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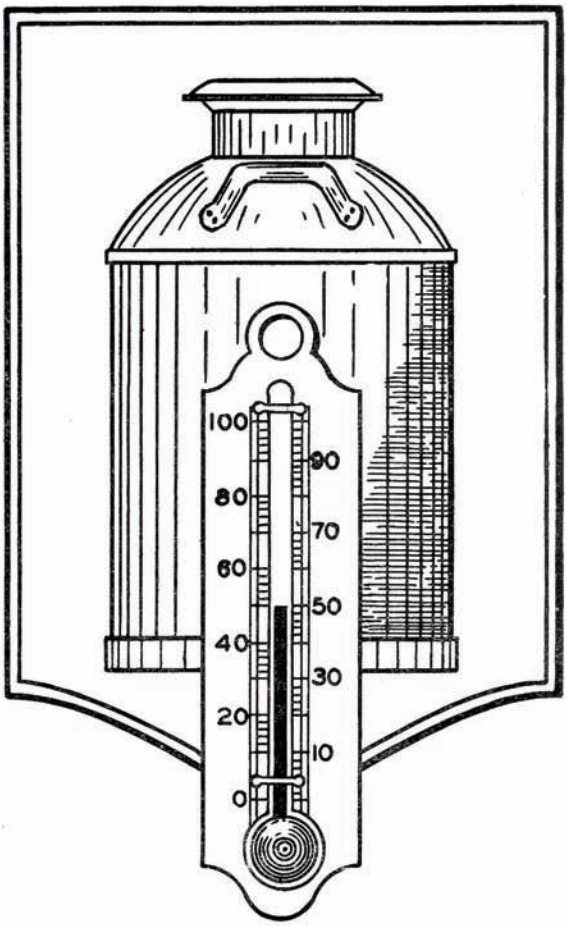
Bulletin 266 January, 1932

Cooling Milk on Nebraska Farms

P. A. DOWNS AND E. B. LEWIS



THE UNIVERSITY OF NEBRASKA
COLLEGE OF AGRICULTURE
EXPERIMENT STATION
LINCOLN
W. W. BURR, DIRECTOR

SUMMARY

Cooling milk is a necessary part of the daily program.

Milk must be cooled in a short time, 1 to 1½ hours, if bacterial growth is to be retarded.

Bacterial growth is very rapid in temperatures of 70° F. and above and is retarded in temperatures of 60° F. and below. A good thermometer is necessary around the dairy room.

Bacterial growth varies in different grades of milk. Clean milk, low in bacterial count, requires less care in cooling. The bacterial count is not, however, lessened materially by cooling.

Cooling milk requires that heat be transferred to some other body. Circulating water requires very simple equipment in cooling small quantities of milk. Rapid circulation of air, water, or other medium is necessary for quick cooling. Positive circulation of the medium gives positive results.

Careless operation causes failure even with good cooling equipment.

Forced circulation of air is necessary in most cold storage rooms.

Elimination of extra equipment and more positive action on all equipment lessen the chances of poor operation.

A definite knowledge of cooling effects and requirements is essential.

Defrosting brine tanks regularly is good practice.

Good arrangement of equipment hastens all cooling.

Cooling Milk on Nebraska Farms

P. A. DOWNS, Department of Dairy Husbandry, and
E. B. LEWIS, Department of Agricultural Engineering

The desire of Nebraska people to continue the improvement of living conditions and to secure more healthful foods has been responsible for many changes in methods of caring for milk. One of the important factors in keeping milk sweet and of good quality is the process of cooling and keeping it cool until used. Three of these processes are as follows: placing containers of warm milk in any quantity of still water or still air at temperatures ranging from freezing to within a few degrees of the temperature of the milk, placing the containers in such positions that air or water are circulated around them, and causing the milk to flow in such manner that a thin film comes in contact with a surface which is cooled by air or liquids varying in temperature from 10° F. to a few degrees below that of the milk. After some of the heat has been removed the milk is stored under conditions very similar to those found in cooling processes.

WHY COOL MILK

Milk is practically free from bacteria when secreted, but as soon as it leaves the udder and comes in contact with anything that has been exposed to the air it will be contaminated with bacteria.

The number of organisms that get into a sample of milk will depend upon the care with which it is milked and handled. If particles of dirt or cow hairs fall into the milk, it will contain many organisms. A large number of organisms may also be kept out of the milk if the pails, strainers, and cans are kept clean, dry, and sterile. It has been shown by experimentation that a large percentage of the increase in numbers of bacteria due to the handling of milk comes from the utensils. It has also been estimated by the United States Department of Agriculture that approximately $40,000,000 a year are lost by the American farmer because of the production of poor-quality milk and cream. This would not be true if the bacteria could be kept out of the milk and not allowed to grow in it.

WHY MILK SOURS

Many different kinds of bacteria are found in milk. Most of these are not in any way harmful to the human family. Many, however, produce acids from the milk sugar and cause the milk to sour. Once they start to grow and produce enough acid to coagulate or curdle the milk, they have reduced its value a great deal. In this condition it has little value except for feeding livestock. From the standpoint of the man who has had to care for the cows and do the milking it is almost

labor lost if the milk is not kept clean and sweet so that he can obtain a good price for it. This is true even if the milk is separated and the cream sold for buttermaking, because the butter will not be better than the milk or cream from which it is produced.

HOW BACTERIA GROW

As long as it is not possible to keep all bacteria out of milk, it is necessary to let as few in as possible and then to keep them from growing. Bacteria, like most other plants, grow best at warm temperatures, 70° to 100° F. When milk is held at these temperatures they grow very rapidly by dividing. Figure 1 shows the comparative bacterial growth when a sample of milk is held at three different temperatures. Some types of bacteria are able to divide once in every 20 minutes under favorable conditions. At this rate a single cell would produce slightly less than 69,000,000,000 cells in 12 hours if all of the cells lived and divided at that rate. As milk always contains more than a single cell when fresh, the time required to produce a large number of bacteria is greatly shortened. The larger the number of bacteria in the sweet milk, the quicker they will produce enough acid to sour it. For that reason milk containing only a small number of bacteria should keep sweet longer than milk containing a large number.

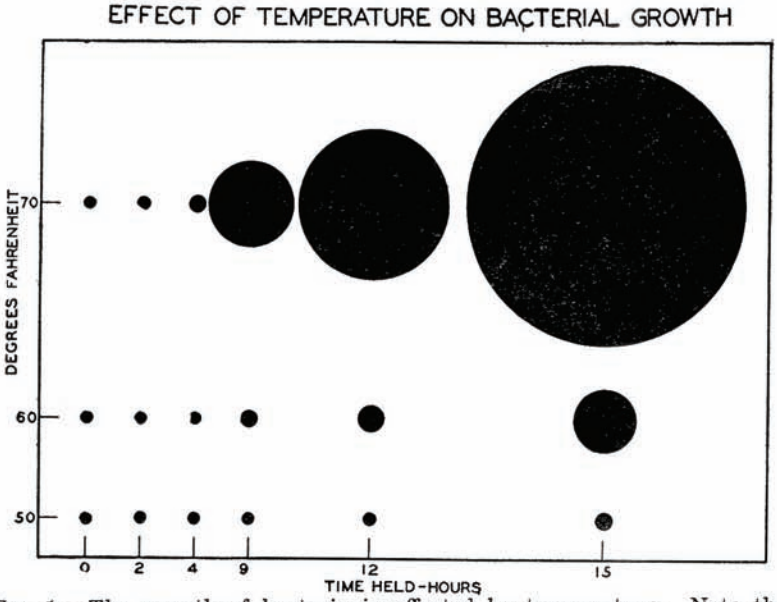


FIG. 1.—The growth of bacteria is affected by temperature. Note the rapid increase in the samples held at the higher temperatures.

EFFECT OF COOLING MILK ON BACTERIAL GROWTH

As the temperature is lowered below the optimum for growth, the division of the cells takes place at a lower and lower rate. For this reason it is possible to control the growth of bacteria that have found their way into the milk and keep the milk sweet for many hours. The length of time that milk will remain sweet will depend upon the kind and number of bacteria present and the temperature at which it is held. It is very evident that dirty milk, or milk high in normal milk-souring bacteria, will act differently from that which has only a few bacteria in it. Also, milk which is not cooled soon after milking is at a temperature which will allow the bacteria to grow much faster than if it has been cooled to a lower temperature. This is shown very clearly in Figure 2, which gives growth curves for three types of milk, with low, medium, and high bacterial counts. This milk was the mixed milk of several cows and adjusted to the desired temperature within approximately 30 minutes after the last of it was drawn from the cows. The cooling was carried out as rapidly as possible by the use of water and ice, and the sample was maintained at the desired temperature throughout the experiment.

Conn and Esten [1] and others have shown that the rate of bacterial growth in milk depends to a large extent upon the types of bacteria in the sample. It should be kept in mind that no two samples of milk have exactly the same flora and therefore cannot be expected to act exactly alike. For that reason three samples of milk were selected for these experiments that would represent milk of different classes or types. It was felt that the results would probably show the trends in bacterial growth as affected by cooling and holding at different temperatures.

To point out the effect of temperature upon the development of bacteria in the samples of three types of milk when held at 40°, 50°, 60°, 70°, 80°, and 98° F., the curves have been shown. It will be noted that no effort has been made to show the final numbers of bacteria in the various samples but rather the point where the pronounced increase in the count took place. This is the important point, for it gives us an indication of how the cooling temperature will affect the quality of milk with similar numbers and kinds of bacteria. It can be readily seen that, in all samples, holding at higher temperatures resulted in rapid growth within a few hours. But even at the temperature of 60° F. all the samples except the very best milk, which contained slightly over 5,000 bac-

[1] Conn, H. W., and Esten, W. M., Connecticut (Storrs) Agr. Exp. Sta. Ann. Rept., 1904.

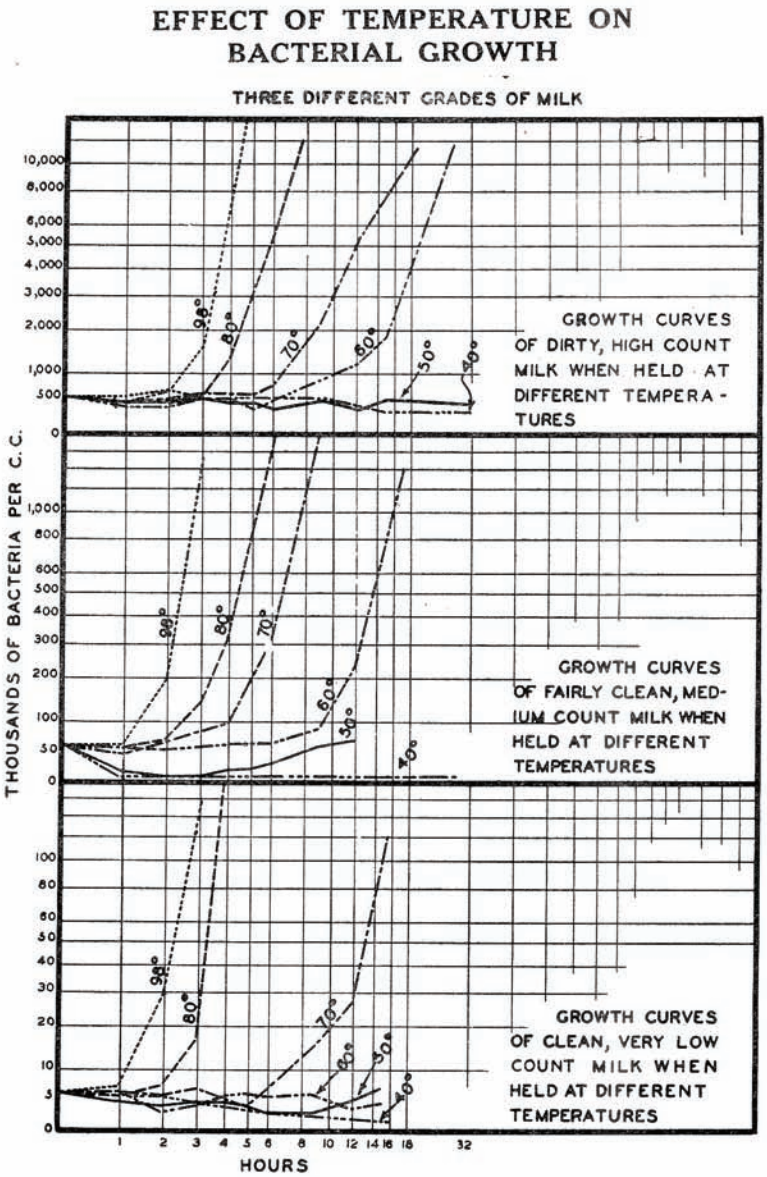


FIG. 2.—The rapid growth of bacteria in milk is retarded by low temperatures. Note that the two lower temperatures were effective in the three grades of milk and that 60° F. was effective in the low-count milk.

teria per cubic centimeter, showed a definite increase when held 15 hours. As this quality is not common in ordinary milk, it is evident that a temperature of less than 60° F. is necessary if the types of milk represented by the other two samples are to be held for 12 to 15 hours without a significant increase in bacterial count and decrease in quality. The night's milk held on the farm and delivered to the plant but once a day must be held in good condition for at least 15 hours or more. If we consider that a practical standard for milk quality is that required by Grade B pasteurizing plants, which is a bacterial count of less than 1,000,000 per cubic centimeter, the following table gives some interesting figures.

TABLE 1.—*Length of time milk was held at different temmeratures and still had a count of less than 1,000,000 bacteria per cubic centimeter*

Type of Milk	Original count per c.c.	Holding temperature					
		40°	50°	60°	70°	80°	98°
		Hrs.	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*	*Hrs.*
Good	5,500	Over 15	Over 15	Over 15	Over 15	6	3
Medium	55,000	Over 15	Over 15	12	6	5	2
Poor	535,000	Over 15	Over 15	9	6	3	2

This would indicate that it is necessary that such milk be cooled as close to 50° F. as the available cooling medium will permit. Where lower temperatures are possible, their use will extend the keeping time of the milk.

HOW SOON SHOULD MILK BE COOLED?

It can be clearly seen from the curves as well as from the table that milk held at high temperatures even for an hour allows bacterial growth to take place. It would seem that if the greatest delay in growth of bacteria is to be obtained, milk should be cooled quickly, but that good results can be obtained if the milk is cooled properly within 1 to 1½ hours after it is milked. As the average producer is not able to use surface coolers to cool his milk quickly, he must adopt some method that will give him the minimum chance of contamination. This, no doubt, reduces his choice to cooling his milk in the can.

SIMPLE HEAT TRANSFER

The process of cooling milk depends upon the transfer of heat from the milk to some other matter. This removal of heat lowers the temperature of the milk and raises the temperature of the cooling medium. This continues until approx-

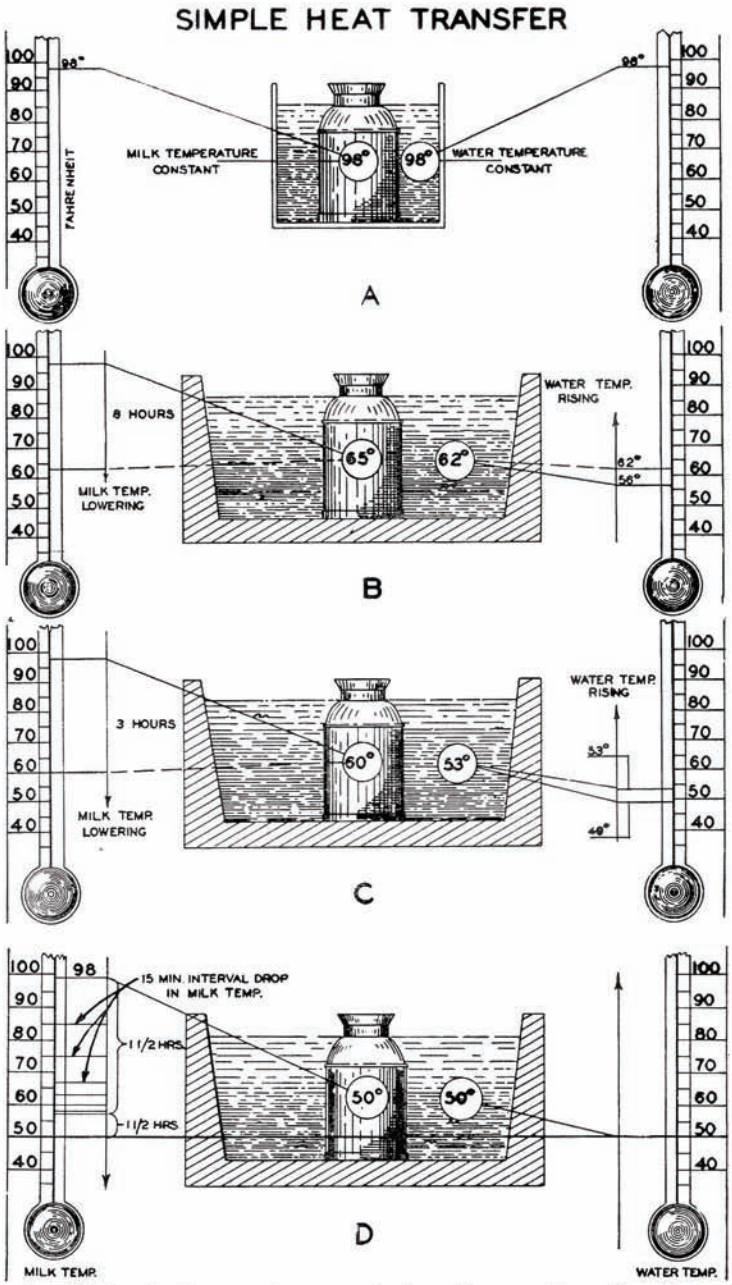


FIG. 3.—Water is the most economical cooling medium found on the farm. The lower the temperature of this water, the more effective it is.

imately the same temperature is produced in the milk and the cooling medium. In order to complete the cooling process the cooling medium must have a lower temperature than that to which the milk is to be cooled. The necessary temperature in the cooling medium depends upon the desired milk temperature and the amount of cooling medium available.

Figure 3A shows that a can of milk does not change temperature or lose heat if placed in any quantity of water at the same temperature as the milk. Figure 3B shows the change, under average Nebraska conditions, when average well water is used as a cooling medium. In a concrete tank holding 200 gallons of still water at 56° F., it was found that 10 gallons of milk originally at 98° F. were cooled to near 65°, while the water temperature was raised to about 62° in 8 hours. Figure 3C shows that 10 gallons of milk at 98° placed in 200 gallons of cold, still well water at 49° were cooled down to 60° F. in 3 hours and the water temperature was raised to about 53°.

Figure 3D shows that when 10 gallons of milk at 98° were placed in 200 gallons of cold well water at 50° with water added at the rate of 3 gallons per minute (an ordinary pumping rate), the milk was cooled to below 60° in 1½ hours and the water temperature in the tank remained at about 50°.

These four illustrations are based on test runs and show the simple principle that when milk is cooled the temperature to which it is cooled and the rapidity of cooling depend primarily on the temperature, quantity, and movement of the cooling water. Thus emphasis is placed on the fact that water that is exposed to sun or artificial heat at the pump spout, in long, lead pipes or big, open, storage tanks does not cool milk nearly as well as the cooler, circulating well water.

CLIMATIC CONDITIONS

The loss and the absorption of heat by milk are affected not only by the temperature of the air but also by the humidity and wind conditions. At Lincoln, Nebraska, these conditions may or may not be correlated as in other sections of the country. The United States Weather Bureau records show that, over a 10-year period, during May, June, July, August, and most of September, the mean temperature was near 75° F., the average humidity at 7 a. m. slightly above 70 per cent and at 7 p. m. slightly above 50 per cent, and the wind velocity below 10 miles per hour more than 60 per cent of the time, with a much larger percentage during night hours. As these are the months through which the greatest amounts of cooling effort are needed, any cooling method must take into consideration the mean conditions.

The Weather Bureau also reports the normal percentage of sunshine for May as 62 per cent, for June, 60 per cent, for July, 76 per cent, for August, 70 per cent, for September, 63 per cent, and for October, 62 per cent. The year 1930 showed higher percentages for each month. Throughout most of these months the maximum temperature was maintained until about 5:30 p. m., although as a rule the air cooled rapidly after this time of day.

Often extreme conditions of temperature are encountered during the summer months. Temperatures as high as 110° F. were recorded in 1930. High temperatures are usually not accompanied by relatively high humidities or high wind velocities. High humidities apparently handicap the quick cooling of milk under some processes. Evaporation has some cooling effects that are lessened when humidity is high. Also, it is generally known that wind velocities affect the heat transfer through insulated walls and that the pressure set up by high velocity winds increases the heat passage through walls 15 to 25 per cent. This condition affects cold storage.

Reference is made to the climatic conditions under which milk cooling experimental data were secured as a partial reason for variation in some results from those obtained in other states.

COOLING MEDIA

Experimental work with milk cooling was carried on in air at or near zero and at or near freezing temperatures. Water temperatures for cooling tests ranged from 33° to 65° F. with a large percentage of trials based on 50° to 55° F., which are the usual temperatures of Nebraska well water. These media were used in a range of circulation rates from still air and still water to positive circulation of large volumes of each.

METHODS OF OBTAINING DATA

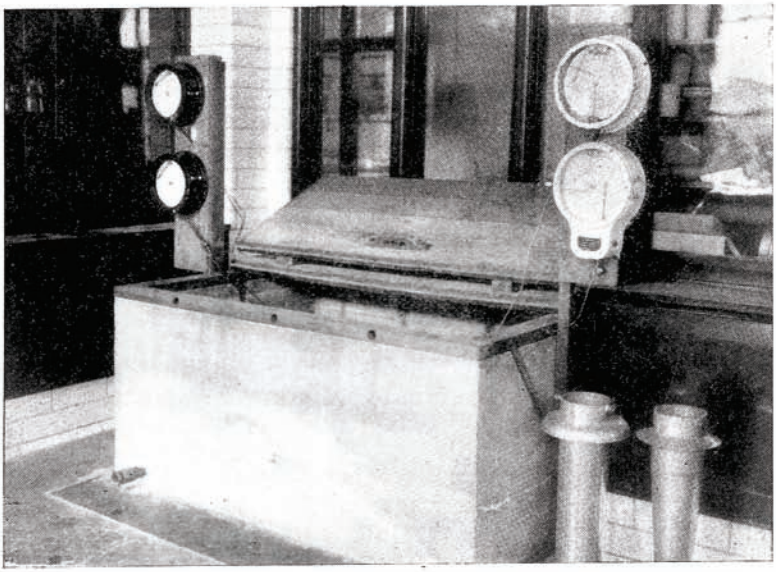
Most of the data in this publication were secured by the Agricultural Engineering and Dairy Husbandry Departments from tests and trial set-ups at the college and on dairies near Lincoln. Recording thermometers, thermocouples, and precision and milk thermometers were used for temperature readings. Recording hygrometers and sling psychrometers were used for humidity records. All bacterial determinations were made in the Dairy Husbandry bacteriological laboratory.

Cooling tanks using well water, ice water, and mechanically cooled water, tubular aerator coolers, "in can" coolers, small containers through which water circulated when the milk can was placed in it, and dry-air walk-in type cold-storage rooms were used. The cooling effects of still air or still water as compared to the effects of the same media when mechanically

circulated were studied. Also, a comparison was made when various volumes of a cooling medium were circulated about a milk container, in most instances a 10-gallon milk can. Trials were also made to determine cooling effects when the milk was stirred in the can. All of these factors were considered in an effort to obtain the best possible results with the various methods. To facilitate some of the trials, water was used in the 10-gallon milk containers when sufficient quantities of milk were not at hand. Although the specific heat of water is higher than that of milk, 0.90 for milk as compared to 1.00 for water, the cooling action was very similar and gave an accuracy as dependable as that of the recording instruments.

RESULTS OF TESTS

Many Nebraska farmers have recently installed concrete milk-cooling tanks. In these tanks the cooling medium is usually well water, the temperature of which, as it comes from the wells, varies from 50° to 55° F. On one or two farms having shallow wells, temperatures as low as 45° F. in June and as high as 52° F. in September were encountered. The curves in Figure 6D show what can be expected when well water with temperatures common to Nebraska or to refrigerated water is used. It should be noticed that the best cooling is done when the most positive circulation is accomplished.



FIR. 4.—A concrete cooling tank similar in design and construction to those used on many Nebraska farms.

Beside the tank, Figure 4 shows two double-walled cylindrical-shaped coolers which can be placed inside the milk can. Water can be circulated between the walls to cool the milk rapidly, with little chance for contamination from outside. Two double-pen and two single-pen recording thermometers are also shown. With these, 6 simultaneous temperature readings were obtained during a test period. Many of the trials with ice water and water at well temperatures were made with this equipment. Many of the test trials with mechanically cooled water were made while using the equipment shown in Figure 5.

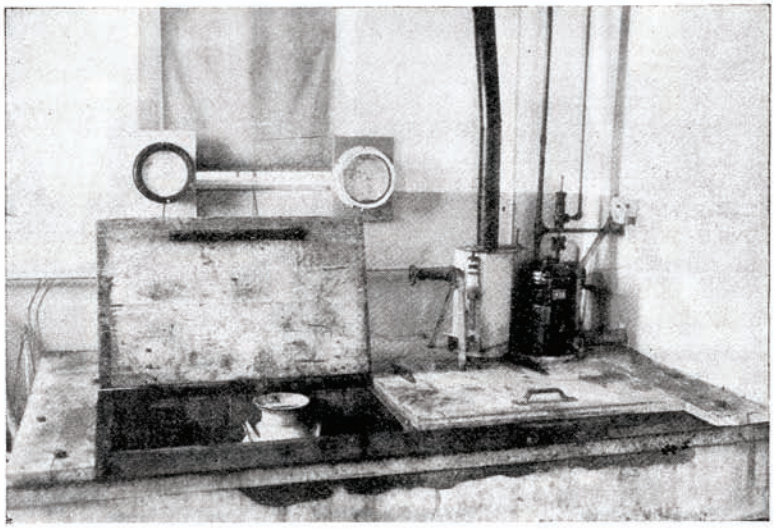


FIG. 5.—This type of tank has been used where lower temperature and more rapid cooling were desired than is possible by the use of well water alone.

When a can of warm milk is placed in still water, a film of warm water, very nearly the same temperature as that of the outside of the can, forms and prevents rapid loss of heat from the milk to the water. This is illustrated in Figure 6A. Figure 6B shows that the film of warm water around the milk can is lessened materially when there is some movement of cooling water.

Figure 6C shows that when this movement of cooling water was positive around the warm can, this warm film became very thin, allowing more rapid transfer of heat from the milk. Figure 6D shows in a graphic way the comparative temperatures possible when the three conditions were tried

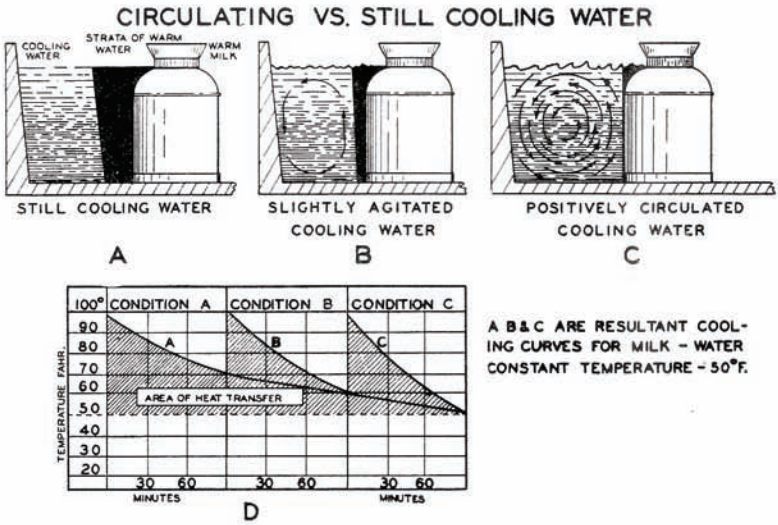


FIG. 6.—Any movement of the cooling medium tends to equalize the temperature. This reduces the warm film around the material being cooled.

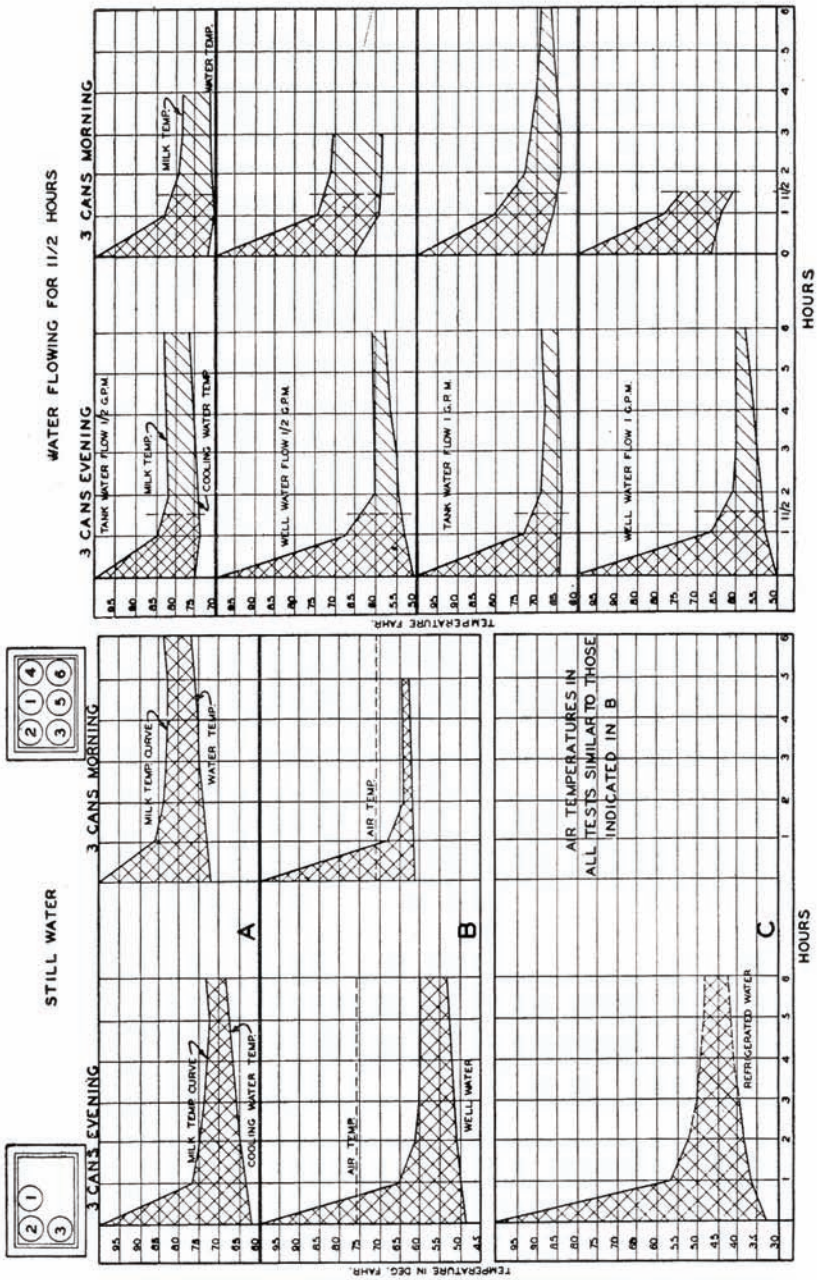
with well water at 50° as a cooling medium. The conditions are exaggerated in Figures 6A, 6B, and 6C, but by tests with galvanometer and thermocouples it was found that, although the warm space outside the can was never more than a fraction of an inch in thickness, this could be made much thinner by movement of the cooling medium. Tests to bring out these facts were also made with air, at several temperatures, as the cooling medium.

To obtain the information illustrated in Figure 6, several thermocouples were fixed in positions to secure temperatures at slightly increasing distances out from the warm milk can. When either air or water was used as the cooling medium, it was found that the outer side of the can was slightly lower in temperature than the inside, and the film of water nearest the can was slightly lower than the metal. Outside the warm film, the temperature lowered rapidly to that of the original cooling air or water.

To prevent the development of large numbers of bacteria, many milk regulations demand that the temperature of fresh milk be lowered to 50° F. in from 1 to 1½ hours after milking. The curves in Figure 2 show the reason for this demand.

In Figure 7 are curves showing the results of trials made mostly with the equipment shown in Figure 4. Part of these trials were made on farms near Lincoln, Nebraska. These few results are representative of many secured in following

COOLING CURVES FOR 10 GALLON CANS PLACED IN 6 CAN CONCRETE TANK



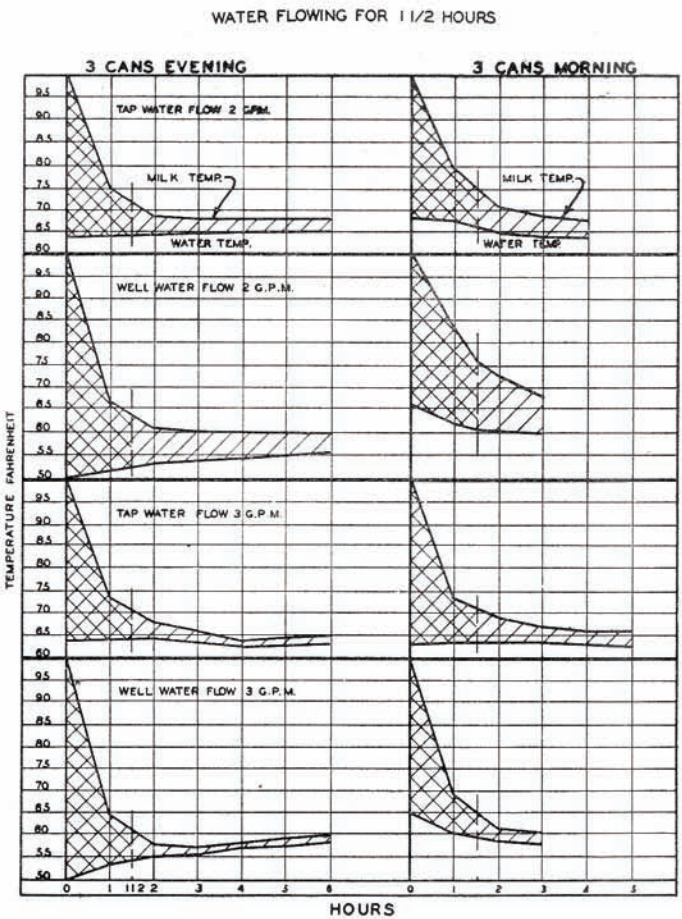


FIG. 7 (continued from page 14).—The necessary amount and movement of the cooling water depend on the temperature of the water and the milk temperature desired.

the procedure found on farms where cooling tanks were being used.

It will be noted in A, B, and C (Figure 7) that the still water must be very cold to bring the temperature down to 50° F. in 3 hours, even in mean summer temperatures as indicated in B. The cooling action is hastened when there is some circulation in the tank. In all the remaining curves the short perpendicular line above the 1½-hour point indicates that water flowed into the tanks at the different rates for 1½ hours both morning and evening.

The temperatures of the water in the tank at the beginning of the morning trials were those found when the water had stood 12 hours with the warm milk stored in it. The pumping in the morning started when the milk was set to cool. The temperature of the evening milk at the end of 12 hours was slightly higher than that of the water. These curves show the practical application of Figure 6.

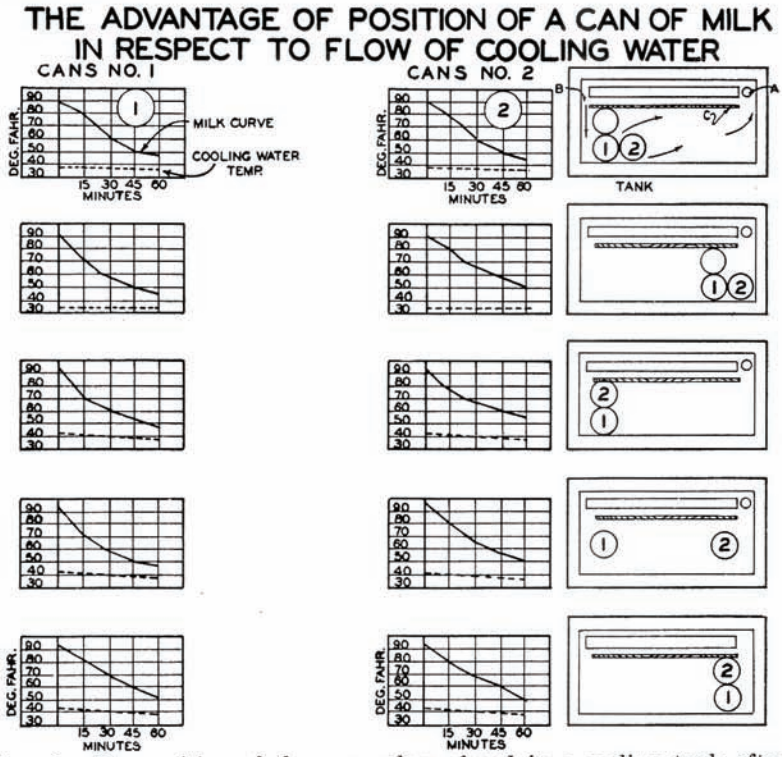


FIG. 8.—The position of the cans when placed in a cooling tank often affects the circulation of the cooling water. This condition should be controlled. A is the pump intake, at the bottom of the tank, and B is the overflow at the top.

The cooling tank shown in Figure 5 was used in securing the curves in Figure 8. When the equipment was first installed the mechanically refrigerated water was agitated by force-pumping 50 gallons of water per minute over the coils containing the refrigerating gas. When the intake and discharge of the pump were near each other as at A in the tank, it was found that the position of the can might cause the temperature to which the milk was cooled in 1½ hours to vary as much as 25 degrees. Baffle C was so arranged that

the water circulated, as indicated by arrows, from the intake at A through the pump, over the coils, and out over weir B near the top and at the other end of the tank. With this definite circulation the small difference in temperature between cans 1 and 2 was obtained. The change of temperature of the milk in can 1 is shown in the column marked Cans No. 1. To the right of the curves in each case is a diagram of the positions of the cans. In all cases, with the cooling water temperature as indicated, the milk was cooled from 90° F. or above to below 50° F. within one hour. In no trial were the results satisfactory unless water circulated about the cans of milk.

It was thought possible that small rates of pumping the circulating water might suffice. To make this test, small pumps were used in the same tank and discharges from the pump were changed to cause the water to circulate at different rates and in different directions within the tank. It was found that if as small a quantity of water as 3 g.p.m. (gallons per minute) was directed against the side of each can, producing what the experimenters chose to call positive circulation, the milk was cooled as low and as rapidly as it was at the better positions in the tank when 50 g.p.m. flowed from one end of the tank to the other. All these trials were made with milk that had not been precooled over the tubular cooler shown in Figure 9. When this refrigerated or mechanically cooled water was used, 1 instead of 1½ hours was the time the milk in the cans was given to cool to 50° F.

The necessity of full submergence of cans in water was shown during the test runs indicated in Figure 8. It was found that when water at 36° F. was circulated about the cans, the milk in the top at the end of 1 hour was as much as 25 degrees warmer in a can half submerged than milk in the top of a can which was submerged high up on the neck. It was also found that it took almost as long to cool 5 gallons of milk in a 10-gallon can as to cool 10 gallons in a 10-gallon can if the can was closed and the water outside was maintained at the level of the milk in the can. If only 5 gallons of milk were to be cooled in a tank, the best results were obtained by placing this quantity in a can of small diameter.

The tubular cooler shown in Figure 9 was installed in the same room with the tank shown in Figure 5 and was used for precooling most of the milk produced by the Experiment Station herd. It is very similar to those found on many Nebraska farm dairies. This cooler and most others are so arranged that an even flow of milk is distributed the full length of the tubes through small holes in the trough above. The milk passes down over the outside of the tubes in a thin

film and is caught below in the containers. As the film of milk goes over the outside of the tubes, cold water (or sometimes cold water in the top half and brine in the lower half) is forced through the tubes at a capacity sufficient to remove much of the heat from the milk. The cooler shown is expected to cool 60 gallons of milk per hour. Most tank methods do not cool milk this rapidly.

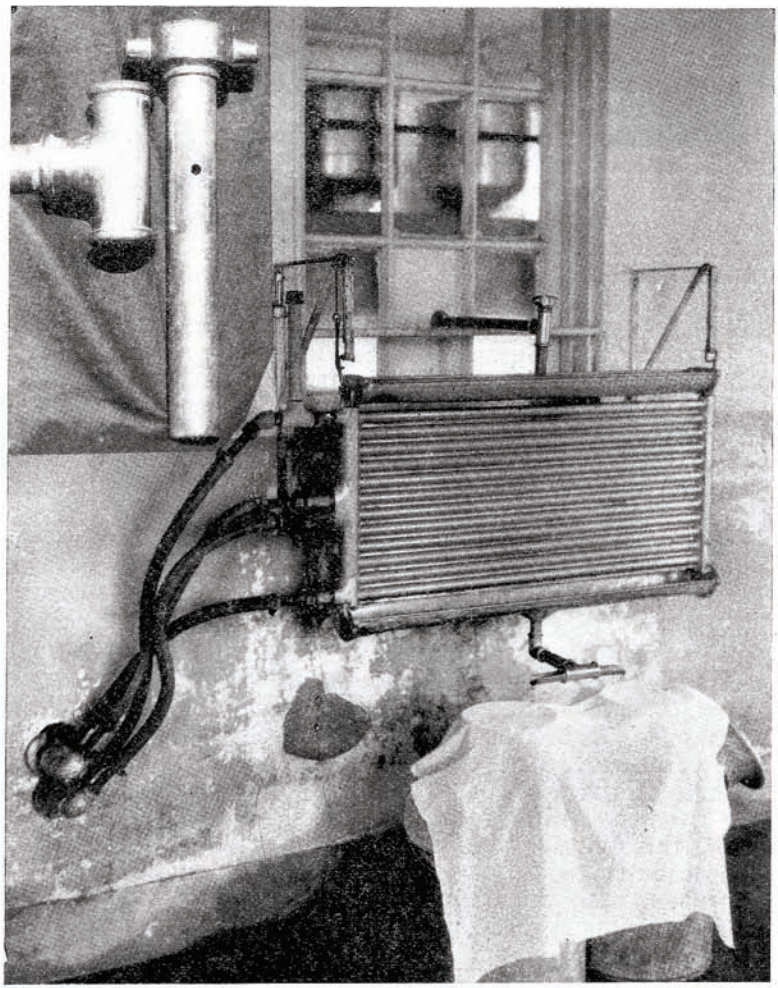


FIG. 9.—A practical tubular cooler arrangement. Note the control valve. At the left this is shown in detail. It is made of sanitary pipe and fittings with one opening, which allows only that amount of milk to flow which will be cooled to the desired temperature.

Some city ordinances and regulations demand that milk shall be aerated. The tubular cooler accomplishes this. Some have been critical of this method, claiming that the chances of contaminating the milk as it passes over the tubes counterbalance the benefits derived by this method of aerating. "Don't let the milk touch any more utensils than necessary" is the advice of the second group. The tests reported in this bulletin were made to show only the cooling possibilities of several methods. It was found that with several of these coolers rated by the manufacturers at 60 gallons of milk per hour, the milk could be cooled at the rate of about a gallon per minute to 40° F. if the cooling water was 36° F. or below or if the upper section of the tubes contained water at 50° to 65° F. and the lower section contained brine at 10° to 25° F. In each set of conditions the flow of the cooling medium was adjusted to give the best results.

Observation of cooling methods on several dairies near Lincoln showed that in many instances where it was possible to cool to 40° F., the milk was going off the cooler at 48° to 50° and even as high as 58° F. Usually this was the result of carelessness on the part of the operator in opening the control valve and allowing the milk to flow too fast. The two-part valve having but the one small opening through which the milk can flow to the cooler was devised by the experimenters to prevent the operator from hurrying the process (Figure 9). The valve is very simple and is easy to sterilize. The pipe in which the hole is made fits inside the "T" of the pipe from the strainer tank (shown in the window, Figure 9) and can be turned to one "on" position. Often after the milk was passed over the cooler it was caught in a warm can and left in a warm room until, when ready for storage, the temperature had risen 5 to 10 degrees above that secured by precooling. Many trials were made by placing 10 gallons of milk in the cooling tanks without precooling to see if the precooling was necessary.

It was found that a 10-gallon can of uncooled milk set into a tank of *circulated* water would have about the same temperature at the end of 1 hour as that of another 10 gallons cooled over the surface cooler and then set in a tank of *still* water if the temperatures of the two cans of milk were the same originally and that of the cooling water the same in each trial. The refrigerating requirements were also greater when the milk was cooled over the surface cooler because of absorption of heat in the pump and cooler.

It was also found that if the milk was brought to the dairy room to be cooled as it was milked and poured into a can held in a tank of circulating water, it would have a lower

temperature at the end of one hour than if it was run over the tubular aerator into a can standing in warm air, as is the usual procedure.

MISCELLANEOUS METHODS OF COOLING MILK

Conical milk coolers, small compartments in which to set a can of warm milk, hand and mechanical stirrers, and internal coolers and combinations of these were tried with general results that were not very satisfactory unless sufficient circulation was available. Contact with a cooled surface did not produce efficient cooling unless there was movement of the warm milk or the cooling water. The conical milk cooler produced much the same results as tubular coolers when carefully used. Stirring milk in the cans during the cooling periods, either by hand or by mechanical stirrers, produced but slightly better results than were obtained when the warm can of milk was placed in a half barrel or similar container through which 3 gallons of water per minute were circulated. The quickest cooling was produced when both milk and cooling water had some forced movement. When the cooling water was circulated at the rate of 3 gallons per minute the milk was cooled to within 10 degrees of the cooling water temperature in one hour and to within 5 degrees of that temperature in 1½ hours.

Circulating the water around the outside of the can produced almost as quick cooling, was more convenient, and lessened the chances of contamination brought about by stirring the milk.

THE INTERNAL COOLER—PARTIAL SUBMERSION TYPE

The type of internal cooler shown at the right of the tank in Figure 4 is a 2-walled, cylindrical utensil through which water is passed down one side and up the other. The use of the internal cooler has merit in that all the equipment is simple, easy to sterilize, and produces quick cooling. Tests were made in the laboratory with this type of cooler under conditions common to many farms. It was found that the best results could be obtained by having the water that passed through the cooler also circulate about the outside of the milk can. The extra surface exposed to cooling action hastened the transfer of heat from the milk. Figure 10 shows graphically some representative data on the change of temperature of the milk in the top 6 inches of milk in the can. Graphic results are shown with refrigerated water at rates of flow of ½ gallon, 1 gallon, and 3 gallons per minute through the internal cooler while somewhat submerged in the milk in a can. It was found that, as in Figure 10B, if the can of milk was placed in a container and the cooling water also circulated

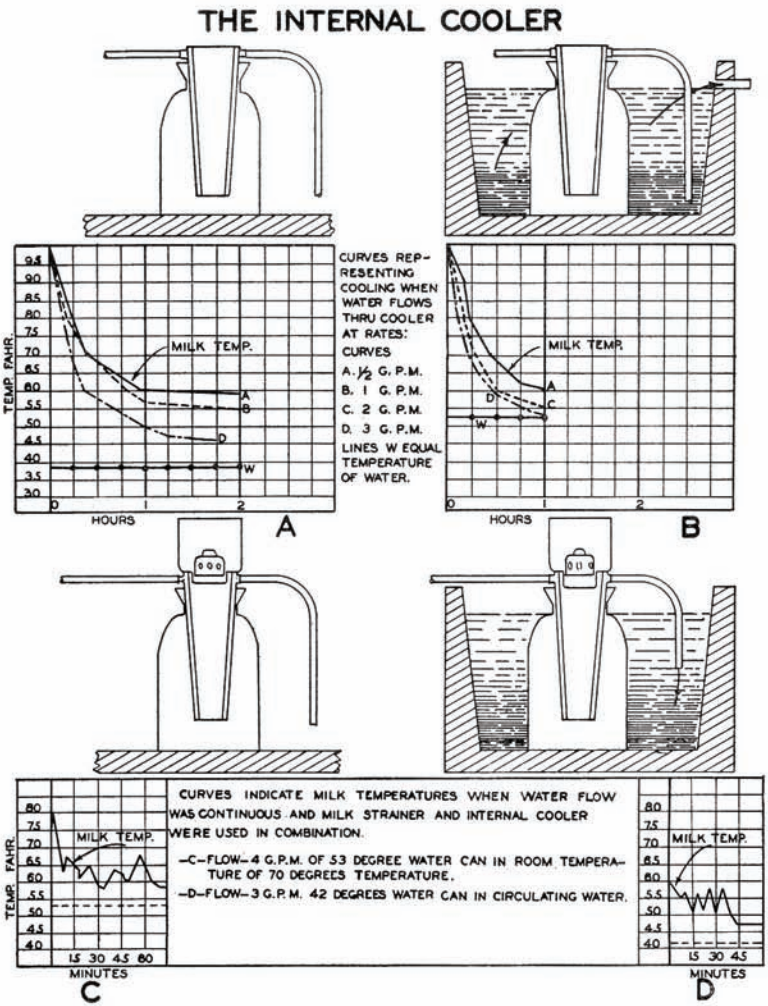


FIG. 10.—Many simple coolers of the type that can be placed inside the milk can have appeared on the market recently. Their simplicity and the ease with which they can be sterilized are reasons for their growing popularity.

about the outside of the can, almost as good results could be obtained with well water as could be obtained if the can of milk was surrounded by warm air when the refrigerated water was the cooling medium as shown in Figure 10A. The resulting cooling curves shown in Figures 10C and 10D were secured when water was circulated through the internal

cooler as the milk was being strained into the can. Again, very much better results were obtained when at the same time the cooling water circulated around the outside of the can.

This can be made into a very simple cooling method for any dairymen who have cold running water near the barn. Those with only well water available could easily use this method by pumping a fresh supply of water into a small elevated tank just prior to milking time and allowing this water to flow through the cooler. If used in conjunction with a cooling tank, a siphon may be used to carry the water through the cooler.

THE USE OF BRINE IN COOLING AND THE AIR-COOLED ROOM FOR STORAGE OF MILK

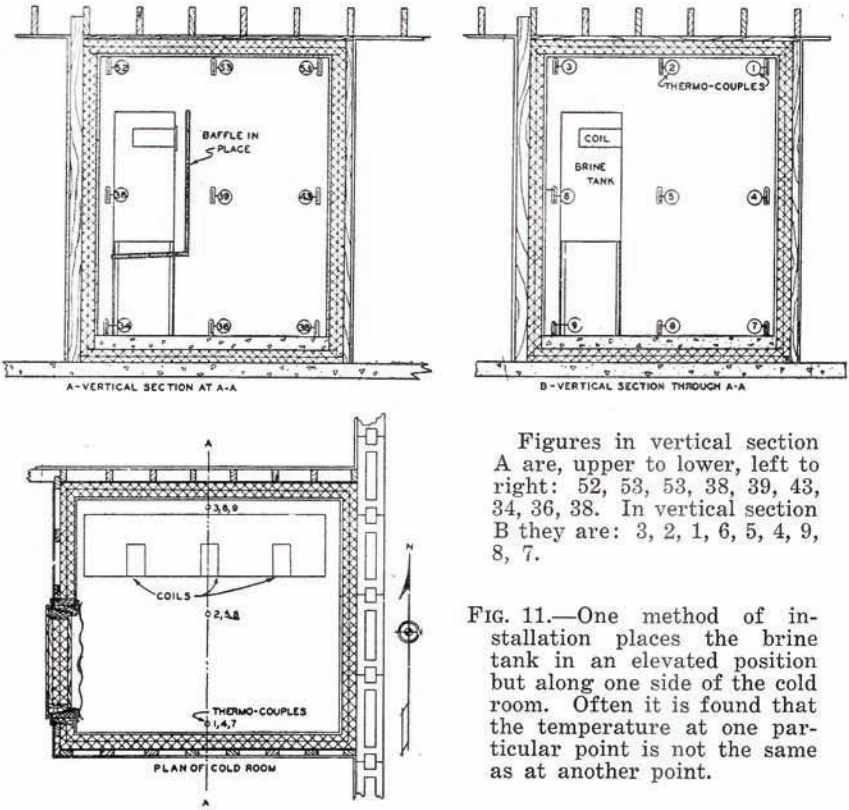
While most producers handle milk in cans and use water for cooling and storage, some of them and most of the large producers do some bottling and retailing and use methods entirely different from those discussed thus far. Many of the producers whose equipment formed the basis of this study were apparently not getting satisfactory results from their cooling operations.

Data were secured from most of the farm dairies near Lincoln that used an air-cooled room for storage of the milk after it was precooled. The precooling was accomplished at all these places by the use of a tubular cooler similar to that shown in Figure 9. Water, either direct from the well or from the water system, was forced through the upper section and brine through the lower section. All observations on this type of cooling and storage were made while the dairies were operating at usual summer practice.

It was discovered that many times milk that had been in a cold room for several hours would still be many degrees higher in temperature than that of the room or that of the milk as it should come from a cooler.

Figure 2 shows how disappointing the bacteria count may be when the cooling equipment or process apparently fails to produce low temperatures in a short period. It has been mentioned that in other processes of cooling and storing milk, the operator often fails to obtain the low temperature desired. This condition seems very common.

Portions of milk that had come from the cooler at a temperature above 50° F. and had absorbed more heat from warm cans in warm dairy rooms, were tested for temperatures when placed in cold storage, after being held several hours and before being delivered to the consumers. It was found that unless the precooling was complete, very much of the milk was never cooled to safe temperatures. Milk showed very much the same temperatures during 6- to 12-hour hold-



Figures in vertical section A are, upper to lower, left to right: 52, 53, 53, 38, 39, 43, 34, 36, 38. In vertical section B they are: 3, 2, 1, 6, 5, 4, 9, 8, 7.

FIG. 11.—One method of installation places the brine tank in an elevated position but along one side of the cold room. Often it is found that the temperature at one particular point is not the same as at another point.

ing periods in many of the cold rooms. Some of the milk had even higher temperatures than were recorded when it was first stored.

Recording thermometers placed in some of these cold rooms showed that during periods when these rooms were closed the temperatures in some storage areas were very different from those in other areas. Apparently the cold was not being diffused as it should have been.

The experimenters found that some of the extreme differences were in cold rooms in which the practice of placing ice or other cold storage bunkers, tanks, or coils overhead had not been followed. In an attempt to determine the causes of these findings, 9 thermocouples were placed near recording thermometers in a cold room having a brine tank installation as shown in the plan and the vertical section in Figure 11B.

Some of these installations had included a baffle to promote diffusion of cold-air circulation. Other installations had not included this. In the cold room which offered the best study, the baffle was in place when the experiment started (Fig. 11A). A condition peculiar to this type of installation (too much moisture in the storage room where the tank holding the brine at 10° to 15° F. was installed) had created enough frost and ice on the brine tank to fill the space provided for circulation of air between the baffle and the tank. The resulting average temperatures are shown in the circles in Figure 11A. The thermocouples were read every 15 minutes over a period of 24 hours as a check against recording thermometers having much slower action or sensitiveness. The baffle was then removed and temperature readings again taken. These were very little different from those taken when the baffle was in place. It was possible to arrange the milk crates and cans to completely cut off circulation of air in this room. This condition was felt to be very poor in view of the fact that often further cooling of the milk was necessary after it was placed in storage.

Fans or different sizes were placed in several places in a cold room, as indicated in Figure 12, and operated separately. It was found that with the storage room in regular use a very small electric fan would in a few minutes produce equal temperatures in the parts of the room indicated by thermocouple positions. It was found that when a 12-inch fan was operated within one foot of a 10-gallon can of milk at 95° F. the milk temperature was lowered below 60° F. in one hour, provided the air temperature at the fan was 36° F.or lower and the air forced towards the can of milk. When

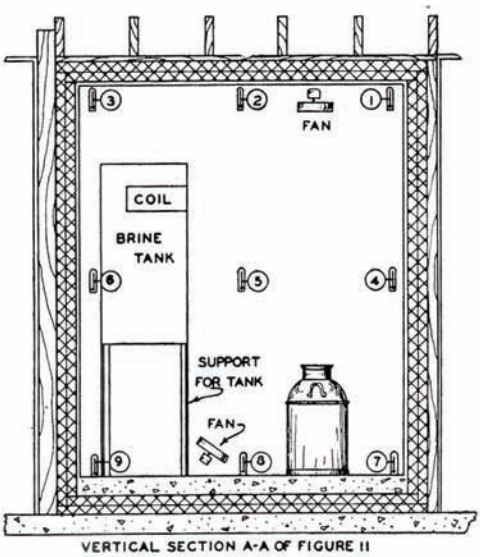


FIG. 12.—Uniform temperature can be maintained in a cold storage space by the use of forced air circulation. Methods of producing circulation are often hindered by the position of articles in the storage space.

milk was bottled at 95° F. and stacked in wire crates out from the walls one inch, successful cooling was produced in the fourth crate from the fan when the air current was directed through the crates. The air temperature at the fan was 36° F. for these trials. While this forced air circulation study was not complete, it did show possible uses for a small fan, possibly thermostatically controlled, in milk storage rooms where further cooling was needed after the milk was stored. In the still-air condition found in many cold rooms, warm milk was not sufficiently cooled to retard bacterial growth after 12 hours in temperatures below 36° F.

Unless the operator kept the frost on the sides of the brine tank down to a minimum, he had difficulty in obtaining the necessary cold temperature (about 36° F.) in a part of the storage room. Figure 13 shows the comparative increase in average temperature over a 12-hour period when the thickness of frost and ice on the tank increased. These temperatures were taken at a point 3½ feet from the floor in the room indicated in Figure 11.

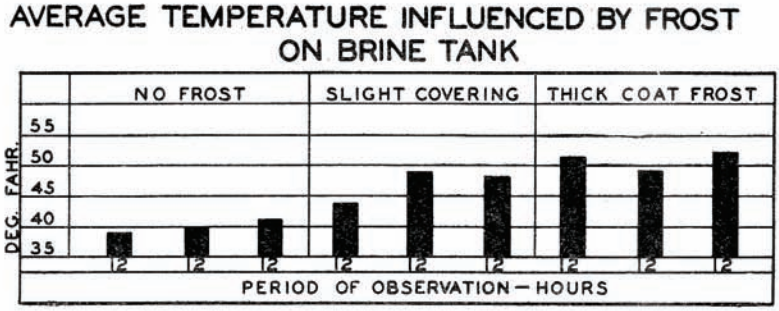


FIG. 13.—Excessive frosting on brine tanks and refrigerating coils may be reduced by the use of higher temperatures in the refrigerating brines and gases and by providing forced air circulation.

Opening the large doors (2′ 6″ x 6′ 6″) to the cold rooms apparently caused an inrush of warm air and a resulting severe rise in temperature inside the cold storage space. In one dairy room the boiler and sterilizing equipment caused the temperature outside the cold room door to be 90° to 110° F. during several hours per day. Near the door the fan of the compressor unit seemed to drag the cold air out of the cold room as the warm air rushed in. A shutter was provided to obtain an open-fan or closed-fan condition (Fig. 14). The refrigerator people had not decided definitely their recommendations for baffles. Some tests were run to determine improvements. Hanging a curtain inside the door was apparently the greatest help in holding down the inrush of warm air.

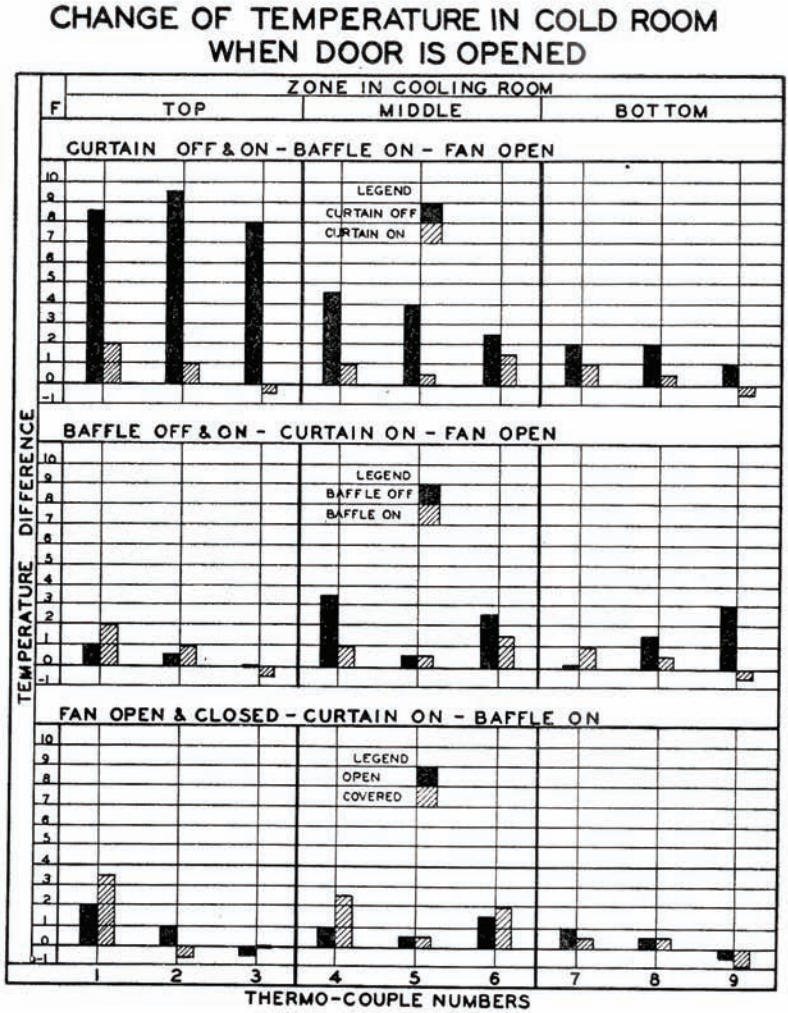


FIG. 14.—The use of a large refrigerator door as compared to the volume of the small storage room has an important bearing on economy of operation.

Figure 14 shows the resulting change of temperature under several conditions at points indicated by thermocouple numbers placed as in Figure 11. It will be noticed that the greatest change was found when the curtain at the door was changed. When the curtain was not on the door the change in temperature was several degrees at each thermocouple

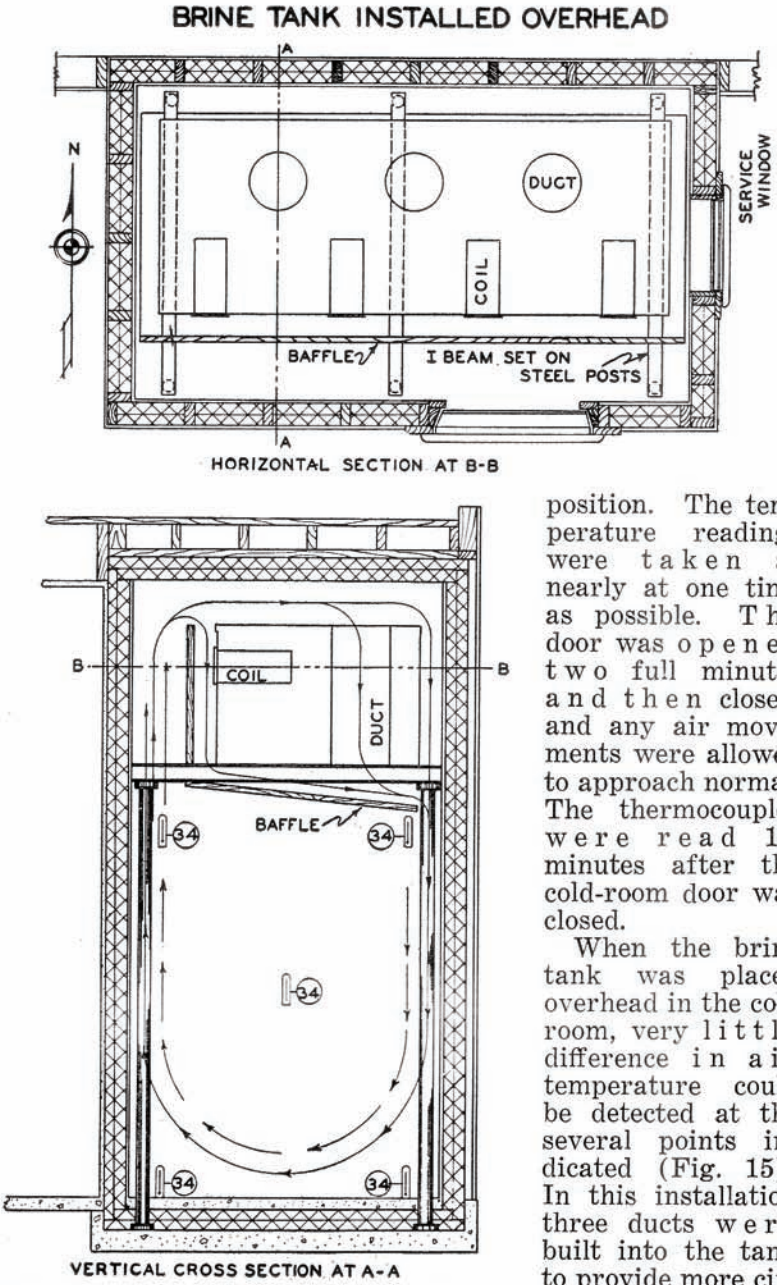


FIG. 15.—Since cold air is heavier than warm air, better circulation results when the brine tank or refrigerating coils are placed overhead.

position. The temperature readings were taken as nearly at one time as possible. The door was opened two full minutes and then closed, and any air movements were allowed to approach normal. The thermocouples were read 15 minutes after the cold-room door was closed.

When the brine tank was placed overhead in the cold room, very little difference in air temperature could be detected at the several points indicated (Fig. 15). In this installation three ducts were built into the tank to provide more circulation of cold air. Increased time of compressor opera-

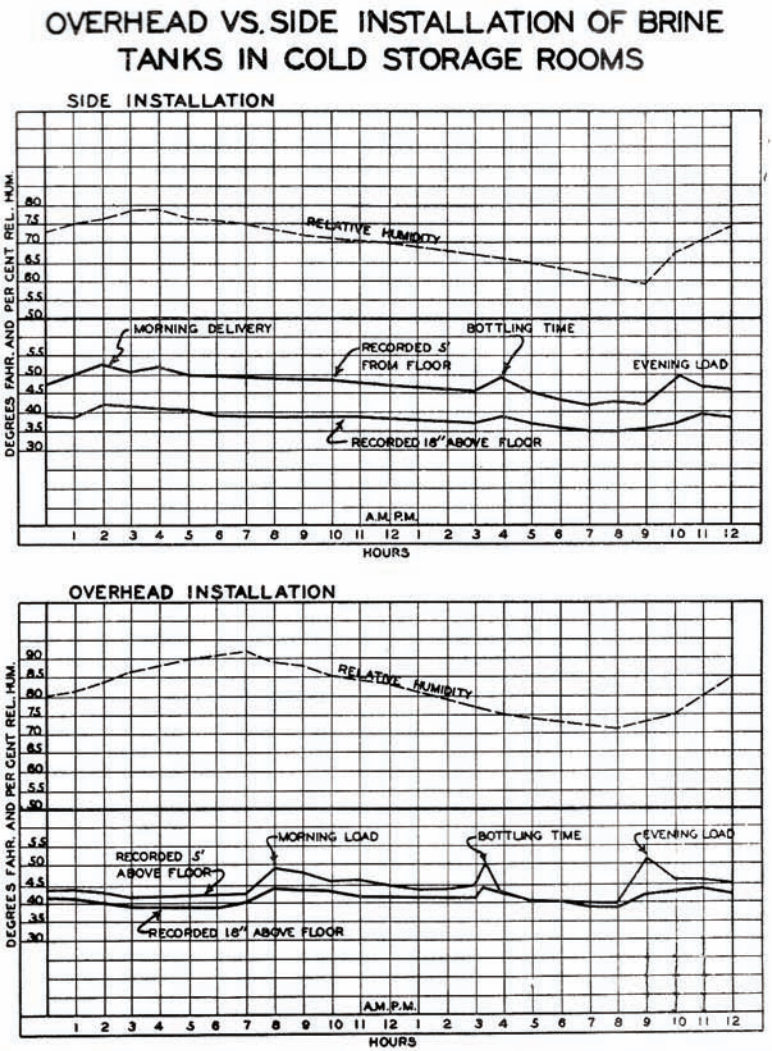


FIG. 16.—The properly planned and equipped storage room operates efficiently only when care and attention are given to its operation. A study of its operation will greatly improve the efficiency of any installation.

tion was caused in this case, because the owner allowed all air passages around the baffles and ducts to become choked with frost and ice. Here, as in the cold room of Figure 11, the addition of a water-proofed curtain inside the door helped in preventing the warm, moist air from passing into the cold

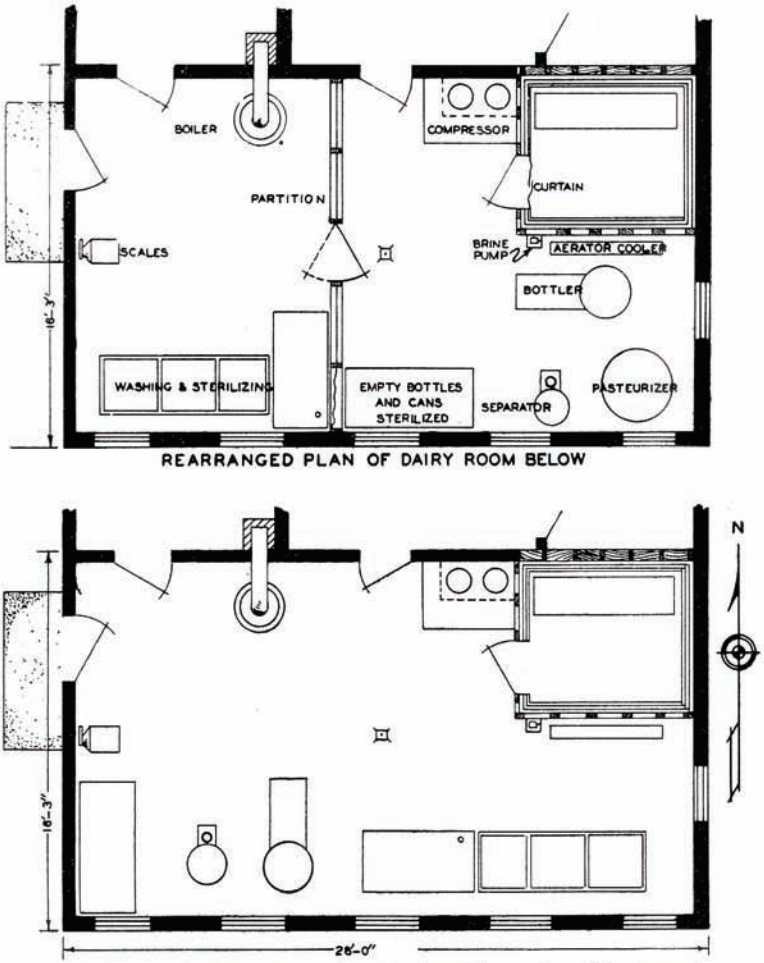


FIG. 17.—Much of the success in the handling of milk depends upon personal attention and care. The arrangement of equipment so as to make it easy to carry out essential principles should insure a better product.

room when the door was opened to allow workers to place or remove the milk.

Typical 24-hour recorded temperatures are shown in Figure 16 for the two types of installation. Neither of the systems was in the best working order when the temperature and humidity records were taken from which the curves were drawn, but conditions affecting temperatures were very nearly the same for each. The curves do show and emphasize

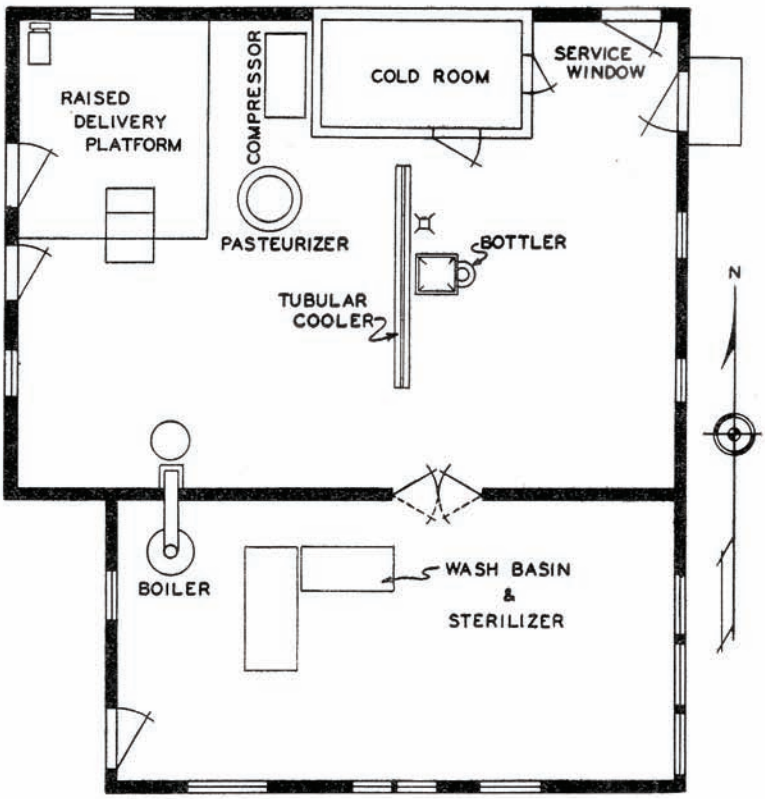


FIG. 18.—Many of the suggestions for a good dairy room have been carried out in this plan. Less floor space would be more economical under some conditions.

that even temperatures were apparently more common when overhead installations were in use.

In the lower part of Figure 17 is the plan of the dairy room in which the cold room of Figure 11 is located. In the upper plan are incorporated several suggested changes. Some of these changes that seem most important are: the addition of a curtain inside the cold-room door, hingeing the cold-room door to swing from the opposite side, the partition to prevent direct radiation of heat from boiler to cold room, the rearrangement of separator, bottler, sterilizing equipment, and pasteurizer. Preventing excessive heat from the vicinity of the cold-room door, swinging the door in such a manner that it is more convenient and does not necessitate full opening, and adding labor- and step-saving features will cut down costs for the dairy.

In Figure 18 is shown the plan of the dairy in which the cold room shown in Figure 15 is located. While more building space is used than many feel necessary, the general arrangement is convenient and provides efficient cooling and storage.

[5M]