FOOD habits of Americans have changed greatly since the advent of refrigeration a little over 100 years ago. We eat more perishable foods the year round, in season and out of season.

We can purchase meat, fish, poultry, eggs, milk, ice cream, lettuce, strawberries, citrus fruits, bananas, and apples, to name only a few perishable foods, almost any day of the year. The variety of fresh and frozen foods available today is truly amazing.

Less than 100 years ago many persons in small cities and villages in America kept a milk cow as the only way to have fresh milk.

Meat came from cattle slaughtered locally, driven or shipped to where they were needed. In those days there were no refrigerated vehicles for shipping dressed carcasses. The mainstays in the diet then were bread and cured meats.

Development of railroads, waterways, and roads brought city and country closer together. Refrigeration made it possible for even perishable foods to be shipped long distances.

Today, a New York City housewife shopping for food may purchase citrus fruits that came from Florida or California, carrots from Texas, lettuce from Arizona, potatoes from Idaho, meat from Iowa, poultry from Delaware, and apples from Washington.

Some of these perishable foods travel 2,000 to 3,000 miles to reach the New York market and are a week or more on their journey. This is time enough for the food to spoil from microbial action or become overripe and worthless. Here is where refrigeration plays its role, arresting the processes that can lead to deterioration.

ICE PROVIDED the only practical means of keeping large quantities of perishable foods cool in warm weather until approximately 1880.

Today ice is still used in great quantities by the food industry for cooling fish, poultry, dairy products, fruits and vegetables, and beverages.

The 1963 production of ice was 20 million tons according to the National Ice Association. Ice production has decreased since World War II, when the annual value was $427 million, compared with $210 million in 1963. The decline has come about because of the replacement of iceboxes in the home and elsewhere with mechanical refrigeration equipment.

The largest use of commercial ice production today is for icing railroad cars, trucks, and the fishing fleet. About 14.5 million tons were used for these purposes.

* * *

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purposes in 1963. The remaining 5.5 million tons produced were used as cubed or crushed ice by restaurants, hotels, and by other institutions.

Fish was one of the first perishable foods to benefit from refrigeration. The captain of a Gloucester, Mass., smack put ice on board to preserve a catch of halibut in 1838.

In 1858 iced containers of fish were shipped from New England ports to New York City.

Fish was frozen with ice and salt as early as 1861. This may have been the beginning of the frozen food industry. Special pans for freezing the fish were developed, and the tightly filled, covered pans were packed in a mixture of ice and salt.

After freezing, the fish was coated with ice by dipping it in water.

Fish frozen in this way was held at 20° F. for 8 to 10 months. The storage rooms were refrigerated with ice and salt, later by mechanical refrigeration.

Present practices have been built on these early techniques.

Fish like haddock and cod, caught by trawl off the New England and Canadian Maritime Provinces coasts, are eviscerated, washed, and iced in pens in the vessel's hold. Other small fish, like ocean perch and whiting, are iced without eviscerating because of their small size.

Shrimp are harvested by trawl and beheaded, washed, and stored in ice in the holds.

Fish of the Pacific Northwest, like halibut and sable, are eviscerated, washed, and iced in the vessel's pens. Pacific salmon, caught by seines for use in canneries, have recently been stored whole aboard the vessel in hold tanks containing sea water refrigerated to about 30° F.

Tuna caught offshore are usually frozen at sea. Those caught inshore are often iced in the round (not eviscerated) on the vessel. Many of the small inshore tuna boats make use of refrigerated holding coils to reduce the ice losses during long trips.

Ice used on board ship must be clean and of low bacterial count, which calls for sanitary practices in manufacture, handling, and storing.

Enough ice must be used to cool the fish to about 32° and keep it cool. Ice does something else. As it melts, it washes off slime and bacteria, and prevents undesirable microbiological conditions in fish stored in the hold of the vessel.

About 1 pound of ice is required for every 2 pounds of fish.

Depending on the species, fish can be kept in ice without spoiling from 2 days to as long as 28 days.

When brought on shore, fish are stored in ice in refrigerated rooms not warmer than 35°, until they can be processed or distributed as fresh fish. Some ice meltage is desired to keep the fish washed with ice water. Ice is used to keep the packages of fresh fish chilled until they are sold.

The fishing industry uses a great deal of refrigeration, and a lot of it is in the form of ice.

Heaviest usage is by Pacific coast fishers and for shrimp.

The annual catch of fish and shellfish by U.S. vessels off our coasts and on the high seas is about 5 billion pounds valued at almost $400 million to the fishermen.

About half the catch is used for food, and the balance principally for fish meal and oil.

If ice was used on board vessel at the ratio of 1 pound per 2 pounds of fish, the 2.6 billion pounds of food fish would have required 650,000 tons of ice.

Loss of ice from melting on board the vessel before use, and other refrigeration required would increase the refrigeration to perhaps 1 million tons. Another 400,000 tons of ice would be needed during distribution.

The refrigeration for food fish would then total approximately 1.4 million tons of ice. (A ton of refrigeration represents the cooling obtained from melting a ton of ice and is equal to 288 thousand British thermal units.)
To freeze fish on board ship, as in the tuna fleet, about 44,500 tons of refrigeration would be needed. To supply refrigeration to the holds of the albacore fleet would require 1,500 tons. To cool precooked tuna prior to cleaning and packing canned tuna would require more than 600,000 tons of refrigeration.

About 285 million pounds of fish, crab, and shrimp are frozen annually, requiring approximately 145,000 tons of refrigeration.

Without counting refrigeration required to store the frozen product, an estimate can be made that the fishing industry uses 2.2 million tons of refrigeration annually to protect fish from spoiling and convert it into a less perishable frozen or canned product.

The meat industry as we know it today could not have developed without refrigeration. Prior to the Civil War, meat slaughtering houses used little refrigeration. They were located in the centers of cities where the meat could be consumed.

As livestock production along the Atlantic seaboard proved inadequate for eastern cities, animals were driven on the hoof to markets. Cattle and sheep withstood this method of transport better than hogs.

When railroads were built, connecting the West with the East, a heavy traffic developed in freighting live animals in stock cars to the East.

Fresh meat could be shipped considerable distances in the winter, but summer temperatures were too high even for curing meat. Curing everywhere was a winter operation. Ice was being experimented with to permit summer curing, but refrigeration was not practiced until the early 1870’s for this particular purpose.

The Pennsylvania Railroad in 1857 insulated 30 boxcars with sawdust and installed iceboxes in the doorways. These cars were later remodeled by suspending the iceboxes overhead at either end, and they were used for transporting meat.

The Davis Refrigerator Car was patented in 1868 and 1869. It was cooled by ice and salt in tanks which could be refilled from the roof. It became one of the most widely used cars of the early days. Successful shipment of fresh meats from Chicago to Boston in 1869 in the Davis car inaugurated the dressed beef industry.

The Michigan Central Railroad experimented in the early 1860’s in transporting fresh meat from Chicago to the East, using boxcars with ice bins built above the floor at each end.

Experimentation with refrigerator cars on a commercial basis was to a large extent by meatpackers and fruit shippers and receivers.

The meat business was growing fast, and Swift had moved his New England packing business to Chicago. Railroads were not anxious to build refrigerator cars for dressed meat. They were satisfied with the returns from transporting live animals in stock cars.

Meatpackers were forced to purchase their own cars, and even today they own a small fleet of refrigerator cars. Improvements were made to provide lower temperatures in the cars.

By 1881 the business of shipping dressed beef from Chicago to the East had become well established.

Ice refrigeration was nowhere more important between 1860 and 1890 than in meatpacking.

Ice was used in transporting meat and to cool it as well as to preserve it in the packing plant.

Some meat was frozen using ice and salt mixtures.

The meatpacking industry, concentrated in Chicago, brought the cold storage warehousing industry there also. They developed together, making the transfer from ice refrigeration to mechanical refrigeration about 1890.

Today, the same requirements for the refrigeration of meat prevail as did 100 years ago.

Body temperature of a beef animal at slaughter is around 102° F. After slaughter and continuing for 30 hours
or more, changes occur that generate heat. Temperature of the deep round part of the carcass is about 105° F. when the carcass enters the chiller. To prevent spoilage the carcass should be reduced to 35° F. as rapidly as possible. In practice, after 20 hours of cooling, surface of the carcass will be 35° to 45° F. and the deep round about 60° F. Cooling will be completed in the holding cooler.

Beef is chilled in rooms held at 32° to 34° F., at 90 to 95 percent relative humidity. About 25,000 British thermal units (B.t.u.’s) would be required to cool a beef carcass of 500 pounds from 102° to 35° F. (A ton of ice, in melting, produces a ton of refrigeration, absorbing 288,000 B.t.u.’s.) This calculation is based on the average specific heat—heat capacity compared with water as 1.0—of meat as 0.75.

With other sources of heat to be considered, like heat leakage and heat generated by fan motors, the refrigeration requirement could well be 20 percent greater or 30,000 B.t.u.’s. This would amount to about 60 B.t.u.’s per pound of meat cooled.

**Chilling of Hog Carcasses** follows much the same pattern as beef. The specific heat of pork is somewhat less, 0.57 instead of 0.75, and the carcasses smaller, averaging 180 pounds compared with 560 for beef.

Present practices require chilling to an internal ham temperature of 37° to 39° F. overnight. Temperature at time of slaughter varies from 100° F. to considerably higher. The refrigeration requirement may not differ much from beef in view of possibly higher initial temperatures.

In cooling lamb carcasses, the objective is to reduce slaughter temperatures of 98° to 102° to 34° to 36° F. in 12 to 14 hours, and to hold the carcass at these temperatures until shipped. Approximately the same chilling procedures are followed for calf cooling.

Humidity and air circulation are controlled in meat cooling to avoid drying the carcass too much, and to avoid forming moisture on the carcass, which promotes bacterial growth.

The packinghouse may provide refrigeration for holding the beef carcasses for aging or the hog carcasses for cutting.

Total slaughter of meat in 1964 as reported by The National Provisioner was 31.8 billion pounds.

The breakdown by species was cattle, 16.4 billion pounds; hogs, 14.1 billion; calves, 600 million; and sheep and lamb, 700 million.

Total dollar sales of meat was about $14.6 billion.

The 1963 census records 2,992 meat slaughtering and processing plants to handle the 31.8 billion pounds of meat.

If a refrigeration requirement of 60 B.t.u.’s per pound is assigned to cool and hold meat at the slaughtering plant, about 6.6 million tons of refrigeration would be required.

If meat freezing is done at the processing plant, the input of refrigeration for freezing 696 million pounds (estimates for 1964 from Quick Frozen Food Magazine) would amount to an additional 348,000 tons of refrigeration, using a rough figure of a ton of refrigeration for a ton of frozen product. This would bring the total refrigeration requirement for cooling, holding, and freezing to about 7 million tons. The meat industry obviously rates as a giant in food refrigeration.

William Taylor in the 1900 Yearbook of Agriculture traces development of the fruit industry in this country and in other parts of the world with the coming of refrigerated transport.

In 1800 there was no important fruit industry in the world other than growing grapes in Europe for making wine. As late as 1871 there were only a half dozen fruiterers in London and all they offered for sale were lemons and oranges and local fruit in season.

The potential in climate and soil for fruitgrowing was the same as today. But rapid and regular transportation and refrigeration were lacking.

As steam was applied to ocean trans-
port and railroads during the middle 1800's, orchards and vineyards expanded. Railroads penetrated the interior of North America and Australia and opened up new fertile regions. California became perhaps the most conspicuous example in history of the rapid growth of a fruit and vegetable industry.

One of the first cold storages built in this country was for fruit. It was constructed in 1856 by the Rev. Benjamin Nyce, preacher, teacher, and chemist of Decatur County, Ill.

**ICE WAS PLACED** overhead in an insulated bunker with a metal floor which made the ceiling of the room. Warm air rising from the product was cooled by the cold ceiling and became heavier, providing air circulation by gravity. Calcium chloride was placed in the room to lower the humidity.

A ventilating fan was installed to bring in outside air. It was powered by a windmill.

Later, Nyce abandoned the idea of ventilation and made the rooms as tight as he could, using metal lining and beveled, tight doors. He had the idea, then considered foolish, that a buildup of carbon dioxide given off by the fruit would make apples keep for a longer period.

Use of airtight storages for apples was not perfected until many years later, in England by Kidd and West in the 1920's and in this country in the 1940's. In fact, the bringing in of outside air to provide ventilation had a heavy following in the early 1900's, and several systems were developed to gain benefits credited to fresh air.

By 1878 there were several commercial fruit storages. One in New York City and another in Chicago were chilled with ice.

The Western Cold Storage Co. of Chicago converted to a semimechanical system in 1866, using coils in the room through which ice-cooled brine was circulated. An ammonia compressor was installed in 1890 to cool the brine.

By 1901 there were 600 cold storage plants for fruits and other produce, using mechanical refrigeration and totaling 50 million cubic feet. All classes of cold storage space, including meat, amounted to 150 million cubic feet.

**REFRIGERATION in transit was also developing fast in the late 1800's.**

The first carlot shipments of fruit from California were made in 1869, consisting of 33 tons of pears, apples, grapes, and plums. The shipments were in nonrefrigerated, ventilated cars. These shipments were successful, thanks to carefully selected fruit from the foothill districts.

All shipments prior to 1888 were made in nonrefrigerated cars.

Refrigerator cars available in 1868 were intended for meat. They had about a 3,000-pound ice capacity. This was enough refrigeration for prechilled meat carcasses but not for warm loads of fruit. Early attempts to use these cars for peaches and berries failed because of decay development.

**PARKER EARLE,** by cooling strawberries before loading them into the car, was successful in shipping fruit from southern Illinois to Chicago, Detroit, and other northern cities in 1878.

Earle and Thomas in 1886 set up a business of fresh fruit transportation with 50 cars owned by the Detroit Refrigerator Car Co. operated over the Michigan Central Railroad.

The California Fruit Transportation Co. was subsequently organized to operate these cars. By 1891 they had about 600 cars operating in all parts of the United States.

The car was known as the Hutchins Refrigerator and was the first with ice bunkers holding 4 to 5 tons. Well constructed, the car had 4 inches of wool insulation, and was equipped with overhead ice tanks as well as end bunkers.

Other carlines were soon formed. Armour Packing Co., which had specialized in equipment for fresh beef, entered the fruit transportation field and became the dominant car owner.
There was no construction standard for refrigerator cars at this time and many were poorly made and gave poor results. Georgia peachgrowers in desperation appealed to the U.S Department of Agriculture for assistance. G. Harold Powell was placed in charge of investigations on picking, packing, cooling, and temperatures in transit in 1903.

Out of these studies came recommendations for a standard refrigerator car. The recommendations were put into effect in 1918 while the carriers were under Government control. The standards were updated after World War II, as a result of joint studies by the Agriculture Department and the Association of American Railroads.

Early work conducted by Powell in California with citrus fruits showed that careful handling during harvest and packing plus good refrigeration would prevent excessive loss from decay.

Similar studies were made with Florida citrus and with peaches, apples, plums, pears, sweet cherries, and cantaloupes as well as with other fruits and vegetables.

Intensive investigations also were made on precooling.

A precooling unit mounted on a railroad car that was owned by the Agriculture Department was sent into fruit districts to demonstrate how to prevent decay and overripeness by means of prompt cooling.

As a result of these studies and demonstrations, precooling plants were built by the fruit industry and the refrigerator car companies.

Later, portable fans were developed for car precooling. Still more recently, cars equipped with fans were built to use for precooling and to insure air circulation in transit.

Research was conducted on cold

Two entire rail cars of freshly harvested vegetables can be cooled in this two-tube vacuum cooler at a cooling plant in Tolleson, Ariz.
storage to determine the best temperatures and humidities for storing each kind of fruit and vegetable.

Diseases that cause serious losses in shipping and storing fruits and vegetables were studied. Market pathology laboratories were established in Chicago and in New York City to help the industry and the inspection agencies recognize the cause of losses.

Current research includes studies on controlling the proportion of oxygen and carbon dioxide in the storage atmosphere.

Today almost 1½ million carloads (30 million tons) of fresh fruits and vegetables are shipped each year by rail and truck in the United States.

About 35 percent are shipped by rail and 65 percent by truck.

It is difficult to find a fruit or vegetable among the 85 kinds listed in the United Fresh Fruit and Vegetable Association’s guide to monthly availability that would not be refrigerated at some time of the year or at some step in moving it from the farm to the consumer.

The 20 most important fruits and vegetables are shown in an accompanying table. They differ in the temperature that is required for storing and shipping.

Bananas, lemons, unripe pineapples, tomatoes, sweetpotatoes, and winter squash suffer chilling injury if stored at temperatures below 56°F.

Avocados, some grapefruit, cucumbers, snap beans, and sweet peppers are injured by holding at temperatures which are below 45°F.

Cranberries, potatoes, watermelons, ripe cantaloupes, and some varieties of apples and oranges keep best in the range of 36° to 40° F. At 32° they are injured by chilling. Florida-grown grapefruit, tangerines, and tangelos are stored at 32°F. even though some chilling injury may occur as a result.

This injury is preferable to decay that will develop at higher tempera-
tures. Symptoms of chilling injury are pitting, internal discoloration and softening, off-flavors, and susceptibility to the development of decay.

Fruits and vegetables listed in the table that are not marked as susceptible to chilling injury keep best at 32°F. or at slightly lower temperatures.

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### Annual Supply of Major Fresh Fruits and Vegetables

<table>
<thead>
<tr>
<th>Million Pounds</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fruits</strong></td>
<td></td>
</tr>
<tr>
<td><em>Apples</em></td>
<td>3,875</td>
</tr>
<tr>
<td><em>Bananas</em></td>
<td>3,824</td>
</tr>
<tr>
<td><em>Oranges</em></td>
<td>3,478</td>
</tr>
<tr>
<td>Peaches</td>
<td>1,796</td>
</tr>
<tr>
<td><em>Grapefruit</em></td>
<td>1,758</td>
</tr>
<tr>
<td>Grapes</td>
<td>699</td>
</tr>
<tr>
<td><em>Lemons</em></td>
<td>548</td>
</tr>
<tr>
<td>Pears</td>
<td>529</td>
</tr>
<tr>
<td>Plums, prunes</td>
<td>265</td>
</tr>
<tr>
<td>Strawberries</td>
<td>263</td>
</tr>
<tr>
<td><em>Tangerines</em></td>
<td>240</td>
</tr>
<tr>
<td><em>Avocados</em></td>
<td>113</td>
</tr>
<tr>
<td>Nectarines</td>
<td>95</td>
</tr>
<tr>
<td><em>Pineapples</em></td>
<td>93</td>
</tr>
<tr>
<td><em>Tangelos</em></td>
<td>81</td>
</tr>
<tr>
<td>Cherries</td>
<td>76</td>
</tr>
<tr>
<td><em>Apricots</em></td>
<td>38</td>
</tr>
<tr>
<td><em>Cranberries</em></td>
<td>38</td>
</tr>
<tr>
<td>Coconuts</td>
<td>35</td>
</tr>
<tr>
<td>Blueberries</td>
<td>31</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>17,883</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Vegetables</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Potatoes</em></td>
<td>15,970</td>
</tr>
<tr>
<td><em>Watermelons</em></td>
<td>3,119</td>
</tr>
<tr>
<td>Lettuce</td>
<td>2,921</td>
</tr>
<tr>
<td><em>Tomatoes</em></td>
<td>2,400</td>
</tr>
<tr>
<td>Onions, dry</td>
<td>2,211</td>
</tr>
<tr>
<td>Cabbage</td>
<td>1,928</td>
</tr>
<tr>
<td><em>Cantaloupe</em></td>
<td>1,607</td>
</tr>
<tr>
<td>Corn</td>
<td>1,550</td>
</tr>
<tr>
<td>Celery</td>
<td>1,470</td>
</tr>
<tr>
<td>Carrots</td>
<td>1,304</td>
</tr>
<tr>
<td>*Sweetpotatoes</td>
<td>1,210</td>
</tr>
<tr>
<td><em>Cucumbers</em></td>
<td>529</td>
</tr>
<tr>
<td><em>Snap beans</em></td>
<td>473</td>
</tr>
<tr>
<td>*Sweet peppers</td>
<td>454</td>
</tr>
<tr>
<td>Radishes</td>
<td>350</td>
</tr>
<tr>
<td><em>Squash</em></td>
<td>310</td>
</tr>
<tr>
<td>Greens, miscellaneous</td>
<td>253</td>
</tr>
<tr>
<td>Turnips, Rutabagas</td>
<td>233</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>227</td>
</tr>
<tr>
<td>Onions, green</td>
<td>187</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>38,706</td>
</tr>
</tbody>
</table>

*Susceptible to chilling injury.

Refrigeration practices used today by the fruit and vegetable industry are specialized to meet specific requirements of the commodity. Cold storage of apples, for example, is adapted to differences in varietal requirements. Most of the apple crop, except early shipments, is placed in cold storage as soon as harvested and moves to market during fall, winter, and early spring. About 75 percent of the crop is marketed from November through August.

Usual storage temperatures are 30° to 32° F. However, varieties like Yellow Newtown from California and McIntosh and Rhode Island Greening from New York and New England require higher temperatures of 38° to 40° F. Controlled atmosphere storage is provided for these varieties to retard ripening that would slowly take place at 38° to 40° F.

Tight rooms are constructed and oxygen is partially depleted by respiration of the fruit, and carbon dioxide (CO₂) from respiration is allowed to accumulate to desirable levels. Excess carbon dioxide is removed by washing the air with water or exposing it to lime or some other absorbent. Oxygen concentrations are maintained by drawing in outside air.

McIntosh apples are usually stored in atmospheres of 2 to 5 percent CO₂ and 2 to 3 percent oxygen and 38° F. The Yellow Newtown variety is stored in 5 to 8 percent CO₂ and 2 to 3 percent oxygen at 38° to 40° F.

There were 1,612 cold storage plants for apples in the United States in 1963 with a total capacity of 243 million cubic feet.

Controlled atmosphere storage rooms were available in 265 plants and represented about 12 percent of the total apple storage space.

The amount of refrigeration used to cool that portion of the apple crop stored, estimated as 59 million bushels, would be approximately 385,000 tons, assuming they were cooled 40° F. and using 45 pounds as the weight of a bushel of apples. A specific heat figure of 0.87 was used for apples and an allowance of 20 percent for inefficiencies and losses. Storage and refrigerated transport of apples would require several hundred thousand tons of additional refrigeration.

Refrigeration plays a very important role in the marketing of bananas. Almost 68 million bunches of bananas were imported into the United States in 1963, practically all from Central America. Bananas are harvested when green in color, brought to the ports, and loaded into refrigerated banana ships that hold approximately 50,000 to 80,000 bunches.

Bananas are usually 75° to 80° F. when loaded and must be cooled in 12 to 24 hours to the desired carrying temperature of about 55° F.

Refrigeration capacity of most banana ships is about 200 tons. The voyage to the United States requires 3 to 9 days.

After reaching port, bananas are sorted by grade and color, and transferred to rail cars or trucks for transport to the terminal market. They are then ripened in special rooms under controlled temperatures and humidities and distributed to the retail trade.

Just the refrigeration required to cool the annual supply of bananas to the desired temperature for transport, say from 80° to 60° F., would require about 265,000 tons of refrigeration. Refrigerated transport could well add 200,000 tons additional refrigeration.

Oranges are produced almost the year round and are stored only to a limited extent to supply requirements in summer and fall until the new crop of oranges comes to market.

Shipments of oranges made in warm weather are precooled before shipment. Warehouse cooling is the most common practice. Some car-precooling is used in Florida and hydrocooling as well for fruit packed in consumer bags.

Peaches are subject to decay and softening unless well refrigerated. Hydrocooling is used in eastern districts and cooling by air in precooling rooms
or refrigerator cars in western districts. Grapes are precooled prior to shipment or as they are stored.

Lemons are usually harvested when green in color and stored at about 55° to 58° F, where they gradually become yellow and more juicy. Refrigeration is used to cool lemons to the desired storage temperature and to hold them at this temperature.

All the other fruits that are listed in the table require some refrigeration for storage and shipment.

The chief crop of potatoes is harvested in the fall and only the first shipments are refrigerated.

The potato crop in Maine, the Red River Valley of Minnesota, and North Dakota move into storages cooled by outside air. The early Southern and California crop is refrigerated to prevent decay.

Special attention is given to potatoes intended for processing. They may be damaged in cooking quality if they are stored or transported at temperatures any lower than 50° F.

LETTUCE, most of it originating in California and Arizona, is almost all vacuum cooled after packing into fiberboard cartons holding 4 to 5 dozen heads.

A typical cooling job would be the removal of 30° of field heat, cooling from 68° to 38° F in about 30 minutes. Cooling is accomplished by evaporating the moisture from the heads of lettuce under a high vacuum at which water boils at 32° F.

The moisture released must be condensed if the vacuum is to be maintained. This is done with a mechanically refrigerated condenser, a second vacuum chamber filled with ice, or with a steam ejector system and a barometric condenser.

There are 45 to 50 vacuum cooling plants in the Arizona-California lettuce districts. It is estimated the refrigeration required to cool the lettuce crop before shipment would amount to about 300,000 tons.

Before vacuum cooling came into use, about 25 to 30 pounds of ice were placed in the package to do the cooling job. The load would also be covered with crushed ice. The amount of ice used to refrigerate a carload of lettuce would often weigh as much as the lettuce.

Consequently, ice would remain in the crates, on top of the load, and in the ice bunkers on arrival.

Today lettuce is not iced. Bunker ice in fan cars or mechanically refrigerated cars are used for transport.

TOMATOES, susceptible to chilling like bananas, are seldom precooled and are transported at temperatures of 55° to 65° F depending on the degree of their ripeness. They are ripened after reaching market.

A crop like dry onions may be stored many months to lengthen the marketing season. A temperature of 32° F and low humidity of 70 to 75 percent are recommended.

Cabbage is another long storage crop and it requires temperatures of 32° F. The spring crop is refrigerated while it is in transit.

Only a rough estimate can be made of the total refrigeration used in getting the fresh fruit and vegetable crop cool, ready to ship, and keeping it cool during storage and transport.

Eliminating some commodities that do not require cooling or transit refrigeration, like watermelons and most of the potato crop, the cooling load alone could amount to 2 million tons. Storage and in-transit refrigeration could well be an equal amount.

The commercial frozen pack of fruits during 1964 was approximately 702,000 tons, with citrus juices and strawberries the most important items. Frozen vegetables amounted to 1,320,000 tons. Potato products made up more than a third of the total. Peas, corn, broccoli, and spinach were other important items.

Over 2 million tons of refrigeration would be required to freeze 2,022,000 tons of frozen fruits and vegetables. A rough estimate then for cooling, storing, shipping, and freezing fruits and vegetables would be 6 million tons.
The poultry industry is another very large user of refrigeration.

The Agriculture Department carried on extensive investigations to improve practices of handling and storing poultry, beginning about 1910. Miss Mary Pennington was one of the pioneers in this early work. Methods of killing, dressing, and refrigeration were gradually worked out.

Cooling in air and nonevisceration, or “New York dressed,” was favored. Later, evisceration under careful sanitation practices and cooling in ice water became the accepted practice.

Broilers today are shipped thousands of miles from the large production areas of Georgia, Arkansas, Delaware, Maryland, Alabama, North Carolina, and Mississippi.

Poultry cooled quickly in special cooling equipment, packed in ice, and transported in refrigerated trucks and cars can be delivered in good condition more than a week after killing. The poultry will still have several days of shelf life if it is refrigerated in the retail store.

In the last 18 years the broiler business has shown a remarkable growth. Production in 1945 was 350 million birds and by 1964 it was 2.16 billion birds, amounting to about 7.5 billion pounds. Broilers are produced throughout the year in this country. Over 90 percent are not frozen.

The primary problem in refrigerating broilers is microbial deterioration. Lowering the meat temperature as near freezing as possible is the best protection against growth of microorganisms and chemical changes in the meat and the fat that affect color and flavor of the birds.

Internal temperature of the chicken after feather removal and evisceration is 70° to 90° F. The poultry should be chilled quickly to about 35° F.

Very few birds are chilled today in air. Cooling in a slush of ice and water under agitation is common, and several kinds of coolers are available to speed up the process. Water in the chill tanks and in the chillers must be kept clean.

Prolonged holding in chill tanks is avoided to keep the meat from absorbing large amounts of water.

The refrigeration requirement for poultry is about 0.7 to 1.5 pounds of ice per pound of poultry processed, with poultry chilling taking 0.4 to 1.0 pound, icing the shipping crates 0.25 to 0.35 pound, and icing trucks and trailers 0.05 to 0.15 pound.

A rough estimate of refrigeration used by the broiler industry to protect this perishable food would be about

Production line at a chicken processing plant near Salisbury, Md. Processed chickens are chilled in the carts in foreground.
7.5 billion pounds or 3.75 million tons of ice.

Most of the turkeys, ducks, and geese produced are marketed frozen and, of course, chickens are also frozen.

Freezing is the best method of preserving poultry meat for any long time, and excellent practices have been developed for fast freezing, packaging, storing, and distributing. Freezing in air at \(-30^\circ\) F., or in brine or other liquid at \(-20^\circ\), and holding at 0° or below are recommended practices.

It is estimated that about 2.3 billion pounds of poultry are marketed frozen, with turkeys more than half the total. Frozen meals containing poultry are not included in this figure.

Using the rough estimate of a ton of refrigeration to freeze a ton of poultry meat, 1.15 million tons of refrigeration would be required for the frozen poultry business, not counting storage and transport requirements.

Eggs were preserved—although not very well—in water glass (sodium silicate), limewater, or by some other chemical means before refrigeration was available. In the 1880’s ice refrigerated rooms began to be used for the storage of eggs.

Quality of storage eggs was not very dependable, for most came from small flocks on the farm. The farmer sold them to grocers. Egg merchants bought them from the grocers, often several weeks later.

The egg business continued to grow despite lack of quality control. By 1917, cold storage of eggs amounted to 7 million cases of 30 dozen each.

The Agriculture Department in 1913 installed a refrigerated egg packing establishment on wheels and sent it on long trips to the Midwest where farmers and dealers were shown how to care for eggs. They were encouraged to produce infertile eggs of lower perishability. Shippers were urged to chill eggs to 50° F. before loading into refrigerator cars.

Eggs were frozen commercially, beginning about 1900. After 1930 when cold storage holdings were 11 million cases, storage of shell eggs declined because of year-round production by commercial flocks. Frozen eggs came into greater use because of the growth of commercial bakeries and less baking in the home.

Annual production of eggs today is about 5½ billion dozen. About 85 percent or 149 million cases are consumed as shell eggs. Cold storage of eggs is no longer large, seldom exceeding several hundred thousand cases. About 15 million cases of the total production of 175 million cases are broken commercially for frozen and dried egg products. Six percent of the production is used for hatching purposes.

Deterioration in shell eggs results from decomposition by molds and bacteria, changes due to chemical reactions, and absorption of flavors and odors from the environment.

If eggs are fertile, serious chemical changes take place at temperatures above 85° F. Commercially produced market eggs are infertile. As the egg ages, the white thins and the yolk flattens. Many different kinds of mold attack eggs.

Oil coatings are often applied to eggs within 24 hours after laying, to entrap the natural carbon dioxide in the egg. This helps retard aging and the loss of moisture.

Prompt cooling at the farm to 29° to 30° F. would give maximum protection, but condensation and resultant mold then is a problem. Cooling to 50° to 60° F. in air of 70 to 80 percent relative humidity is recommended.

Cold storage at 29° to 30° F. and at humidities of 85 to 90 percent are recommended, using the lower humidity if the eggs have been oiled.

Cooling 149 million cases of eggs consumed as shell eggs would require approximately 484,000 tons of refrigeration, if all the eggs were cooled 20°, say from 80° to 60° F:

About 360 million pounds of liquid eggs are frozen annually. Using again a rough estimate of a ton of refrigeration to freeze a ton of product, 181,000
Stainless steel bulk milk tank.
tons of refrigeration would be required for this purpose.

The refrigeration required by the poultry industry is estimated as 3.75 million tons for cooling broilers, 1.15 million tons for freezing poultry, and approximately 700,000 tons for cooling and freezing eggs, making a total of about 5.5 million tons.

Milk producers in colonial times knew milk would sour quickly in warm weather, but they did not know why. Sultry weather and thunderstorms were directly associated with souring. Not much could be done to protect the milk except keep it in a cool place such as the well, cellar, or spring. About 1860 ice came into general use to prevent milk from souring.

As early as the 1840's milk was shipped from upstate New York by rail into the city. The Erie Railroad transported 3 million quarts of milk in 1842–1843.

Some farmers in 1849 were cooling milk in cans by stirring it with a tin tube filled with ice. In 1851 butter was shipped by rail in small iced containers. Ice refrigerated rooms were to be found in well equipped dairies in the Northern States in the 1880's.

Long distance shipment of butter and cheese to eastern markets from the Midwest began about the time refrigeration cars became available in the early 1880's.

On-the-farm cooling of milk, placing the cans in cold water or flowing the milk over cold metal surfaces, began to be practiced in the late 1800's and early 1900's as it became generally understood that low temperatures checked the multiplication of bacteria in the milk.

The Agriculture Department advised producers in the Northern States to harvest a crop of ice each winter for the summer cooling of milk.

Some cities prohibited entry of milk warmer than 60° F. Insulated jackets over milk cans helped prevent warming during the trip by wagon to the railroad receiving station. When milk reached the city for bottling, it was cooled to 45° to 50° F.

Butter churning moved from the farm to creameries where a more uniform, higher quality product could be made, largely through better sanitation and controlled temperature.

By 1915 mechanical refrigeration had replaced ice refrigeration in the large creameries. Butter storage became quite extensive.

During 1915, the first year for cold storage statistics, a total of 100 million pounds of butter were in storage by September 1, the peak of production.

Cold storage warehousing stabilized the dairy industry.

Cheese manufacturers found controlled temperatures the answer to the problem of curing cheeses of various kinds that had specific temperature requirements.

The present era of the dairy industry has seen the once widely used milk can replaced by stainless steel tanks, at the farm and on trucks and rail cars, for the bulk handling of milk.

Total milk production in 1964 was 126.6 billion pounds. Factory products accounted for 64.1 billion pounds, with butter, cheese, and ice cream the most important. Consumption of fluid milk off the farm was 52.9 billion pounds. Farm consumption made up most of the rest of total production.

Present day practices call for cooling milk to 38° F. within an hour after it is produced. Milk is kept cool in refrigerated holding tanks or cans at the farm and during its transport to the milk plant.

Since the plant seldom has capacity to pasteurize milk at the rate it is delivered, holding tanks often equipped with refrigeration are used. Some plants cool all milk received to about 36° F. before the milk is transferred to the holding tanks.

Before pasteurization, milk is separated and blended to provide the butterfat content which is desirable in fluid milk.

After standardizing, the milk is
In coin-operated canteens, refrigeration plays a big role for milk, ice cream, and other food products.

pasteurized by heating it to 145° F. and holding it at that temperature for 30 minutes. High-temperature-short-time pasteurization is now commonly used. In this method the milk is heated to 161° F. and held at this temperature for 15 seconds. It is then cooled to 40° F. or lower.

Cold milk to be pasteurized may be passed through a heat exchanger in which the cold milk is heated and the warm pasteurized milk is cooled. About 70 to 80 percent of the refrigeration which otherwise would be needed to recool the pasteurized milk can be saved in this manner.

From the pasteurizer, the cooled milk is passed to bottles or cartons. They are held in a storage room at 34° to 40° F. until loaded into refrigerated trucks for delivery.

If we assume that 80 percent of the milk production of 126.6 billion pounds is cooled from 90° to 50° F., and assign a specific heat of 1.0 to milk to allow for some inefficiencies in cooling, the refrigeration load would be approximately 14.1 million tons.

Milk marketed as fluid milk—about 52.9 billion pounds in 1964—is heated to 145° or 161° F., depending on the pasteurizing process, and then it must be cooled to 40° F. or lower.

Assuming the milk is cooled a total of 100° F. and that the regeneration process of heating-cooling was 80 percent efficient, there would still remain about a 20° F. temperature reduction for which refrigeration would be required. This would take approximately 3.7 million tons of refrigeration, making a whopping total of 17.8 million tons for the milk cooling job before and following pasteurization.

Refrigeration is used in churning and storing butter, curing cheese, and to make ice cream, harden it, and transport it. These processes fall more into the field of manufacture and are not included in this chapter on how refrigeration protects the food supply.

Among the industries that developed to take care of the expanding perishable food business was the refrigerated warehousing industry.

By 1891, the industry had become large enough to have a trade association. The American Warehousemen’s Association was formed in Chicago that year, consisting of 29 companies.

The U.S. Department of Commerce and Labor was requested to make a survey of cold storage plants. This was the forerunner of the report issued monthly since 1915 by the Agriculture Department on cold storage holdings of major perishable commodities.

Refrigerated warehouse capacity in 1963 was 1.1 billion cubic feet, excluding Alaska and Hawaii, representing a gain of 84 million cubic feet over the 1961 survey. Freezer capacity was 52 percent of the total. Per capita availability of space in 1963 of 5.88 cubic feet represented a gain of approximately 23 percent over 1943.

The perishable food industry depended on transportation and refrigeration for its development, with the refrigerator car playing an essential
role. But the total number of refrigerator cars available has declined in recent years because much traffic has moved to trucks.

As of July 1, 1965, the breakdown of the refrigerator car fleet was 65,020 ice bunker cars of all types; 10,945 mechanically refrigerated cars of all types; and 2,360 express refrigerator cars. This makes a total of 78,325 refrigerator cars.

In addition, there are 32,645 insulated bunkerless cars for transporting canned goods and other commodities that don't require refrigeration but do require protection from freezing during cold weather.

About 5,000 mechanically refrigerated cars are on order, which will soon make a fleet of almost 16,000 cars of this type.

Refrigerated trailers transported on flatcars are also owned by the railroads. The total is 5,451 regular service trailers, 728 meat trailers, and 1,499 insulated containers.

Perishable freight traffic of foods and beverages for the railroads in 1963 amounted to 1.4 million carloads, totaling 34.7 million tons.

The 1963 Census of Transportation indicates that 1.2 percent of all motor trucks registered were refrigerated, or 152,700 vehicles.

About 20,000 were classed as 35 feet or larger, and 17,000 as 25 to 34.9 feet. These are the size used for between-city carload traffic.

Many of the smaller refrigerated trucks are used primarily for in-city delivery service. The most popular size was 10 to 15.9 feet, with some 73,000 vehicles representing about 48 percent of the total.

Trucks carry 65 percent of the frozen food traffic, and about the same percentage of fresh fruit and vegetables.

Most broiler production is transported in trucks, and most milk.

Refrigerated trucks probably move more than 65 percent of perishable foods from farm to market. Long distance hauling is more likely to be by rail than by truck.

A highly essential part of the cold chain for food is refrigeration in the retail store. Without it, there would be little business in perishable foods.

Most of the retail food business is done in supermarkets in this country. The United States has approximately 28,000 supermarkets.

A well equipped market has refrigerated display cases for frozen foods, meats and dairy products, fruits and vegetables, and a battery of reach-in refrigerators for milk, cheese, and other refrigerated products. It usually has a produce cooler and a meat cooler near the preparation areas for these commodities where the reserve supplies can be held.

The store is air-conditioned for the comfort of the customers and this, too, is beneficial to the perishable foods.

Temperatures recommended for display cases used for meat are 28° to 38° F. and for produce and nonfrozen dairy products, 35° to 45° F. Frozen food cases should maintain 0° F. and ice cream cabinets —12° F.

Restaurants and other firms that provide food services to the public have estimated sales of $20 to $26 billion, and rely heavily on refrigeration.

One meal in four is eaten away from home. Commercial restaurants make up 76 percent of the total annual sales. Clubs, airlines, schools, hospitals, and other institutions take care of the rest.

There are about 530,000 eating establishments in the Nation.

Recent surveys by American Restaurant Magazine indicated that all medium-to-large-volume restaurants, serving 500 meals or more a day, had two reach-in refrigerators. Fifty-six percent had two walk-in coolers and 71 percent had ice cream cabinets. In addition, many had refrigerated beverage dispensers.

There were approximately 40,000 restaurants of this size. If each had two reach-in refrigerators of ½-horsepower size, a walk-in cooler of 1-horsepower size, and ice cream cabinets, milk cooler, and other fractional horsepower equipment that totaled
horsepower, a total of 3 horsepower or approximately 3 tons of refrigeration would be used. This would add up to just about 120,000 tons for medium to large restaurants.

The last link in the cold chain is the home refrigerator and freezer. The estimate for 1965 sales of new farm and home freezers is 1.1 million. The 1960 census counted 9.8 million freezers in the 53 million households included in the census. This represented 18.4 percent of all the households. In the 5 years since 1960, with sales averaging over 1 million per year, consumers must have acquired almost 5 million homefreezers, making the total now over 14 million.

There are 9,900 commercial locker plants that are primarily engaged in provisioning homefreezers. The total 0°F storage space controlled by consumers in locker plants and homefreezers is estimated at over 200 million cubic feet, capable of holding 6.5 million pounds of food.

It was expected that 4.7 million new household refrigerators would be sold in 1965. There is no current census estimate for home refrigerators in use. The last figure was in 1950 when the market was 80 percent saturated. In 1960 when the household market was estimated to be 90 percent saturated, there would have been 47.7 million refrigerators. Today the number is probably well over 50 million.

Manufacturers of refrigeration equipment have worked closely with the food industry, making improvements and supplying new kinds of equipment as the need arose. Requirements of the food and beverage industry once dominated the market and they still do if household equipment is included.

The value of total shipments manufactured by the refrigeration equipment industry in 1963 was $1.9 billion. This figure did not include household refrigerators or home and farm freezers. Packaged air conditioning made up $611 million of the total. It is not possible to determine how much equipment in the remaining $1.3 billion is used for food refrigeration.

If you take only commercial refrigerators and related equipment, $279 million, and add to it household refrigerators, $688 million, and home and farm freezers, $143 million, the total would be approximately $1.1 billion for food refrigeration equipment manufactured in 1963. This is almost twice as much as the value of packaged air-conditioning equipment.

This is the story of the food refrigeration industry in the United States.

Links in the chain of refrigeration reaching from farm to kitchen are ice manufacturing plants, icemaking machines, milk coolers, vacuum coolers, hydrocoolers, poultry coolers, refrigerated warehouses, refrigerated trucks, refrigerated rail cars, walk-in and reach-in refrigerators, refrigerated display cases, locker plants, household refrigerators, and home and farm freezers.

The food industry uses over 20 million tons of refrigeration to chill and freeze fish, meat, fruits and vegetables, poultry, and eggs. The dairy industry uses an estimated 18 million tons just for cooling milk alone.

This country has 1.1 billion cubic feet of cold storage space, amounting to 5.88 cubic feet per capita.

The refrigerator car fleet totals 78,325 cars and 7,678 trailers for flatcar transport. There are approximately 152,700 refrigerated trucks.

Household refrigerators total about 50 million and home and farm freezers 5 million. There are 9,900 commercial locker plants. Manufacturing of refrigeration equipment for food is big business, amounting to an estimated $1.1 billion during 1963.

The future will bring new foods and new ways of refrigeration. Fresh quality will be captured by virtually instant cooling and freezing. It will be retained by continuous low temperature refrigeration. The variety of foods will continue to grow as fast transportation and refrigeration bring exotic foods to our markets from far-off places.