COOLING MILK ON THE FARM

BY

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DIVISION OF BACTERIOLOGY

DOMINION EXPERIMENTAL FARMS

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WHY COOLING IS NECESSARY

Every summer, farmers shipping milk for the city and town trade lose thousands of dollars because they fail to control bacterial growth. Not only is sour milk rejected, but progressive dairies nowadays penalize shippers whose milk shows poor keeping quality[1]. In both cases the trouble is due almost entirely to the rapid growth of bacteria in the milk. While this does not mean that proper care need not be taken in the production of milk[2], it is obvious that such care is largely wasted unless proper provision is made to prevent bacterial growth by adequate cooling.

Farm crops, such as corn, grow well only when the soil is sufficiently warm. During cool weather little or no growth takes place. Like the corn plants, bacteria in milk grow best at certain temperatures, usually between 70° and 100°F. although considerable growth takes places at temperatures approaching 50°F. If milk is to keep properly it must be cold enough to check bacterial growth. The rates of bacterial growth at various temperatures are illustrated in Fig. 1. At 40 degrees there was practically no change in the num-

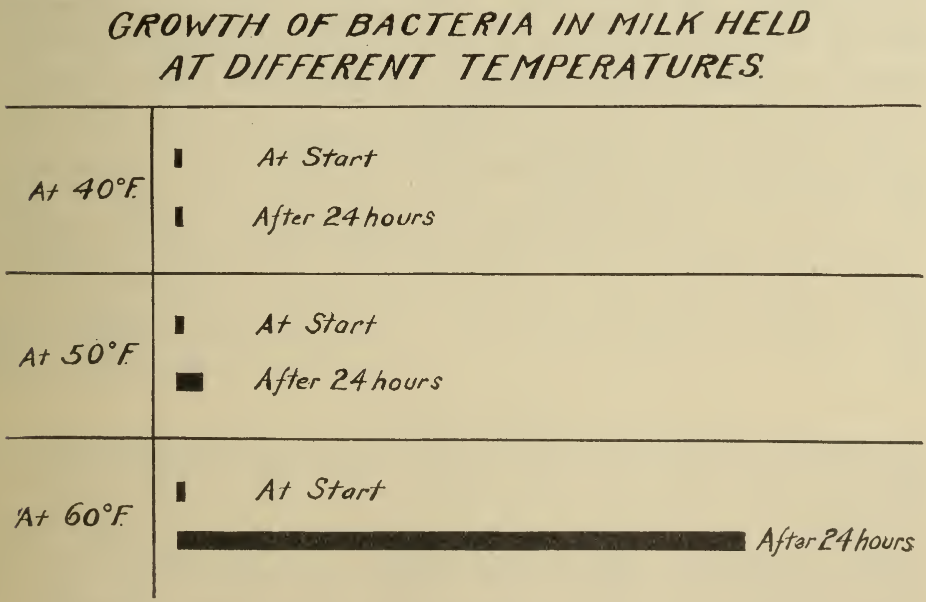

Fig. 1—The number of bacteria present in each case is indicated by the length of the black bar.

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[1] For a fuller discussion of the subject of keeping quality see Bulletin No. 123 entitled "Testing the Producer's Milk for Quality".

[2] The essential factors in the production of clean milk are pointed out in Pamphlet No. 79, entitled "Producing Clean Milk".

ber of bacteria at the end of twenty-four hours; at 50 degrees the number had increased fourfold, while at 60 degrees there were nearly a hundred times as many as at the start. From this it is evident that *milk must be held at 50 degrees or lower if it is to keep sweet for a reasonable length of time.*

WHEN COOLING SHOULD BE DONE

Milk should be cooled as promptly as possible. This advice is scientifically sound and is of greater importance than is generally realized. Freshly drawn milk contains a substance known as *lactenin,* which is able to restrain bacterial growth for a certain period. If cooling is delayed, this effect soon passes off. On the other hand, by prompt cooling the lactenic effect may be extended, sometimes even to 24 hours or longer. Where night's milk is in transit for several hours, exposed to summer temperatures, the value of this lactenic effect is obvious. If it has been preserved by prompt cooling, it will restrain bacterial growth as the milk warms up. On the other hand, if it has already spent itself as a result of delayed cooling, the bacteria are free to multiply with increasing rapidity as the temperature of the milk rises.

Toward the end of a hot summer it frequently happens that the ice supply is exhausted. Under these conditions prompt cooling is of great value in preventing bacterial growth in milk held overnight, even where it is not possible to cool the milk to a safe temperature, i.e. below 50°F. Experiments at the Central Experimental Farm have shown that when a flask containing freshly-drawn milk was immediately placed in a refrigerator at 50°F. to 55°F. the bacterial count after 24 hours showed only a moderate increase. Another portion of the same milk, allowed to remain in the laboratory for three hours before placing in the refrigerator, showed a marked increase in bacterial count during the same period of storage. Results from a typical experiment appear in Table 1. Here the storage temperature was not low enough to prevent bacterial growth, but where the lactenic effect was conserved through prompt cooling, the increase was very small compared with that in milk not promptly cooled.

TABLE 1.—VALUE OF IMMEDIATE COOLING IN RETARDING BACTERIAL GROWTH IN MILK

(Refrigerator Temperature 51°–54°F.)

Hours in refrigerator	Milk cooled at once	Milk cooled after 3 hours
	per cc.	per cc.
0	18,700	17,700
6	14,900	19,800
12	17,900	37,300
24	42,300	788,000

In certain cases, morning's milk must leave the farm so early that complete cooling is impossible. Often the only alternative is to hold this milk over until next morning before shipping, since certain milk companies and cities still require *all* milk to be below a certain temperature on arrival. In more progressive communities, it is realized that the fresh milk, although warmer, is more desirable than the older milk, and regulations have been framed to allow for the acceptance of uncooled or partially cooled morning's milk which is not more than two or three hours old on arrival at the plant. During this period the lactenic effect serves to restrain bacterial growth. However, the exhaustion of the lactenin from the delay in cooling ultimately results in a shortening of the time the milk will keep, hence *it is highly desirable that the cooling process be carried as far as possible before the milk leaves the farm.*

HOW COOLING MAY BE ACCOMPLISHED

When a substance is said to cool, it give up its heat to the surrounding medium. Where this is a poor conductor of heat, such as air, the rate of cooling will be extremely slow. A can of warm milk placed in a refrigerator where the air is below the freezing temperature requires approximately twelve hours to cool to 50°F. Consequently, attempts to cool milk in snow banks or exposed to outdoor temperatures in winter are never satisfactory. Water, on the other hand is a good conductor, and will cool down the milk over twenty times as fast as cold air at the same temperature. Other factors influencing the rate of cooling are (1) the difference in temperature between the warmer and the cooler bodies, (2) the relative volumes of these, and (3) whether either the milk or the cooling medium are kept in motion. Where the milk is at 95° and the water at 35°, cooling proceeds much more rapidly than when the milk is at 60° and the water at 45°. Since the milk must give up its heat to the cooler body, the water, it is evident that the greater the amount of water per unit of milk, the lower the temperature of the water will remain, and the faster the cooling of the milk will proceed. This point must be considered when deciding upon the dimensions of a cooling tank. Finally where either milk or cooling medium is kept in motion, cooling proceeds far more rapidly. Milk producers have long recognized the value of stirring the milk in hastening cooling, but the practice is not encouraged by many sanitary authorities on account of the risk of bacterial contamination where the washing and sterilizing of the stirrer have been neglected. Almost equally good results may be obtained by stirring the water instead of the milk, thus bringing fresh cold water in contact with the sides of the cans to withdraw the heat from the milk.

This bulletin deals primarily with cooling from the market milk standpoint. Most cities require that the night's milk shall show a temperature of 50°F. or lower on arrival, since at higher temperatures the keeping quality is quickly affected. To meet this requirement during the warm months, particularly where the milk is exposed to higher temperatures for some hours while in transit, it is necessary that milk be cooled to at least 45°F. and held at that temperature. Consequently certain methods which are fairly satisfactory for the cooling of cheese milk or churning cream are not included. Details concerning these may be obtained from the Dairy and Cold Storage Branch, Department of Agriculture, Ottawa, the provincial dairy branches and the agricultural colleges.

Surface Coolers

Quick cooling of milk is highly desirable. This is readily accomplished by the use of a tubular surface cooler or aerator (Fig. 2) through which cold water under pressure (or brine) is circulating, followed by immersion in a cooling tank. While the surface cooler has the advantage of speeding up the cooling process and of saving ice, it means a further investment, more labour, and danger of serious bacterial contamination. Surface coolers are generally difficult to wash, and harder still to sterilize adequately, consequently the tendency nowadays is to discourage their use. At one time it was believed that milk required "aerating" to remove the animal heat, odours, etc., but experience has shown this process to be unnecessary with clean flavoured milk. Certified milk, the highest grade

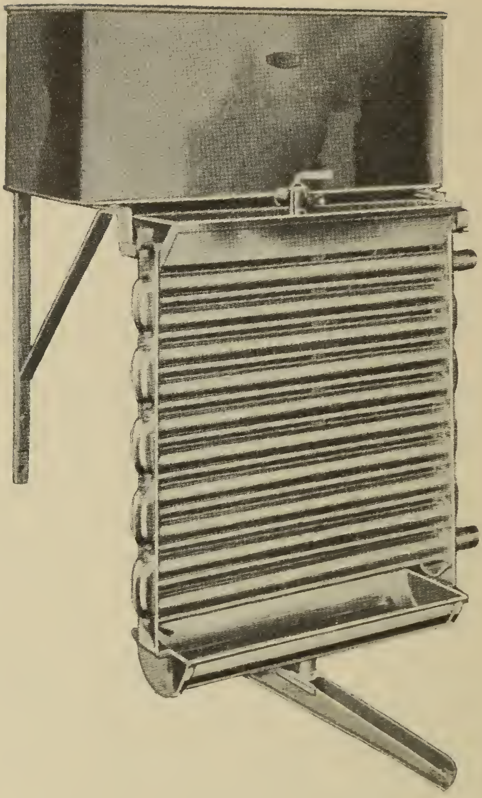

Fig. 2—Surface cooler or aerator.

produced, is rarely exposed to the air from the moment it leaves the cow's udder until it is bottled and capped, yet the flavour of this milk can rarely be criticized. An alternative method for rapid cooling, which avoids the disadvantages of the surface cooler, is discussed on p. 9.

Cooling Tanks

Except where the dry storage type of mechanical refrigeration is employed, a cooling tank is necessary to complete the cooling process and to maintain the milk at a sufficiently low temperature until shipping time. Such tanks have been constructed from a variety of materials, but concrete is generally favoured as being more sanitary and durable. In any case, it is essential that the water in the tank be of the same depth as the milk in a full can, otherwise cooling will be altogether too slow in the portion of the milk above the water level.

Cooling with Water

The common practice of placing the cans of warm milk in a tank containing cold water, while simple, is usually not very satisfactory. Unless provision is made for stirring either the water or the milk, cooling takes place quite slowly, and unless the water is unusually cold and the volume large in proportion to the volume of milk, the milk will not be cooled down sufficiently to prevent bacterial growth.

On a number of farms running water from a spring or flowing well is allowed to flow through the milk cooling tank before discharging into a watering trough

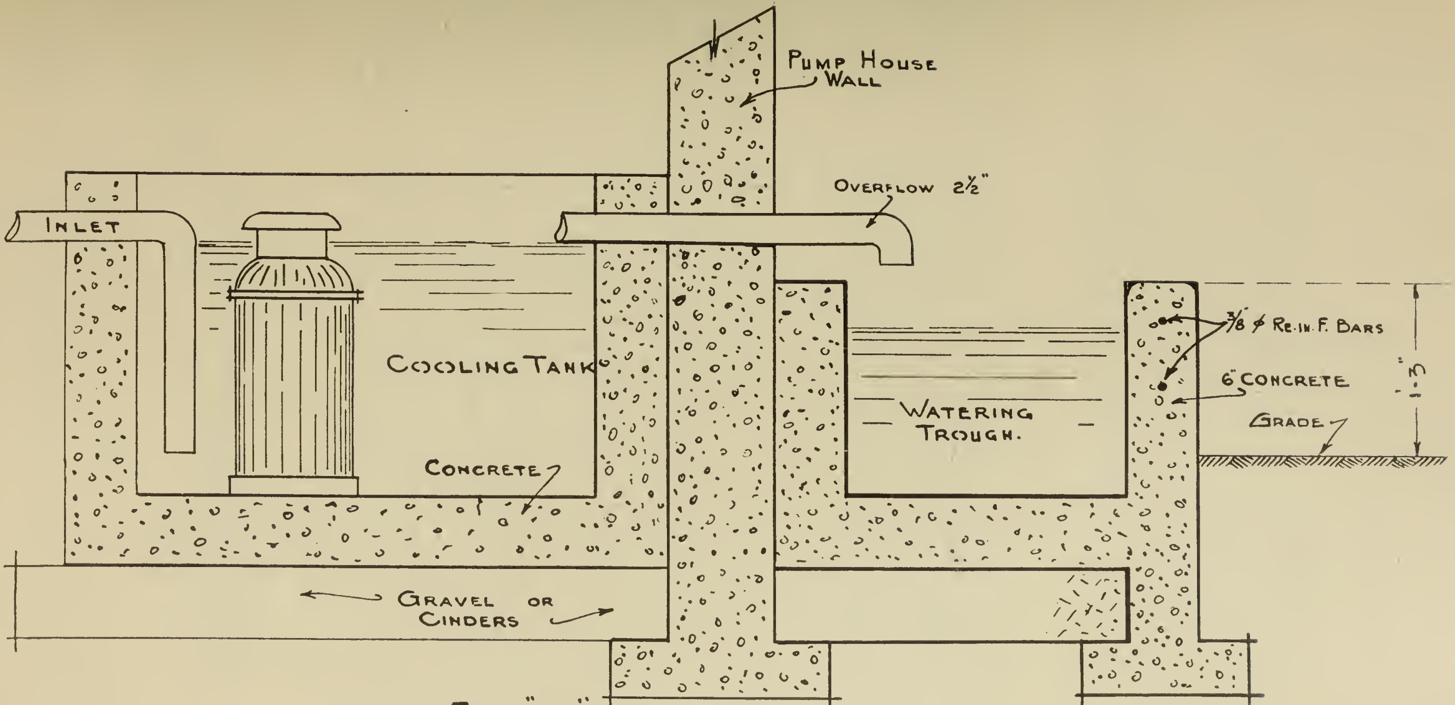

FIG "3"

Fig. 3—Arrangement for cooling with running water.

(See Fig. 3). In certain cases, water as pumped from the well is passed through the cooling tank in this manner. While both of these methods are an improvement over that mentioned above they are open to the objection that in many dairying districts it is rarely possible to find a supply of water which remains cold enough in the hot summer months to enable milk to be cooled to 45°F. Where milk or cream does not have to meet such strict requirements or where very cold water is available, this method of cooling may be employed. The water should be piped to enter the tank at the bottom at one end, with discharge or overflow pipe arranged to take the water from the surface at the other end. The tank should, of course, be housed to protect it from the direct rays of the sun.

Where cans of milk are cooled in ice water as discussed in the next section, some saving in ice may be made by a preliminary cooling in running water from a well or spring. This however, necessitates an additional handling of the cans, and results in slower cooling than where the cans are placed directly in ice water.

Cooling with Ice

Nowadays few farms producing milk for the city trade attempt to get along without a supply of ice. The great value of ice lies in the fact that *it requires as much heat to transform a pound of ice into water at the same temperature as it does to raise the temperature of an equal amount of water from 32° to 176°F.* Consequently, when ice is present in the water in a cooling tank, the heat which passes from the milk to the water is used up in melting the ice, thus preventing the temperature of the water from rising as high as it would if no ice were present.

Doubtless because there is little direct expenditure of money in connection with the ice supply, few farmers have attempted to get the maximum cooling value from the ice they put into the cooling tank. Ice, however, has a definite money value, as has also the labour expended in preparing it for the tank, particularlv since the demand is heaviest when field work is pressing. And yet on the vast majority of farms more than half of the cooling value of the ice is allowed to go to waste because of the tremendous leakage of heat into the cooling tank. It is just as wasteful to attempt to cool milk in an open, uninsulated concrete or metal tank as to try to keep a house built of one ply lumber, without a door, warm during the winter by burning extra fuel. In both cases the waste is due to failure to provide insulation to prevent heat leakage. In the case of the cooling tank, the leakage of heat is inward, while with the house, it is outward.

Some idea of the amount of ice wasted through the use of uninsulated cooling tanks may be obtained from the figures in Table 2. In these studies equal weights of ice were added to the water in each tank, no cans of milk being present. After nine hours, the blocks of ice were re-weighed and the amount lost through melting determined. It will be noted that even the provision of a simple cover means a saving of around 20 pounds of ice in 9

TABLE 2.—LOSS OF ICE IN COOLING TANKS OF VARYING CONSTRUCTION DURING 9 HOURS (AVERAGE AIR TEMPERATURE 84°F.)[1]

Type of tank	Without cover	With cover
	lb.	lb.
Galvanized iron	107	84
Concrete	80	61
Wood	50	30·5
Insulated (2-inch cork)	30	7·6

[1] Taken from United States Department of Agriculture Bulletin No. 976.

hours, while the ice saved by the use of an insulated tank will generally more than pay for the cost of the insulation during the first summer. It should be mentioned here that three-inch insulation shows a marked advantage over the two-inch, but the difference between four-inch and three-inch is not sufficient to justify the use of four-inch insulation.

In addition to the great saving of ice, a well-insulated tank possesses other advantages. By preventing the leakage of heat into the tank, the ice water remains at a much lower temperature. This means that the milk cools down more quickly, thus conserving the lactenic properties previously referred to, while the final temperature reached is often 10° lower. Similarly, the insulated tank prevents the subsequent warming up of the milk on a warm night. It not infrequently happens that milk in an open uninsulated tank shows a marked rise in temperature after the ice has all melted, so that considerable bacterial growth often takes place while the milk is still in the cooling tank. A further advantage of the insulated tank lies in the prevention of freezing of the milk during the cold weather, with consequent avoidance of deterioration in the quality of the milk.

In milk production nowadays, the aim should be to reduce the opportunities for bacterial contamination to a minimum. With the old style cooling tank, satisfactory cooling required that the milk be stirred at frequent intervals unless it had been pre-cooled over a surface cooler. By the use of a well-insulated cooling tank containing an ample quantity of ice water at a temperature well below 40° F., milk may be cooled very satisfactorily without pre-cooling or stirring. This means a saving in time, labour and washing up, and at the same time avoids the danger of bacterial contamination from aerators and stirrers. Where morning's milk must be cooled rapidly, stirring of the water, instead of the milk, is recommended. The installation of a water circulator, consisting of a small propeller mounted on a shaft extending through the top of the tank and operated by an eight H.P. electric motor should be seriously considered, since it enables milk to be cooled in a much shorter time. Such an arrangement is much more satisfactory than pre-cooling over a surface cooler or aerator, as cooling is accomplished at least as rapidly, without any of the disadvantages attending the use of an aerator. Similarly, an arrangement whereby the milk can may be suspended in the tank and the milk strained directly into the can, helps speed up the cooling process. Either a screen-door spring or a pulley and counter-poise system may be employed for this purpose, the weight of the milk causing the can to sink in the water of the tank as it is filled.

It might be noted in passing that one of the largest manufacturers of milking machines has recently brought out a device whereby the cans of milk may be suspended in the ice water of the cooling tank and mechanically rotated back and forth. This tends to keep the milk and ice water in motion thus speeding up the cooling process while the milking machine is in operation.

Cooling with Electricity

Mechanical refrigeration units for cooling milk on the farm have been developed during recent years, and are generally regarded as being practical, efficient and reliable. There are two distinct types; in the first, known as the "dry storage" type, the milk is cooled by running it over a surface cooler through which brine is pumped. It is then stored in a refrigerated cool air chamber until shipping time. In the second, "wet" or "immersion" type, the cans of milk are set in water in a well insulated tank, the water being previously cooled to near the freezing point by the action of the refrigeration unit through the expansion coils or brine tank (Fig. 4). While the former type is most convenient for the dairyman who bottles and distributes his own milk, the wet type is generally cheaper and more satisfactory where milk is stored and shipped in cans. The air-cooled compressor is considered to be more satisfactory than the water-cooled type, because of the danger of freezing with the latter during the colder months.

Fig. 4—Cooling milk by mechanical refrigeration in an insulated cooling tank.

As compared with ice, electrical cooling has certain advantages. First and most important is the saving of labour in preparing the ice for the cooling tank, a disagreeable task which is heaviest during the warm months when field work is pressing. Secondly, there is little danger of running short on refrigeration, as may happen with ice in a hot summer. Again, the milk is cooled automatically to a set temperature, while in cooling with ice, mistakes in judgment as to the amount of ice required on a hot night may result in poor keeping quality of the milk. Finally, milk in electrically cooled tanks is generally cooled faster and reaches a lower temperature than in ice-cooled tanks.

Despite these advantages the following facts must be considered. Electric cooling units are fairly expensive to install, while little is yet known regarding the rate of depreciation. Again, electric cooling is practically limited to those farms where electric power is available at a reasonably low rate. Gas engine refrigeration units are now being tried out, but these are still in the experimental stage. Furthermore, the average farmer has already invested in an ice house, an investment which would largely be lost if electric cooling were employed, while the ease with which natural ice is obtained and the fact that this crop is harvested during the slack time of the year are arguments in favour of cooling with ice.

The cost of cooling with ice per hundred pounds of milk is approximately twice as great on small as on large farms. With electric cooling the cost on the smaller farms is generally too high to compete with ice cooling. Studies in Rhode Island[1] indicate that under their conditions electric cooling would probably be cheaper than ice cooling only where a herd of 23 or more cows was being milked. In Canada, where electric cooling units are more expensive,[2] while ice is cheaper, it is probable that an even larger herd would be required before electric cooling would be as cheap as ice cooling. However, electric cooling might well be considered for moderate to large farms in spite of its being a little more expensive, since the advantages of an automatic, dependable cooling system must be borne in mind. The farmer who contemplates installing an electric cooling unit in a few years' time might well construct an insulated cooling tank, and then use this tank for ice cooling until such time as he is able to purchase the electric cooling outfit.

Tank Sizes and Ice Requirements

Since the rate of cooling is influenced by the ratio of ice water to milk, it is necessary that the cooling tank be of ample capacity. While in some cases a well insulated tank may be satisfactory where there is twice as much ice water as milk, it is far better to construct the tank of such a size that the proportion will be three of ice water to one of milk when the tank is filled, whether ice or electric cooling is employed. The approximate inside dimensions required are indicated in Table A, which appears in the section on "Constructing an Insulated Milk Cooling Tank" in the Appendix.

With a well insulated tank, approximately thirty pounds of ice should be allowed for each eight-gallon can of milk to be cooled. (An uninsulated tank will require approximately twice as much). This amount will naturally vary from one section to another, depending upon the location of the tank and the average summer temperature of each district. Similarly there will be variations from one year to another in any district, depending on whether the summer is warmer or cooler than the average. In calculating the amount of ice to be stored, allowance should be made for a shrinkage of 33 per cent or more in storage and during preparation for the cooling tank. Assuming that ice is required for cooling from May 15 to November 15, a farmer with an average production of 400 pounds of milk per day would require around 150 pounds of ice in an insulated cooling tank each day. Making due allowance for shrinkage, he would need to provide at least 18 tons of ice. The amount required for greater production will be proportionate to this figure, while for smaller production, a slightly larger proportion will be needed, since the percentage shrinkage is heavier the smaller the quantity of ice put up. Table 3 shows the

TABLE 3.—NUMBER OF CAKES OF ICE REQUIRED PER TON

(All Cakes 18 x 36 inches)

Thickness of cake	Number of cakes per ton
8 inches	12
10 "	10
12 "	8
14 "	7
16 "	6
20 "	5

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[1] Costs of Cooling Milk on Farms. Roger B. Corbett. Rhode Island Agricultural Experiment Station Bulletin No. 223, 1930.

[2] Since the time when this section was prepared (July, 1931), prices have fallen considerably and several electrical coolers are now being offered in Ontario at prices which are within the reach of many producers. The very considerable differences in cost of power at different points also caused electrical cooling costs to vary widely.

TABLE 4.—INSIDE DIMENSIONS OF ICE HOUSES TO HOLD VARIOUS QUANTITIES OF ICE

Quantity of ice	Length	Width	Height
	ft.	ft.	ft.
10 tons	10	7	7
20 "	14	8	8
30 "	14	10	10
40 "	18	10	10
50 "	16	12	12

number of cakes of ice required per ton, while Table 4 gives the inside dimensions of ice houses. Plans for the construction of ice houses, small cold storages, etc., may be obtained from the Dairy and Cold Storage Branch, Dominion Department of Agriculture, Ottawa.

Futher Observations

For satisfactory tank cooling, there must be an ample supply of ice water at a temperature as far below 40°F. as possible. Herein lies the main weakness of the old style open tank. Ice placed in the water during the daytime soon melts, due to the unhindered leakage of heat into the tank; consequently many farmers put no ice in the tank until just before milking. The water in the tank, which has warmed up considerably during the day, is now expected to cool down the milk to below 50°F. What actually happens in many cases is that the cooling effect of the ice is barely sufficient to balance the heat from the cans of fresh milk, so that unless large quantities of ice are used the temperature of the water changes very little. Under these conditions the milk cools far too slowly, and bacterial growth makes considerable headway during the night, with resulting trouble from souring, poor keeping quality, etc.

With an insulated tank, on the other hand, sufficient ice may be kept in the tank at all times. In this way the temperature of the water may be kept well below 40°F. and the milk cooled more quickly to a much lower temperature by the use of less ice than in the old style tank.

Much of the loss due to high bacterial counts and souring could be avoided if farmers would actually *measure* the temperature of the ice water and of the milk each day instead of merely *guessing* at it. A floating dairy theremometer, protected by means of cork rings cut from a cork stopper, should be part of the equipment of every cooling tank.

SUMMARY

The keeping quality of milk is determined more by the temperature at which it is held than by any other factor. To keep satisfactorily, market milk must be cooled to around 45°F. and held at that temperature.

Promptness of cooling, by conserving the lactenic power, is also an important factor in determining how long milk will keep.

Of the various methods available, cooling by immersing the cans of milk in ice-water in an *insulated* cooling tank is recommended. This method is simple, and well adapted to use on the average farm.

With an insulated tank, milk may be cooled more rapidly to a lower temperature with about one-half the amount of ice required with a non-insulated tank.

Electric refrigeration offers automatic cooling to a set temperature at all seasons, together with freedom from the task of putting up ice and preparing it for the tank. Where electrical power is available at reasonable rates this method should receive the careful consideration of milk producers.

LIST OF PUBLICATIONS DEALING WITH COOLING MILK IN INSULATED TANKS, EITHER BY ICE OR ELECTRICITY

1. The Production of High Quality Milk. I. Cooling—The Electric Brine Cooler with Cold-Air Storage versus Ice and Water. Vermont Agricultural Experiment Station Bulletin No. 300, July 1929.
2. Electric Cooling of Milk on the Farm. New York (Geneva) Agricultural Experiment Station Bulletin No. 581, February 1930.
3. Costs of Cooling Milk on Farms. Rhode Island Agricultural Experiment Station Bulletin No. 223, May 1930.
4. Mechanical Refrigeration of Milk in a Tank Type Refrigerator. Oregon Agricultural Experiment Station Bulletin No. 268, July 1930.
5. Cooling Milk on the Farm. Vermont Department of Agriculture, Bulletin No. 39. July 1930.
6. The Mechanical Dairy Cooler on Nebraska Farms. Nebraska Agricultural Experiment Station Bulletin No. 249, September 1930.
7. The Cost of Cooling Milk with Electricity. Storrs (Conn.) Agricultural Experiment Station, Bulletin No. 170, November 1930.
8. Ice and Electricity Compared for Milk Cooling. New York State College of Agriculture, Department of Rural Engineering Stencil No. 1.
9. The Production of High Quality Milk. III. Electric Cooling versus Ice Cooling. Vermont Agricultural Experiment Station, Bulletin No. 326, April 1931.
10. Farm Electric Milk Refrigeration. Bulletin No. 267, The Pennsylvania State College, April 1931.
11. Factors Affecting Tank Type Milk Coolers. Earl M. Knepp, Purdue University. Agricultural Engineering, September 1930, Volume 11-9.
12. Cooling Milk and Cream on the Farm. U.S. Dept. of Agriculture Farmers' Bulletin No. 976, 1929.
13. Refrigeration in the Handling, Processing and Storing of Milk and Milk Products. U.S. Dept. of Agr. Misc. Publication No. 138, March, 1932.
14. Cream Refrigeration on the Farm and the Quality of Butter Manufactured. Oregon Agricultural Experiment Station Bulletin No. 305, June, 1932.
15. Cooling Milk on Nebraska Farms. Nebraska Agricultural Experiment Station Bulletin No. 266, January, 1932.
16. Temperature Gradient in Milk Cooled by Direct Immersion. R. G. Bressler and J. E. Nicholas. Agricultural Engineering, September, 1932. Vol. 13. No. 9.
17. Precooling Milk. New Hampshire Agricultural Experiment Station Bulletin No. 262. 1932.

LIST OF PUBLICATIONS DEALING WITH THE CONSTRUCTION OF AN INSULATED MILK COOLING TANK

1. How to Build an Insulated Concrete Milk Cooling Tank. New York State College of Agriculture, Department of Agricultural Engineering, Stencil No. 101.
2. Plans for a Simple Milk House. Cornell Extension Bulletin No. 200, November 1930.
3. Insulated Concrete Milk Cooling Tanks. Agricultural Engineering Department, New York State College of Agriculture, Reprint No. 3.
4. Building an Insulated Milk Cooling Tank (1932 Edition). Portland Cement Association, Chicago.
5. How to Insulate Milk Cooling Tanks with Armstrongs' Type WP Corkboard. Armstrong Cork and Insulation Company, Lancaster, Pa.
6. Construction of Insulated Milk Cooling Tank. Department of Agricultural Engineering, Massachusetts Agricultural College Special Circular No. 11, February 1931.
7. Milk House and Cooling Tank Facts. The Celotex Company, 191 N. Michigan Ave., Chicago, Ill.

APPENDIX

CONSTRUCTING AN INSULATED MILK COOLING TANK[1]

The directions given here are for the construction of a concrete tank having a layer of insulation incorporated in the base, walls and cover to cut down the passage of heat into the tank. It is of vital importance that the insulating material be thoroughly waterproofed before being set in position. If water should penetrate it, its value in preventing the passage of heat into the tank will be almost entirely lost. For this reason, special precautions must be taken to ensure the insulation layer remaining perfectly dry.

The method originally employed in building an insulated tank required the construction of an outer shell of concrete four inches thick, against which slabs of corkboard (one by three feet by three inches) dipped in melted asphalt were placed in position, and then an inner shell of three inches of concrete was poured. In order to simplify the process, a method was developed in New York State whereby "packages" of waterproofed insulation are employed, and both outer and inner concrete walls poured at the same time. These packages may be built up by placing the asphalt-coated slabs of two-inch corkboard between two sheets of half-inch insulating fibreboard of the correct size, then wrapping the package with strips of asphalt-impregnated cotton cloth stuck on with hot asphalt and the ends folded in and stuck in place. The whole package is then coated with two moppings of hot asphalt. A similar package may be built up from three sheets of one-inch fibreboard, all surfaces being mopped with hot asphalt before fastening together and wrapping with cotton cloth. Such a package would be a little less efficient than where corkboard is used, the latter being slightly better insulating material.

In building up these packages, the first step is to work out the dimensions required. Knowing the inside dimensions of the proposed tank (see Table A), we require insulation packages of the following sizes:—

Floor package—
    Length = inside length of tank + 12 inches.
    Width = inside width of tank + 12 inches (52 inches).

Side packages—
    Length = inside length of tank + 12 inches.
    Width = inside depth of tank + 2 inches (28 inches).

End packages—
    Length = inside width of tank + 12 inches (52 inches).
    Width = inside depth of tank + 2 inches (28 inches).

Having calculated the sizes of packages, proceed as follows:—

(1) Lay a sheet of fibreboard on a platform raised at least a foot from the ground. This will keep the mop from picking up dirt. The board should overhang the platform an inch or so on all sides.

(2) Cut the cork exactly to fit the package board. Pile the pieces of cork at one side in order.

(3) Cut a piece of board smaller than the pieces of cork. Nail a handle on one surface. Drive nails through to project beyond the other surface. This will be called "the hawk."

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[1] Grateful acknowledgement is made of the great assistance rendered by Prof. H. W. Riley, Department of Agriculture Engineering, Cornell University, in the preparation of this section. Prof. Riley is an acknowledged authority in this field, and has contributed many of the improvements described in this section. The assistance of the Drafting Room, Central Experimental Farm, Ottawa, in the preparation of the drawings is also acknowledged.

(4) Heat the asphalt until it is thin enough to flow into cracks and yet thick enough to leave a coating of $\frac{1}{16}$-inch thick. Stir frequently to prevent overheating in spots.

(5) Push the nails of the hawk into the first piece of cork. Dip the bottom and edges of the cork into hot asphalt in a shallow pan. With a kalsomine brush, brush out the air bubbles from the asphalt.

(6) Set the cork firmly in place on the fibreboard.

(7) Dip, brush, and set the other pieces of cork.

(8) With a cord mop take hot asphalt from a pail and mop the top surface of the set cork and at once apply the second fibreboard.

(9) Cut a length of asphalt-impregnated cotton cloth sufficient to go around the package and to overlap the first end by 6 inches.

(10) Lay the cloth across the end of the package with
  (*a*) the edge of the cloth extending beyond the edge of the package $2\frac{1}{2}$ inches, and
  (*b*) the end of the cloth extending beyond the edge of the package by 7 inches.

(11) Let a helper kneel on the cloth at the edge of the package and raise the free end of the cloth from the package.

(12) Mop with hot asphalt the top surface of the package that was under the cloth.

(13) Quickly stretch the cloth tight and smooth down into the hot asphalt.

(14) Repeat this process for the cloth that the helper was kneeling on.

(15) Apply the cloth at the other end of the package in the same way.

(16) Apply cloth to fill in between the two end strips, being sure to make water-tight laps of at least 3 inches.

(17) Turn the package over.

(18) For each strip of cloth in its proper turn mop asphalt on the package and lay the cloth. Make all laps water-tight.

(19) With the end of the package overhanging the platform, mop the end of the package and fasten up the cloth that overhangs from the bottom of the package. Pull the folds horizontally and back.

(20) Mop the end of the package and fold in the side folds.

(21) Mop the exposed surface of the side folds and complete the folding in of the end cloth.

(22) Seal the outer end of the package in the same manner.

(23) Give the outside of the package two moppings of asphalt and give the folds at the ends an extra mopping.

(24) After the last mopping it may be well to cover the package with wrapping paper to prevent sticking and tearing of the asphalt.

Standard Sized Packages of Waterproofed Insulation

More recently, standard sized packages of insulation already waterproofed at the factory have been put on the market in the United States. These standard sized packages are 28 by 52 by 3 inches, and are set up as shown in the sketches in Table A. These are available there in either corkboard or fibreboard, and are decidedly more convenient, besides having the advantage of a more thorough waterproofing than can conveniently be given on the farm. The standard-sized corkboard package, which is the most efficient type, is unfortunately not available in Canada at a reasonable price at the present time. However, the larger manufacturers of fibreboard insulation in Canada have agreed to make up these standard-sized waterproofed packages of fibreboard at a more reasonable price, and since fibreboard is almost as good an insulating material as corkboard, these should be quite satisfactory for this purpose.[1] In view of the greater convenience in using the standard-sized waterproofed packages of insulation, the present directions cover this type of construction. Directions for the use of the ordinary corkboard slabs may be obtained from the manufacturers of corkboard, cement, etc.

It is possible to build an insulated tank having an inner shell of boiler plate or heavy galvanized iron, but since the all-concrete tank is more durable, cheaper, and can be constructed on the spot, only the latter type will be dealt with here. Those anxious to build a tank with a metal shell may obtain directions from the manufacturers of electric cooling units, or from Special Circular No. 11 of the Massachusetts Agricultural College, Amherst, Mass.

Location of Tank

The cooling tank should be so located in the milk house that the direct rays of the sun do not fall upon it. Due regard should also be had to accessibility from the driveway and barn. It is also well to find out from the local health department whether they have any special regulations which must be complied with.

If electric cooling with an air-cooled unit is contemplated, it is important that the refrigerating unit be so located that when in operation the heat given off by the condensing coils will pass away rapidly. If this heat can accumulate around the coils, it is more difficult for the machine to get rid of subsequent charges of heat and the efficiency of the refrigerating unit will be lowered. Location in a spot where there is good air circulation is thus essential.

Size of Tank

In deciding upon the size of tank it is well to allow for possible expansion in milk production, and to build a tank large enough to take care of this, since it is a difficult matter to enlarge a tank once it has been constructed. When well insulated there is little extra loss on account of heat transmission in an oversized tank, while the greater quantity of cold water in relation to volume of milk enables quicker cooling.

It is generally considered that for satisfactory cooling with either ice or electricity, *the volume of ice water should be at least three times as great as that of the maximum amount of milk to be cooled.* This requires a minimum floor space of 420 square inches for each eight-gallon can, when the depth of water in the tank is 22 inches. Where the standard waterproofed packages of insulation (52 by 28 by 3 inches) are used, the inside width of the tank is set at 40 inches. This width is especially desirable since it is the narrowest which will accommodate the coiling coil of every mechanical refrigeration machine now on the market. When the tank is 40 inches wide, a length of 10½ inches for each can will give the minimum desirable proportion of ice-water to milk. The relation between tank size and tank capacity, as well as the manner in which the standard size waterproofed packages of insulation are set up is illustrated in Table A.

Excavation

The labour involved in lifting cans in and out of a concrete tank is greatly reduced by sinking it into the ground to a point where the rim of the tank is

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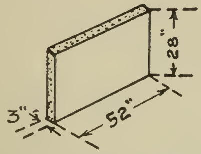
[1] The possibility of employing aluminum foil for insulating milk cooling tanks is receiving the attention of the manufacturer.

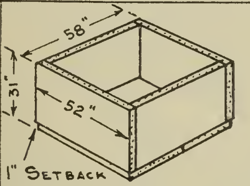
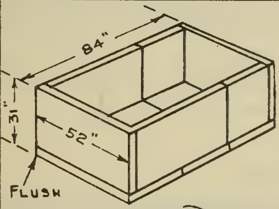
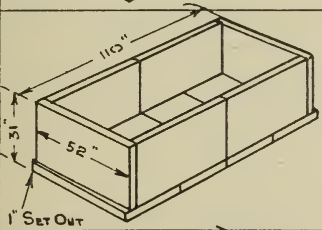
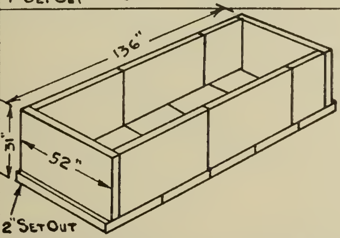
MILK COOLING TANKS

SHOWING METHOD OF SETTING UP PACKAGES OF INSULATION

— TABLE A —



STANDARD PACKAGE
OF
INSULATING MATERIAL

No 8 Gall Cans	Assembled Insulation before Concrete is Poured	Inside Dimensions Concrete Tank Depth x Width x Length	Number Insulating Packages	Insulating Board for Cover	Insulating Board for Tank
		Inches		½"	3"
				Sq Ft	
4 Cans		26 × 40 × 46	6.	17.	61.
6 Cans		26 × 40 × 72	8.	25.	81.
8 Cans		26 × 40 × 98	10.	32.	102.
10 Cans		26 × 40 × 124	12.	40.	121.

NOTE :- The above Table shows the Size of assembled insulation, for Tanks 40" Wide inside by 26" Deep.

12 inches above the floor level of the milk room. The excavation should therefore be made to a depth of approximately 30½ inches below the floor level so that a 6-inch fill of gravel or cinders may be made. The other dimensions of the excavation should be approximately one foot greater than the outside dimensions of the tank to allow room for the outside forms for the concrete.

Overflow and Drains

Upon completing the excavation, the gravel or cinder base is put in and pounded down solid. If a solid base is not provided, there is danger of the concrete base settling and cracking, with consequent development of leaks in the tank. The outlet drain is then located so that the centre will come at least 7 inches from one side and 6 inches from one end of the inside of the tank. A cast iron 4-inch sub-drain is recommended for ice cooling, or a 2-inch for electric cooling. A double hub of extra heavy cast iron drain pipe is cut off at 10½ inches (10 inches from 2-inch pipe). (See Fig. A.) The proper length of 2½-inch overflow pipe (1 inch for electric cooling) is then screwed into a wooden plug of oiled maple set in the bell of the short piece of cast iron drain pipe, which connects with the longer horizontal portion by means of a quarter bend. The cast iron joints of the outlet drain are packed with oakum to prevent cement mortar from getting into the pipe, then filled in around with mortar.

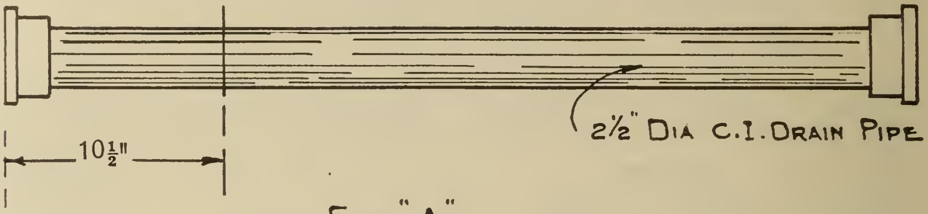


Fig "A"
Double Hub

Concrete Base

The concrete base is next laid level to a depth of 4 inches, and over at least the same area as the outside dimensions of the tank. The top of the base should be 20 inches below the level of the finished floor of the milk house. The concrete should consist of one part of cement, two parts of *clean* sand and two parts of *clean* gravel not over 1 inch in size. The mixture should be fairly stiff, and should be carefully tamped and levelled off to provide an even surface on which to lay the insulation packages.

The end package of insulation for the floor is next laid in place over the drain, marking on it the exact location of the drain. A hole is then cut through the insulation at this point, using a sharp chisel, and the package tried out in place. The hole should be amply large. The insulation which has been exposed should now be thoroughly waterproofed with hot asphalt. The floor insulation is now set in the exact place on the concrete base and the hole around the drain filled with melted asphalt. When this is cold it should be filled again. Fill cracks in the insulation with hot asphalt.

Wall Construction

The insulation packages for the side and end walls are now set in place. (See Table A and Fig. C.) These packages have true and square edges and are set up by joining them with hot asphalt. Prepare the contact surfaces by brushing off the talcum powder that comes on the packages and apply with a brush asphalt that is very hot. In cold weather it will be necessary to heat the surfaces to ensure a good bond. The outside forms, constructed of 1-inch tongue and groove material nailed to 2- by 4-inch studs, are now set in position four

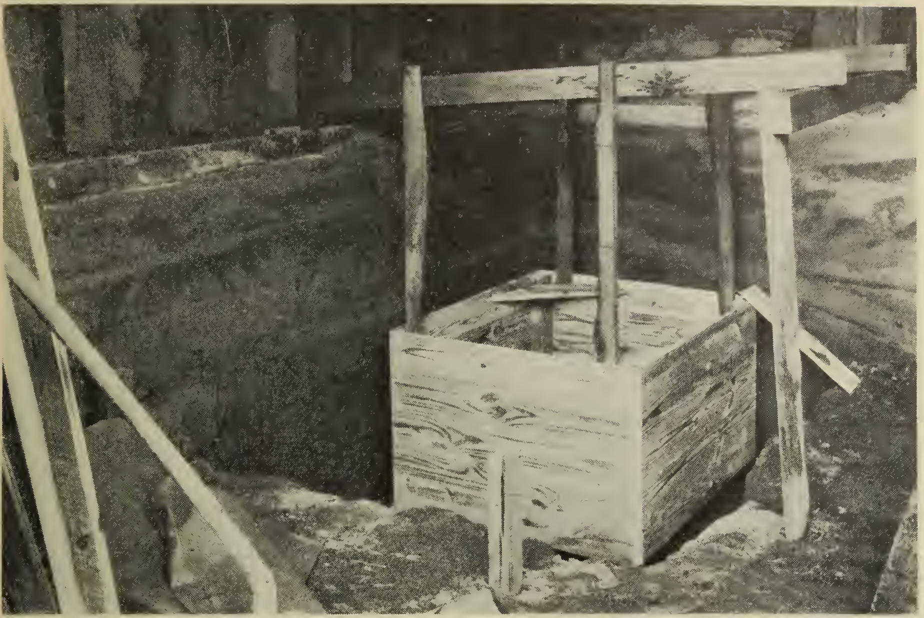


Fig. B—Excavation and inner form for a 4-can tank. Wall of milk house in background. (Photo by Prof. H. W. Riley).

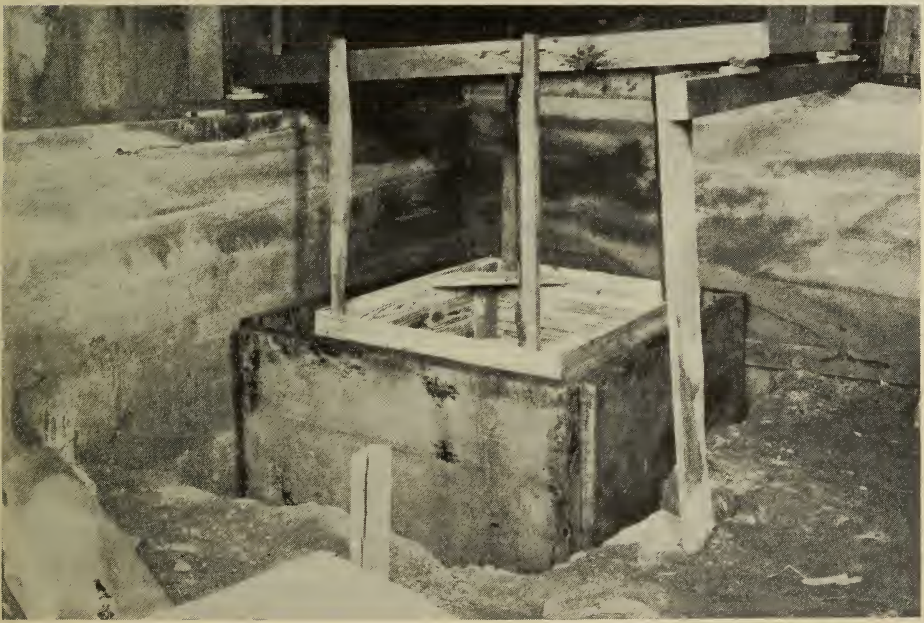


Fig. C—Inner form and standard-sized packages of insulation ready to be fastened in position. (Photo by Prof. H. W. Riley).

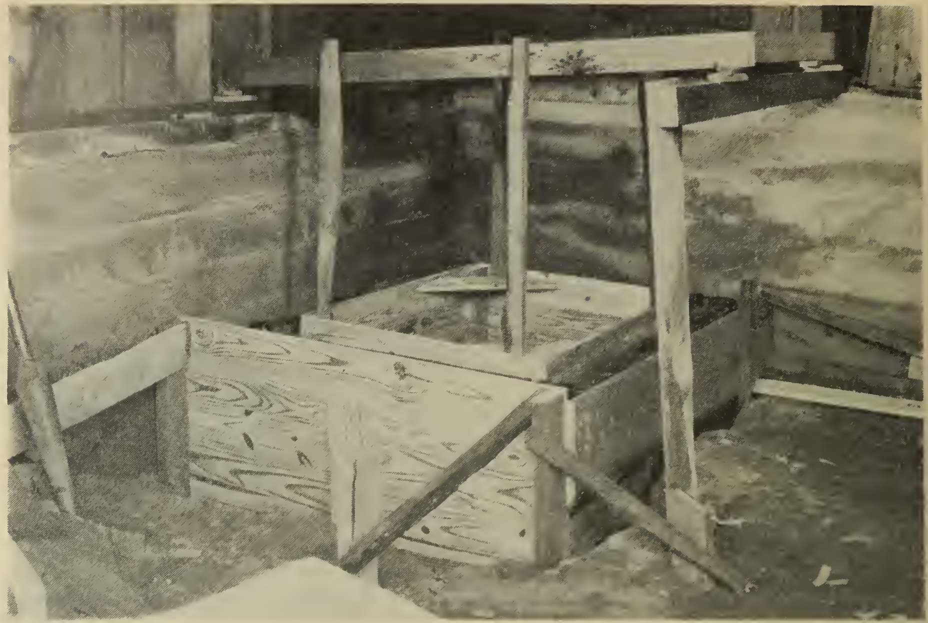


Fig. D—Outer form in position. All is ready for pouring the concrete.
(Photo by Prof. H. W. Riley).

inches from the outside of the insulation (Figs. D and H), while similar forms for the inside wall are set up three inches from the inner surface of the corkboard (Figs. B and G).

The insulation packages and forms are properly braced, and may be held in the exact position by means of wooden block spacers placed at various points. (These are removed as the forms are filled with concrete.) For the outer form at the back of the tank, the milk house wall may be employed (Fig. D). However, a sheet of tar paper should be placed between this and the wall of the tank, so that the tank will not be damaged if the milk house wall should settle. In order to prevent the concrete from sticking to the forms, all form faces should be treated with oil from an automobile or tractor crank-case.

To protect the front rim of the tank from wear as the cans are lifted over, it is best to use a length of 10-inch channel iron (15·3 pounds to the foot) along the entire front. The necessary length of channel iron beam may be ordered through any hardware merchant. (An alternative form of construction is to attach a plate or rim of 2- by 10-inch material at the top of the tank wall and to run strap iron along both edges of the front rim for protection.) Holes should be drilled in the channel iron to take two $\frac{5}{8}$ by 6-inch bolts at both ends, and one in the centre for attaching the fixed section of the cover. As the flanges of this channel iron extend down $2\frac{5}{8}$ inches, it is necessary to cut out the insulation of the end walls to make room for these flanges, and then to waterproof the cut surface with asphalt. Try the channel iron in place before commencing the concreting. By leaving an opening $1\frac{1}{2}$ by 8 inches in the top wall (Fig. J) the cooling coils of a mechanical refrigerating unit may readily be installed. This opening may be plugged with wood or cork treated with asphalt in case the refrigerating unit is not to be installed right away.

All is now in readiness for pouring the concrete. A mixture of one part cement, two parts of clean sand and two parts clean gravel or stone (not over

1 inch in size) is employed. The concrete should be just wet enough to work well. Too much water in the mix should be avoided. When starting to pour the thin walls on either side of the insulation, make a mortar of one part cement to two of sand and place three or four inches of this at the bottom of the forms. This is followed by the 1:2:2 mix until the top is reached, then more of the 1:2 mortar is used for finishing the rim of the tank. About three inches of mortar should be placed under the channel iron, as gravel may interfere with its settling into place, and it is extremely important that the tank rim be perfectly level.

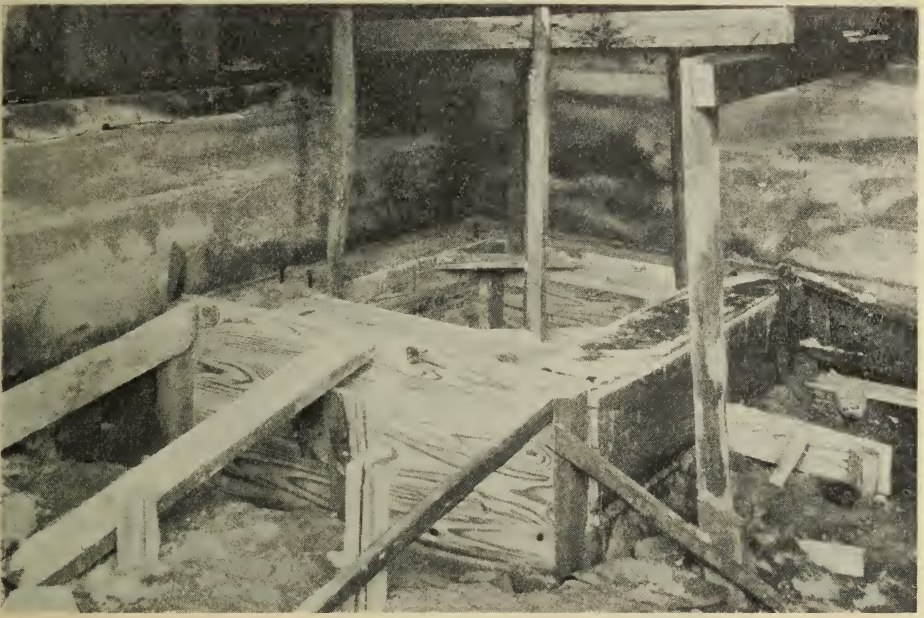


Fig. E—Tank after pouring concrete. Note ten-inch channel iron beam on front rim of tank, also anchor bolts for rear plate. (Photo by Prof. H. W. Riley).

Care should be taken to fill and trowel the tops of the walls smooth, true and level with the top surface of the channel iron. There must be an absolutely smooth level surface for the cover to rest upon.

As protection against cracking by frost, three reinforcing bars of ⅜-inch round iron are laid in the concrete outer wall. The first should be placed about four inches from the base, the second in the middle, and the third about four inches from the top. Rods should be carefully bent around corners, and joints lapped 15 inches and wired. Pairs of bolts (½ inch by 10 inches) to hold the 2 by 10 inch planks to which the cover is hinged must be set in the rear wall at intervals of approximately 2 feet while the concrete is soft. The channel beam, with two ⅚ by 6 inch bolts at each end and one in the middle, is set with flanges down and bolt heads hanging down in the mortar and concrete, and driven down until just flush with the end walls. Nuts should not be tightened on any bolts until the concrete is at least 48 hours old. The forms may usually be removed in 24 hours in warm weather, but should be given longer in cooler weather. After they have been removed, the inner concrete floor layer is put in to a depth of 3½ inches, sloping down to 3 inches at the drain. The surface is then finished with a steel trowel. It is well to place a tin tube 3 inches long over the drain so as to keep concrete ½ inch away from the pipe. The drain is plugged with an old bag. When the concrete is well hardened, remove the tin tube and fill in around the drain with melted asphalt. After the forms are removed, the inside of the tank should be painted with a wash of cement and water of the consistency of thick cream. This will help make the concrete water-tight. The concrete should then be carefully cured by covering with burlap and keeping it moist for a week. This aids in securing strong, water-tight concrete. Further details regarding the concrete work are given in a leaflet issued by the Portland Cement Association, which may be obtained by writing to the Canada Cement Company, Montreal.

Fig. F—Concrete work completed and ready for the attachment of the cover.
(Photo by Prof. H. W. Riley).

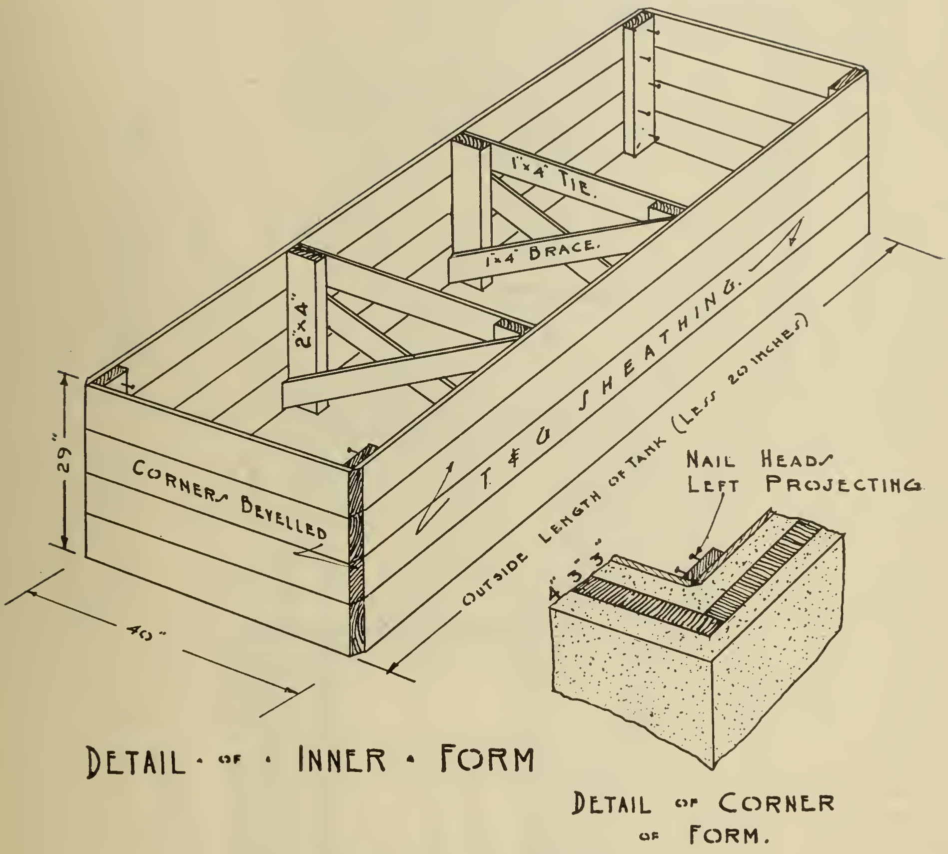
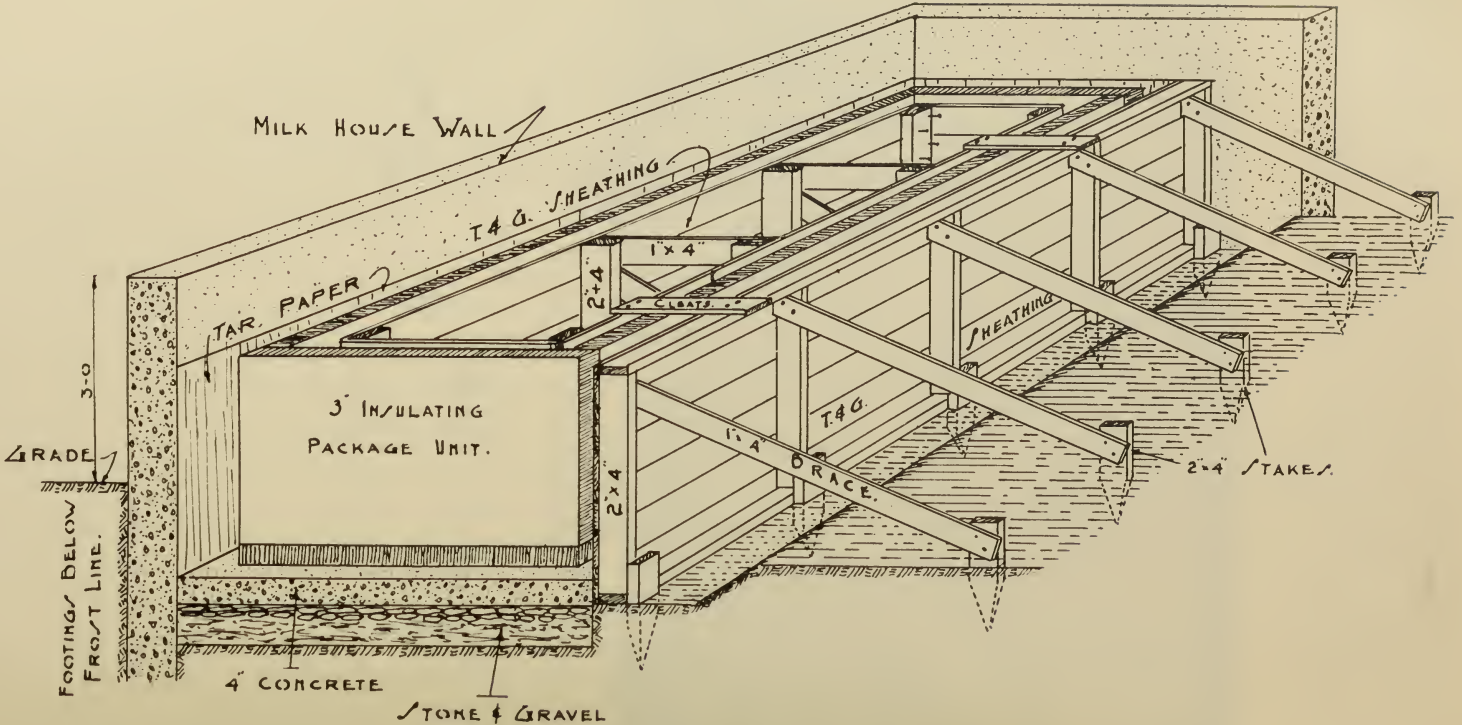
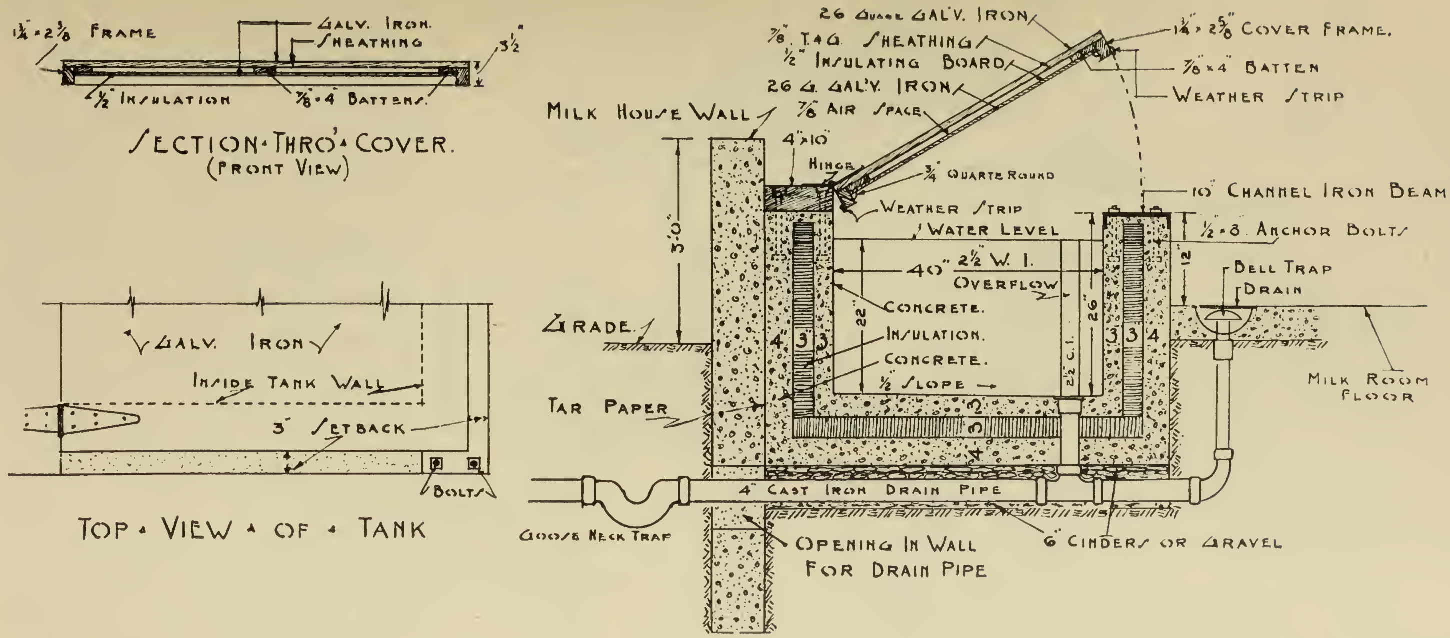


Fig. G—Detail of inner form.



DETAIL · of · TANK · CONSTRUCTION

Fig. H—Detail of tank construction.



SECTION · THRO' · COVER.
(FRONT VIEW)

TOP · VIEW · OF · TANK

CROSS · SECTION · OF · TANK

Fig. I—Further detail of tank construction.

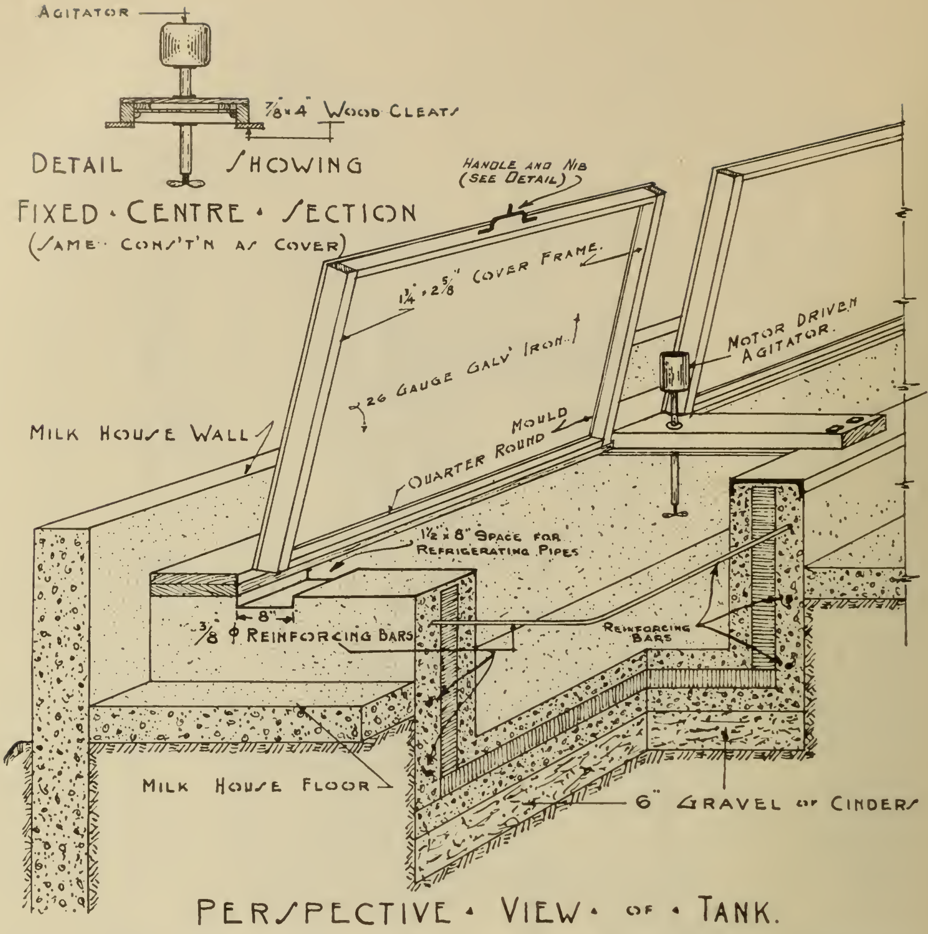


Fig. J—View of tank in perspective, with corner cut away to reveal details of construction.

Cover Construction

It is extremely important that the cover be so constructed as to fit tightly to the rim of the tank, in order to avoid air leakage. The type of cover illustrated is one recently devised by Professor H. W. Riley, and embodies a number of improvements. In this cover insulation is provided by the ⅞-inch matched spruce, ⅞-inch air space and ½-inch fibre insulating board. In addition the inner and outer surfaces are covered with No. 26 gauge galvanized iron. Such a cover is reasonably light, well insulated, and easily kept in a sanitary condition.

In order to get around the obstacle presented by the pair of ⅝-inch anchor bolts at each end of the channel iron beam on the front rim, Professor Riley suggests making the cover sections about three inches short of being flush with the tank wall. (See Figs. I, J for details.)

The marked advantage of circulating the ice water by means of a motor-driven agitator has already been referred to. The most convenient place to locate such an agitator would probably be in the centre of the tank and close to the rear wall. To do this, the cover should be in three sections, with the outer two hinged and the centre one fastened down. This requires an additional

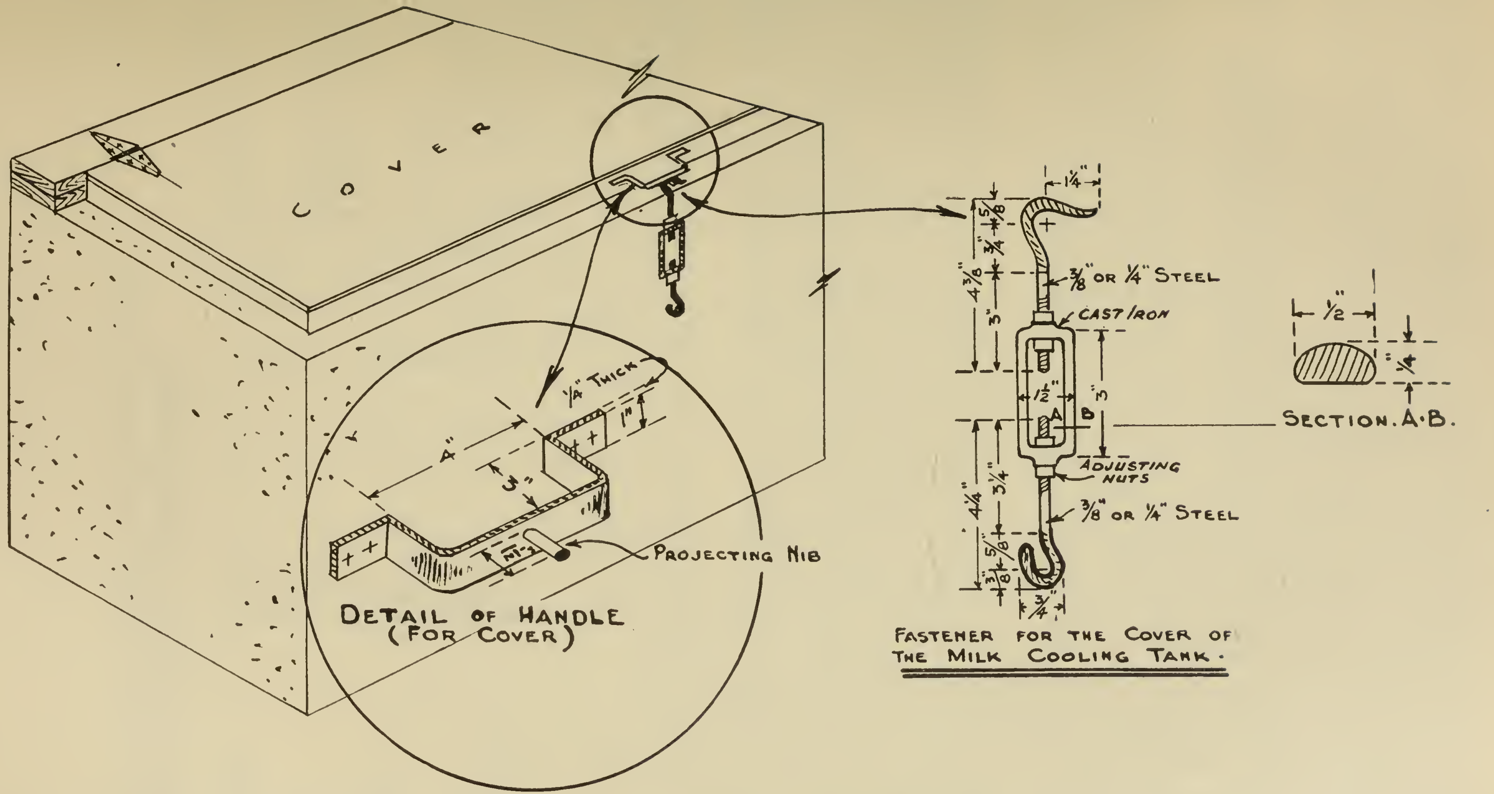


Fig. K—Details of adjustable fastener for cover of tank.

anchor bolt passing up through the centre of the channel beam from the inner concrete wall; the attachment at the rear may be made by strap iron. Strips of $\frac{7}{8}$-inch material may be cleated to the under sides of the centre section to break the joint (See Fig. J). The divided cover is almost a necessity on any but the smallest size of tank. Counterweights will be found helpful in opening the hinged sections and holding them open.

In the plan it will be noted that the cover is $3\frac{1}{2}$ inches total depth. Before placing the sections in position, two 2 by 10-inch planks are attached in place on the rear wall by means of the anchor bolts embedded in the concrete. The sections of cover are then attached to this back plate by means of hinges (strap iron for the fixed central section).

When the cover sections are in place, they may be shaped to fit any irregularities in the surface of the tank rim. Since only the frame of the cover comes in contact wtih the rim, this is much more easily accomplished than with the usual flat type of lid. Metal edged weather stripping may now be fastened to the outside edge of each of the hinged cover sections in order to reduce air leakage to a minimum.

Leakage of heat into the tank may be still further decreased by employing an adjustable fastener to hold the tank cover tightly closed. The fastener illustrated in Fig K was designed by Prof. H. E. Ross of Cornell University and is made from a small turnbuckle (purchaseable at any hardware store) by bending one end to form a hook. This has the advantage over the ordinary hook fastener in being readily adjustable to different lengths. Since the cover sections on the tank described here are set back three inches from the edge to avoid the anchor bolts of the channel iron beam, a convenient arrangement is to construct a handle with a projecting nib over which the fastener may be hooked. This type of handle was suggested by Mr. John Lowe, Assistant Architect, Central Experimental Farm.

QUANTITIES OF MATERIALS REQUIRED FOR INSULATED CONCRETE TANKS

Materials	Unit of measurement	Can capacity				Remarks
		4	6	8	10	
Galv. iron sheeting	Sq. ft	18	25	32	39	No. 26 gauge.
$\frac{7}{8}$-inch matched spruce	Sq. ft	17	25	32	40	For cover of tank.
$\frac{1}{2}$-inch insulation	Sq. ft	17	25	32	40	
3-inch insulation	Sq. ft	61	81	102	121	For walls and base.
Cement	Sacks	12	15	18	22	
Sand	Cu. yds	1	$1\frac{1}{2}$	$1\frac{3}{4}$	2	1:2:2 mixture.
Gravel	Cu. yds	1	$1\frac{1}{2}$	$1\frac{3}{4}$	2	
$\frac{3}{8}$ Rd. iron bars	Lin. ft	60	74	88	98	
10-inch channel iron	Lin. ft	5′ 6″	7′ 8″	9′ 10″	12′	
Anchor bolts	$\frac{1}{2}$″ x 10″	4	6	8	10	For plank to which cover is hinged.
Anchor bolts	$\frac{5}{8}$″ x 6″	5	5	5	5	For fastening channel iron in place.
Tar paper	Sq. ft	18	24	32	38	
Asphalt*	Gallons	23	28	34	39	
Galvanized hinges	$\frac{7}{8}$″ (pairs)	4	4	4	6	For covers.

*Asphalt must meet the following specifications; it must
(a) dissolve almost entirely in cold carbon bisulphide,
(b) melt at 150 to 160 degrees F.,
(c) bend and stretch at ordinary temperatures without cracking.

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