VIRGINIA AGRICULTURAL AND MECHANICAL COLLEGE AND POLYTECHNIC INSTITUTE AND U. S. DEPARTMENT OF AGRICULTURE, Co-operating
EXTENSION DIVISION, JNO. R. HUTCHESON, DIRECTOR, BLACKSBURG, VIRGINIA
E — 295
May, 1931

MECHANICAL REFRIGERATION FOR DAIRIES

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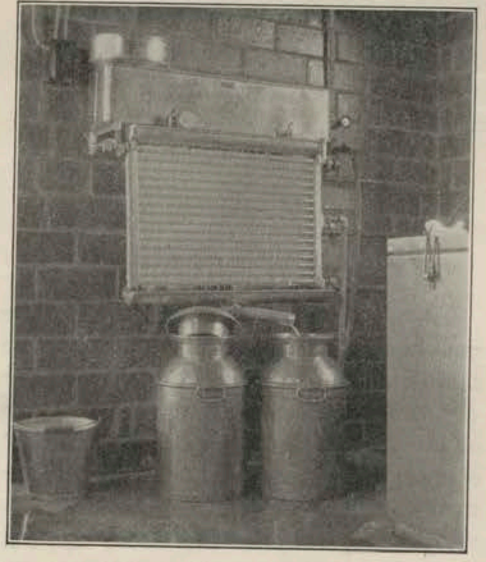
ONE of the most important operations on the dairy farm is the proper cooling and storage of milk. It is well known that bacterial growth in milk may be materially checked by prompt cooling to a temperature of 50° F. or lower, and that this cooling should be done within the first hour after milking by the most effective methods available. While ice may be used, mechanical refrigeration has been found not only more efficient but more economical as well.

Many of our larger markets now require cooling and delivery at 50° F. or below. Other markets are considering this requirement, and it is only a matter of time before it becomes an almost universal practice. The progressive dairyman is looking ahead to this time and preparing for it, if he has not already had to meet the problem.

The purpose of this circular is to help the dairyman with this cooling problem by a practical discussion of cooling and storing market milk. The technical side will not be taken up and only those points mentioned which are of importance in helping to select the plant suitable to conditions as they exist on the farm.

Selection

Needless to say the selection of proper equipment is vital to success in operation. If too small a machine is selected, or inadequate storage and accessories provided, results will never be satisfactory. On the other hand, if too large equipment is installed, operating costs and overhead will be excessive. Another point to consider is the probable expansion of operations in the near future. It may be desirable to install larger capacity than at first required in order to provide for this future expansion.



Double tubular cooler. Note that well water is used in upper half of cooler and refrigerated water in lower half. This method is economical and efficient

Before attempting to select or purchase cooling and refrigerating equipment the dairyman should have this information:

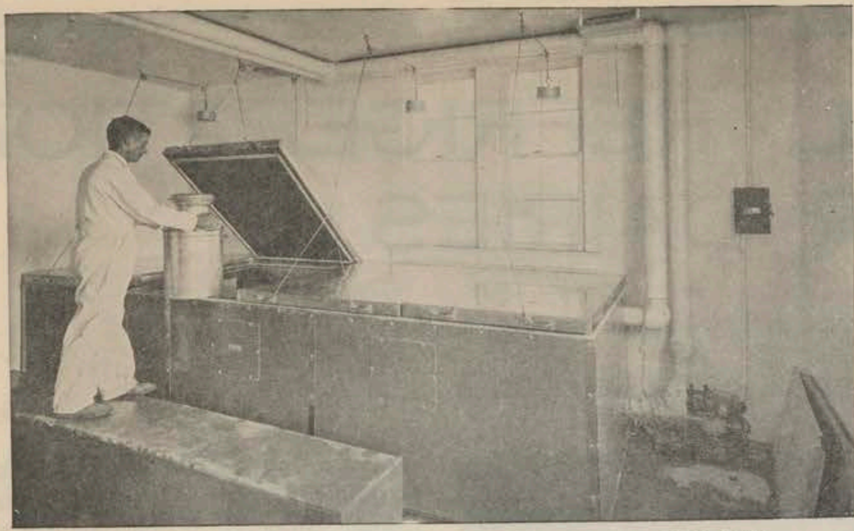
(1) Maximum amount of milk to be cooled per day.
(2) Temperature to which this milk must be cooled.
(3) Amount of milk to be stored per day.
(4) Temperature at which this milk must be stored and delivered.
(5) Method of cooling and storage preferred.
(6) Kind of box to be used.
(7) Probable average milkroom temperature in summer.
(8) Is ice to be manufactured, and if so, how much?
(9) Temperature of available water for pre-cooling in summer.
(10) Amount of expansion contemplated in near future, if any.

In securing this information, it is important that hot weather conditions be figured, since this is not only the maximum load on the equipment, but also the critical period so far as quality of milk and operation of plant is concerned. A plant to take care of these maximum conditions without overloading is essential.

So far as type of equipment, kind of refrigerant, and special features are concerned, these are matters for the farmer to decide on presentation of facts by the salesman. The important thing is to buy equipment of the proper size for the job. That is the proper size compressor, proper size brine tank, and proper storage capacity. Other items to consider are (1) manufacturer's reputation, (2) which company can and will service their equipment best, and (3) be sure operating time will not exceed 15 hours per day or current consumption exceed 1.5 kilowatt hours per 10 gallon can of milk cooled 35 or 40 degrees Fahrenheit, (4) speed of compressor (excessive speeds mean short life).

The Wet System

There are in use in Virginia at present two types of cooling and storage systems. Where the market is largely wholesale, and storage and shipment is in 10 gallon cans, the most common method is the "wet" system, where the cans of milk are set in refrigerated water up to the neck of the can. With this system, the milk may first be run over a tubular cooler and cooled by (1) well water, (2) well water in upper half of cooler and refrigerated water in the lower half, (3) circulation of refrigerated water only through the cooler by means of a centrifugal circulating pump. The second method is the most common and most efficient, because pre-cooling water from well or spring is taken



"Wet" type storage of large capacity. Note step to aid in lifting cans in and out

advantage of to reduce the temperature of the milk from 95° to 65° or less, making the cooling system carry only the load from 65° to say 45°. This affects a considerable saving in current. The milk is cooled more promptly to the desired temperature by circulating the refrigerated water through the lower half of the cooler, and as a rule, morning's milk so treated need not be put in the storage at all.

In the smaller dairies the cans of milk may be set directly in the storage tank without pre-cooling. This method is very slow unless hastened by an agitator which will keep the water in the tank in circulation, making temperatures throughout the tank more uniform, and hastening the removal of heat from the milk. It is too slow as a rule for cooling morning milk for immediate shipment, and of course more expensive because pre-cooling water is not employed.

The advantages of the "wet" system are (1) low first cost and high efficiency, (2) easy to build, (3) constant supply of refrigerated water or stored refrigeration.

Disadvantages are (1) limited to can storage and provides no dry storage space, (2) hard to lift cans in and out, (3) likely to result in rusty cans and unsanitary conditions if neglected, (4) limited as to size and capacity, (5) water must be changed occasionally.

In "wet" storage three gallons of refrigerated water should be provided for each gallon of milk cooled. This means a box much larger than is necessary to hold the cans of milk only.

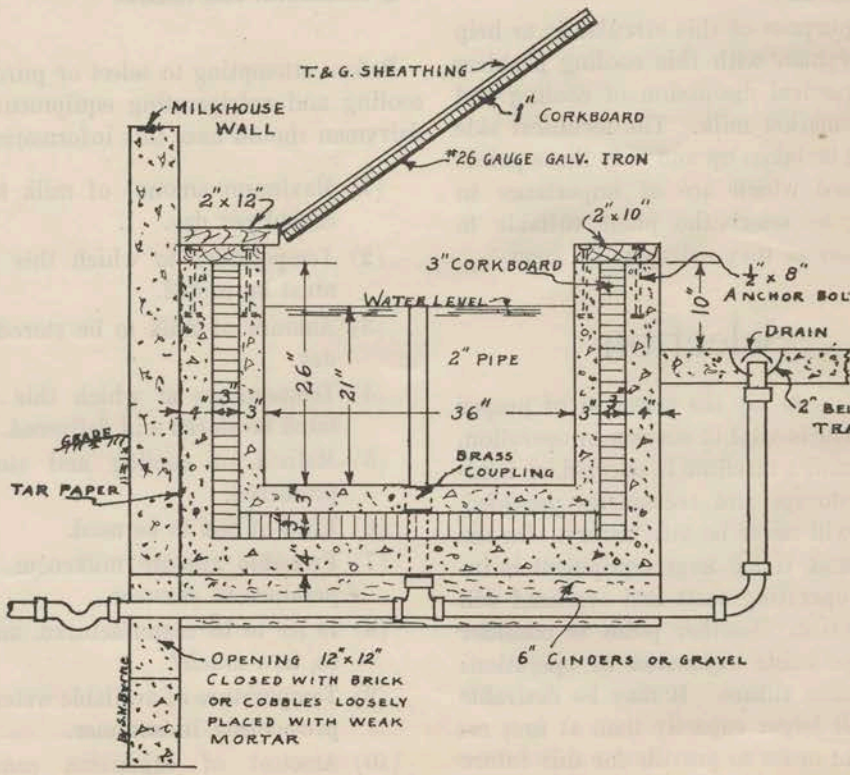
Dry Box System

The other system in common use is the dry box which is most popular where bottled milk is produced. The smaller dry box systems are being used with one or more of the small "household type" compressors, using sulphur dioxide or methyl chloride for a refrigerant and developed originally for household use, but later adapted also to commercial and milk cooling work. The larger systems as a rule are operated by ammonia machines of sufficient capacity to take care of the job, and frequently have additional ice making capacity; the ice being used to pack around the bottles in delivering.

The small sulphur dioxide type compressors have some distinct advantages where the load is not too great. Among these advantages are (1) low first cost, (2) low operating cost, (3) more readily serviced when in need of repair, (4) air cooled, (5) automatic in operation, requiring little attention, (6) where more than one compressor is used, if one should break down the other by continuous operation can be forced to carry the load until repairs are made, and in cool weather only one need be operated.

On larger installations where more than one compressor of the sulphur dioxide type would be required, the ammonia type is usually cheaper and has these advantages, (1) greater capacity and reserve, (2) ice may be made where needed, and (3) more sturdily built with probable longer life, (4) usually slower speed.

The advantages of the "dry" system as compared with the wet are (1) quick cooling, (2) dry cold storage is easily provided, (3) easier and cleaner handling of cans or crates, (4) where brine system is used, refrigeration is stored in brine, (5) can be used in any size and for cans or bottles, (6) can be used for storage of other farm products. The product from

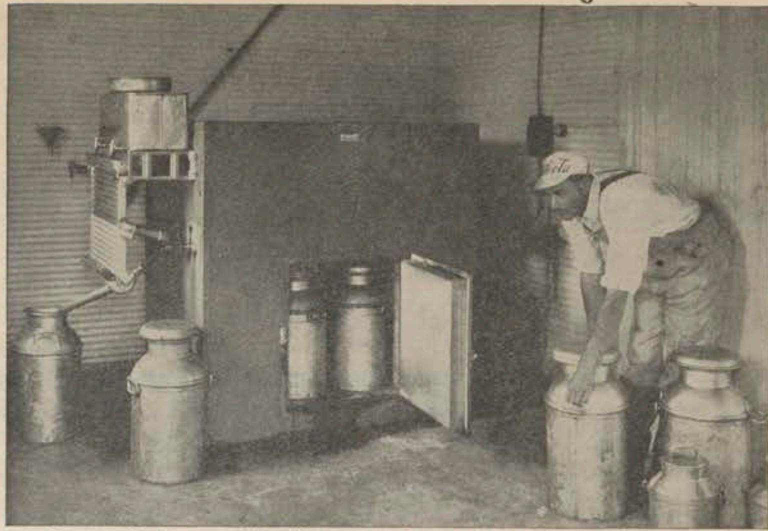


Cross section of insulated concrete storage tank of "wet" type

extremely large herds may be cared for with the large "dry" systems.

Disadvantages are, (1) high first cost, (2) takes up more space in small jobs, (3) operating costs usually higher for small jobs, (4) considerable water required for cooling large ammonia type compressors.

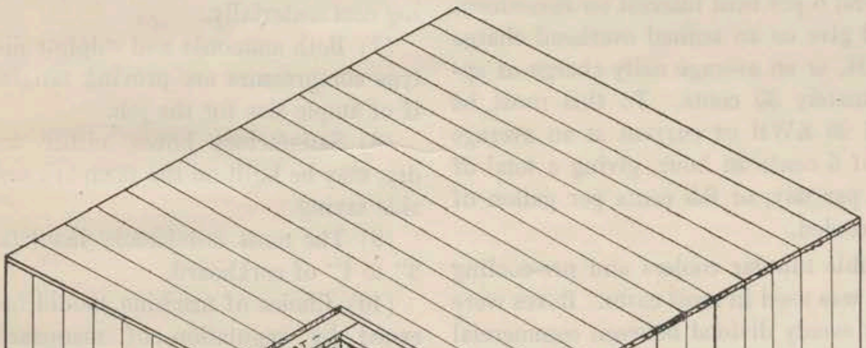
In the "dry" system there are two methods of cooling, namely with brine and by direct expansion. In the brine system the brine is cooled by the refrigerating machine and in turn cools the room, and also furnishes brine for circulation through the aerator. In the direct expansion system the machine operates at milking time and cools both room and milk directly. The brine system is more commonly used because it requires a smaller compressor, maintains a more uniform box temperature, and stores refrigeration in the brine tank. About 50 per cent greater capacity is required for direct expansion.



Non-walk-in type "dry" storage box. Can be used for bottled milk as well as cans

In "dry" storage where brine is used, 1½ gallons of brine for each gallon of milk should be provided. The brine solution should be 20 to 25 per cent if sodium chloride is used or 15 to 20 per cent if calcium chloride is used for 10° brine. (A common rule is brine strong enough to float a potato.) Calcium chloride is less corrosive, and the tank will last longer where it is used. The brine tank should have as much exposed surface as possible. That is, it should be long, high, and narrow. It may be located overhead, or along a wall, but high enough to set cans beneath it, or it may be separate. Where it is separate it should be insulated with 3 inches or preferably 4 inches of cork.

In figuring storage space allow 15″ x 15″ for 10 gallon cans and 18″ x 20″ for crates of bottles. The crates may, of course, be stacked to a reasonable height.



"Cut-a-way" view of "dry" storage box showing method of construction. Plans for both "wet" and "dry" storage may be secured from the agricultural engineering department, V. P. I. extension service

Surface Cooling

Common practise in Virginia is to aerate the milk. A good rule to remember is that the aerator tubes should be six inches in length for each 10 gallons of milk to be cooled per hour. Too much emphasis cannot be placed on the use of a double section or two-way cooler, and the use of well or spring water for pre-cooling. It can readily be seen that a large saving may be effected by taking off 25 to 35 degrees with well water, thus reducing the load on the refrigerating machine nearly one-half. This pre-cooling water may be allowed to flow into a stock tank for drinking purposes, making the cost very slight for cooling. A flow of one gallon of pre-cooling water per minute for each 10 gallons of milk cooled per hour is about right. The same rule applies to the circulation of brine or refrigerated water through the lower half of the cooler, and the proper size circulating pump should be chosen. If too much refrigerated water is supplied, the milk may freeze on the aerator. For this reason, a valve or some throttling device should be provided on pump. Generally speaking, a ¾-inch centrifugal pump and ¼ h. p. motor will handle milk up to 400 gallons per day.

Insulation

"Wet" storage tanks should have three inches of corkboard insulation in walls and bottom and one inch in lid. "Dry" storage boxes should have four inches of corkboard in walls, floor, and ceiling. The insulation in all cases must be carefully and completely waterproofed by mopping and dipping in hot asphalt. Two thicknesses of corkboard should be used with all joints staggered and broken to prevent leakage through joints. Extra care should be taken where walls join floor and ceiling to prevent leaks at these joints. In the dry box two coats of cement plaster should be applied to give a smooth finish and prevent frost damage. The doors must be carefully built and insulated, and fit tightly against good gaskets. Floors should usually be two thicknesses of concrete with cork between.

The following table gives capacity of compressor required to cool a given quantity of milk per day. This is based on the fact that the refrigerating machine should have a capacity equal to 5 to 6 pounds of ice per gallon of milk cooled and stored.

Capacity of compressor in pounds of ice per 24 hours	Gallons of milk to be cooled per day
250	30 - 60
500	60 - 100
750	90 - 160
1000	120 - 200
2000	240 - 350

Note: Capacity depends on amount of milk stored and whether pre-cooling is used. For direct expansion add 50 per cent to compressor for cooling same quantity of milk.

During the last year a study of milk cooling by mechanical refrigeration has been made at the V. P. I. dairy barns in cooperation with the dairy department. Fifty representative dairy farms in various sections of the state were visited also in search of data. Farms visited ranged in production from 20 gallons of milk per day to 400 gallons, and while a majority were wholesale milk producers, a number of large retail producers were also included in the study. Practically all of the more common types of refrigeration were observed in both wet and dry storage. (Only one direct expansion machine was observed.)

Results of this study indicate that the average cost of the "wet" storage, including compressor, box and coils, tubular cooler and circulating pump, runs from $450 for the 4-can size to $650 for the 10-can size. Current consumption where pre-cooling is done should not exceed .1 KWH per gallon of milk cooled and stored in a well insulated box. It would appear that 10 per cent is a safe allowance for depreciation. By taking local cost for current, adding 10 per cent for depreciation, and 6 per cent for interest on investment, the total cost of operation may be arrived at very closely. For example, take a 10-can job, where 200 gallons of milk are cooled, half of this amount being stored. The cost of such equipment would be $650. Allowing 10 per cent depreciation and 6 per cent interest on investment would give us an annual overhead charge of $104, or an average daily charge of approximately 30 cents. To this must be added 20 KWH of current at an average cost of 5 cents an hour, giving a total of $1.30 per day, or 6.5 cents per gallon of milk cooled.

Double tubular coolers and pre-cooling water was used in most cases. Boxes were pretty evenly divided between commercial boxes and home-built concrete boxes. The latter are cheaper, and if well insulated, with the insulation carefully waterproofed, are very satisfactory. They are also usually built so that handling of cans is much easier.

"Dry" storage costs varied from $850 for a 6-can box to $3,000 for a plant with 300 gallons capacity making 750 pounds of ice per day in addition to cooling and storage. Cost of operation ran slightly higher, usually around .8 of a cent to 1 cent per gallon of milk cooled and stored; but compared very favorably with wet storage. This figure includes depreciation and interest on investment.

In other words, mechanical refrigeration is not only practical, but very reasonable both as to first cost and cost of operation. In most instances operating costs are only half those of ice, and the handling of the ice is eliminated. Almost universal satisfaction is expressed by owners of refrigeration, most of them saying, "The question is not do I like it, but how could I do without it." Upkeep as well as operating costs appear to be low, and if not overloaded, all observations indicate that long life and satisfactory service can be expected.

Summary

(1) Control of bacterial growth and quality of milk depend largely on proper cooling.

(2) Market requirements are now such that adequate refrigeration is necessary.

(3) Mechanical refrigeration best meets these requirements.

(4) Installation cost and cost of operation are low as compared with ice.

(5) Both "wet" and "dry" storage is being used, depending on containers used and owner's preference. Each type is satisfactory and has advantages and disadvantages.

(6) Pre-cooling of milk lowers operating cost materially.

(7) Both ammonia and sulphur dioxide type compressors are proving satisfactory if of ample size for the job.

(8) Satisfactory boxes, either wet or dry, may be built on the farm at considerable saving.

(9) The most satisfactory insulation is 3'' to 4'' of corkboard.

(10) Choice of machine should be governed by reputation of manufacturer, service available, and adaptibility to job; as well as cost.

(11) It is highly important to select a machine that will not run over 15 hours per day regardless of weather.

(12) It is wise to allow for reasonable expansion, but remember over-size equipment means high operating cost.

(13) Dependable electric service at a reasonable cost is the most satisfactory power.

(14) Farm light plants or gasoline engine may be used if of sufficient size.

Note: For those dairymen who do not have dependable electric service the use of an insulated cooling tank, a double tubular cooler, and a small circulating pump operated by gas engine or farm light plant, is recommended. The tank should be "wet" type, similar to those used with refrigeration plants, and large enough to hold plenty of ice to lower the temperature of the water in the tank and keep it cold. A tank holding 3 to 5 gallons of water per gallon of milk cooled is recommended. Ice water should be circulated through lower half of cooler by motor, or gas-engine-driven centrifugal pump of same type used in mechanical cooling.