes and permits operators to place the stock in freezers or in the trade channels the same day it is dressed. The method of liquid chilling is useful and adequate, providing that the procedure is carried on properly. The temperature of the liquid should be kept below 35 F at all times during the chilling process, and the birds should be removed from the chill tank promptly after adequate chilling. Prolonged holding of carcasses in ice slush should be avoided, because it results in unnecessarily large amounts of water absorption by the meat, and in extreme cases by the leaching and loss of flavor constituents, as shown by the results of Pippen and Klose. The water in the chill tank should be kept clean and clear at all times, and the containers used for chilling should be thoroughly cleaned at least once daily.

If liquid chilling is adequately performed the poultry will be in good condition from a bacteriological point of view. Cook conducted an experiment in which five lots of poultry were chilled successively in the same water. The results showed that the bacterial counts generally tended to increase with each lot of poultry, but that the increase was not serious in view of the number of bacteria originally present. The water used in this experiment was held at 32 F. These results merely serve to indicate that bacteria will not grow rapidly in water held at temperatures that are desirable for ice slush chilling. Studies relative to the product itself, under commercial conditions of handling, demonstrate that it does not become unduly contaminated with bacteria during the ice slush chilling process.

The most common method of ice chilling is to use galvanized iron tanks in which the birds and crushed or flake ice are placed in alternate layers, using ½ to 1 lb of ice per lb of poultry. Sufficient water is added to fill all voids. This water is circulated by means of compressed air introduced through a perforated pipe or manifold in the bottom of the tank; or by a small circulating pump.

The proportion of ice to water required depends to a large extent on the temperature of the water available to fill the tanks. In locations where tap water temperature is normally high, a considerable saving in ice may be made by the use of a water chiller to provide refrigerated water.

In designing such a system it is, of course, necessary to determine the actual requirements of the plant, but the following will give some idea as to problems involved:

1. The quantity of water required is on the order of one pound of water per pound of poultry.
2. It is desirable to add water at quite a high rate—about 50 to 75 gpm.
3. The demand for water may be rather irregular.
4. The water used must be potable, so chiller and storage tanks must be designed to same standards of sanitation as any other potable water system.

In addition to the system of icing described above, some installations have been made using a system of piping and pumps to deliver a mixture of slush ice and water directly to the chill tanks. This system has been limited to installations including ice makers of a type which produce ice in the form of fine crystals mixed with a fairly high proportion of water. Some of the problems in the design of such a system are:

1. Plugging of lines and valves due to separation of ice and water.
2. Control of proportion of ice and water delivered to the chill tanks and in the circulating system.
3. Storage of the slush ice-water mixture to meet peak demands.

A major change in ice slush chilling techniques in the past several years has been the introduction of mechanical devices to agitate the carcasses or the ice slush or both, thus greatly accelerating the rate of chilling. Mechanical chillers permit a continuous operation in contrast to batch type tank chilling, and so offer the possibility of greatly increased efficiency. Careful control in the application of mechanically agitated chilling is required in order to avoid excessive absorption of water, and to provide adequate aging (tenderizing) times for products to be frozen and cooked from the frozen state. Continuous chillers vary greatly in their mechanical design, and include continuous drag chiller, in which the suspended birds are pulled or pushed through troughs containing agitated cool water and ice slush; parallel-flow tumble system, which involves passage of the free floating birds through horizontally rotating drums suspended in tanks of cool water and ice slush, the movement of the birds being regulated by the rate of flow of recirculated water in each tank; counterflow tumble system, in which the birds are carried through tanks of cool water and ice slush by horizontally rotating drums containing a helical drive on the inner surface of the drums; and oscillating vat system, in which tanks of cool water and ice slush are rocked from side to side as the birds are conveyed through by the flow of recirculating water. These mechanical chillers have been reported to be able to reduce the internal temperature of eviscerated broilers to below 40 F in one-sixth to one-half the time required with static tank chilling (Kotuls *et al*, 1960).

REFRIGERATION DESIGN DATA

The average specific heat of fowl is 0.8.

Cold storage rooms to await shipment at +35 F (temperatures lower than 32 F are apt to cause burns). The poultry crates are generally stacked five high close together and moved into the trucks or trailers by means of belt or roller conveyors. In shipping in transit, the poultry is generally iced in the crates.

Requirements for poultry plants expressed in pounds of ice per pound of poultry processed:

Poultry chilling[a]	0.4 –1.0
Icing poultry crates	0.25–0.35
Icing trucks and trailers	0.05–0.15
Total requirements	0.70–1.5

[a] The amount of ice actually needed to cool the poultry from 100 F to 32 F is only about 0.38 lb ice, the remainder being used to cool down the water used to make the slush, and to overcome heat gain from the air around the tank, air used for agitation, and other losses.

REFRIGERATION IN DISTRIBUTION AND RETAIL HOLDING

Marketing forms of chilled poultry are in general limited to whole, ready-to-cook and cut-up, ready-to-cook. In the first case, the chilled whole eviscerated carcasses are ice-packed in wooden cases in the processing plant, trucked to the retail store where they are cut up and packaged in a tray with a plastic film overwrap prior to their display in the refrigerated retail display case. This procedure may be replaced by the alternative cutting up and packaging in the processing plant. In some marketing channels, whole birds may keep better than the cut-up. Amount of drip may be reduced by holding the birds as whole carcasses until just before retail display. Baker compared the keeping quality of ice-packed and dry-packed (35 F) half carcasses. While there were no differences between the two types with respect to bacteria count or raw appearance, a taste panel preferred the dry-packed cooked broiler halves over the ice-packed with regard to general surface appearance, aroma, and flavor and juiciness of the meat.

A review of packaging materials and requirements for chilled as well as for frozen poultry has been made by Stewart. Films that are used include polyethylene, polyvinylidene chloride, rubber hydrochloride, cellophane and aluminum foil. Many of the available packaging films are satisfactory with respect to relative moisture and gas permeability, but they sometimes lack sufficient strength to withstand the rough handling encountered in normal marketing operations. Trays used in the packaging of cut-up chilled poultry need to contribute a certain amount of rigidity and form to the package, and with a blotter liner provide absorbency to pick up the drip which exudes from the meat during storage. Plastic film overwraps should be tight fitting and reasonably moisture and air proof. Wells *et al* (1958) reported that partial evacuation of the air from packages wrapped in impermeable films tended to inhibit bacterial growth by reducing oxygen tension.

The major portion of poultry in the United States is marketed as a chilled rather than a frozen product, the ratio between the two being as large as four to one in some reports. Economic considerations that so far have favored the ice-packed or chilled product involve the cost and limited availability of freezing and of frozen storage facilities, and the flexibility and superior merchandising characteristic of marketing the chilled product. Chilled poultry handled under proper conditions is an excellent product. However, there are certain problems and limitations in its marketability, all centering around the relatively short shelf life of chilled poultry due to bacterial deterioration.

Bacterial growth proceeds on poultry flesh in very much the same manner as it does on other meats. Temperatures have a very marked influence on the rate of bacterial growth. Studies, based on total bacterial counts, have shown that birds held at 36 F for 2 weeks are somewhat similar to birds held at 50 F for 5 days or birds held at 75 F for 1 or 2 days. Spencer and Stadelman compared the shelf life of chilled chicken fryers held at 31 F and 38 F in mechanical refrigerators, in crushed ice, and packaged in various plastic films. Birds at 31 F had 8 days additional shelf life over those at 38 F.

The bacterial flora found in poultry meat include the genera *Pseudomonas*, *Achromobacter*, *Micrococcus*, and *Flavobacterium*. Nagel *et al* (1960) found that the pattern of distribution of bacterial genera (mostly *Pseudomonas* and *Achromobacter-Alcaligenes*) was unaffected by geographical location of processing or cutting-up operations, or by use of antibiotics. Ayres, Ogilvy and Stewart observed that the growth and coalescence of colonies of the above microorganisms on the surface of chilled poultry led to a characteristic off-odor, accompanied by development of bacterial slime. The shelf life, or time before which this loss in quality occurred, was dependent not only on the holding temperature but also on the initial amount of bacterial contamination. This emphasizes the importance of adequate sanitation in processing, which will minimize initial contamination and thus prolong the shelf life. Frequent cleaning of processing equipment, as well as thorough washing and scrubbing of the eviscerated carcasses, is necessary. The effectiveness of this