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PASTEURIZING MILK IN BOTTLES AND BOTTLING HOT MILK PASTEURIZED IN BULK.

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CONTENTS.

	Page.
Introduction	1
Method of bacteriological analysis	3
Method of pasteurizing in bottles	3
Bacterial reductions by pasteurization in bottles	3
Advantages and disadvantages of pasteurization in bottles	7
Machinery for pasteurizing milk in bottles	7
Method of pasteurizing in bulk and bottling while hot	11
Comparison of bacterial reductions in milk pasteurized in bottles and milk pasteurized in bulk and bottled while hot	12
Prevention of bottle infection by bottling hot milk and by pasteurization in bottles	14
Cooling milk which has been bottled hot	16
The cream line and flavor of pasteurized milk cooled by various methods	23
Bottles to be used in the process of bottling hot pasteurized milk	24
Process of bottling hot pasteurized milk under commercial conditions	24
Summary	25
Citation to literature	27

INTRODUCTION.

The process of heating milk in bottles is by no means a new one, for it probably dates back to the work of Soxhlet (1),[1] from 1886 to 1891. In general, however, the object has been partially or completely to sterilize the milk by the use of high temperatures rather than simply to pasteurize it at low temperatures. While the practice of sterilizing or partially sterilizing milk in bottles has been extensively practiced in several countries in Europe, the pasteurization of milk in bottles has not been so common.

[1] The figures in parenthesis refer to the list of citations to literature at the end of the paper.

NOTE.—This paper is of interest to milk dealers, health officials, and all who have to do with the milk supply of cities; it is suitable for distribution in all parts of the country.

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It is evident from the report of Gerber and Wieske (2) that pasteurization in bottles has been practiced in certain localities for a considerable period of time. According to these authors, pasteurization in bottles by the process of Gerber, which consists of heating milk in bottles for one hour at 65° C. (149° F.), during which they are agitated, had been practiced in certain dairies for 15 years previous to 1903.

In this country milk has been pasteurized directly in bottles at various Strauss infant milk stations for several years, but this process has not been used on an extensive commercial scale until within the last two years. During the summer of 1910 an investigation was started of the bacteria which survived pasteurization in flasks and of the efficiency of the process. A report of this work has been published in Bulletin 161 of the Bureau of Animal Industry (3).

While this work was in progress North (4) suggested the pasteurization of milk in bottles on a commercial scale by the use of machines similar to those which have been in use in breweries for several years.

The process of pasteurizing in bottles consists in bottling the milk in specially constructed bottles of sufficient size to allow a space in the top of the bottle to take care of the expansion of the milk during heating. The bottles are capped with special water-tight caps and submerged in hot water. After the milk in the bottles has reached the pasteurizing temperature, the temperature is maintained for 30 minutes; the hot water is then replaced by cold and the milk cooled. In general it takes about 30 minutes to heat the bottles, 30 minutes for the holding period, and 30 minutes to cool. Milk is also pasteurized in the bottle by heating and cooling with water which is sprayed over the bottles. By this method of spraying, ordinary caps with a protective covering can be used; this will be described in another place in this bulletin.

This process of pasteurizing in bottles is now used on a commercial scale in a number of milk plants throughout this country.

Numerous advantages of this method of pasteurization over the ordinary methods have been claimed particularly in relation to the far superior bacterial reductions obtained. The most obvious point of advantage of this process is the prevention of reinfection after pasteurizing, but it seems as though a modification of the present system of "holder" pasteurization by bottling the pasteurized milk while hot, as suggested previously by the senior writer (5), would help to solve the problem of reinfection.

Accordingly, the general object of the work hereinafter described has been to compare on a laboratory scale pasteurization in bottles with the process of bottling hot pasteurized milk. The special objects have been to determine the bacterial reductions in each process, to study any special points which must be considered in the operation of each process, and to present preliminary data on the cooling of milk in bottles by an air blast.

METHOD OF BACTERIOLOGICAL ANALYSIS.

Since bacterial counts are widely influenced by differences in media and incubation it is always essential in discussing the results of bacteriological work to explain exactly how the counts were obtained. In this work plain infusion agar, made according to the recommendations of the committee on milk analysis (6), was used. The plates were incubated for five days at 30° C. (86° F.) and counted.

METHOD OF PASTEURIZING IN BOTTLES.

Milk was placed in special bottles, similar to those supplied to the trade, and capped by machine with patented metal caps. The bottles were heated by being submerged in hot water at a temperature of from 145° to 147° F. After the temperature in the bottom of the bottles had reached 145° F. they were held at that temperature for 30 minutes and removed, plates being made while the milk was hot. The bottles were so constructed that after a full quart of milk was poured in there remained an air space of sufficient size to allow for the expansion during the heating. While heating it was noticed that the milk expanded and pressure enough was generated to lift the caps slightly so as to allow air to escape. Special care was taken to see that the temperature in the bottom of the bottle of milk was maintained for the full 30 minutes.

The method of pasteurization was the same as is used on a commercial scale; hence, the results obtained are directly applicable to commercial conditions. The fact that the bacterial counts were taken directly after heating has no effect on the results, since it has been shown that cooling plays no part in the destruction of bacteria in the pasteurizing process (3).

BACTERIAL REDUCTIONS BY PASTEURIZATION IN BOTTLES.

It has been claimed that remarkable bacterial reductions have been obtained by pasteurization in bottles which were far superior to those obtained by other methods even when the same temperature and holding period were used. In order to determine what reductions could be obtained, 34 samples of milk were pasteurized in bottles.

The results are seen in Table 1. The bottles for samples Nos. 2 to 23, inclusive, were washed clean in hot water, but not steamed, before they were filled with raw milk. The bottles for the other samples were steamed two minutes and then cooled before they were filled with raw milk.

TABLE 1.—*Bacterial reductions during the process of pasteurization in bottles.*

Sample No.	Raw milk.	After pasteurization in the bottle for 30 minutes at 145° F.	Percentage reduction.	Sample No.	Raw milk.	After pasteurization in the bottle for 30 minutes at 145° F.	Percentage reduction.
	Bacteria per c. c.	*Bacteria per c. c.*			*Bacteria per c. c.*	*Bacteria per c. c.*	
2	58,000	1,630	97.18	20	80,000	2,010	97.48
3	63,000	1,070	98.30	21	160,000	29,500	81.56
4	5,100,000	11,800	99.76	22	151,000	12,500	91.72
5	580,000	8,000	98.62	23	81,000	9,800	87.90
6	5,900,000	15,600	99.74	24	24,900	570	97.71
7	99,000	980	99.01	25	94,000	2,200	97.66
8	7,400,000	7,100	99.90	26	305,000	55,800	81.70
9	191,000	7,600	96.02	27	235,000	7,600	96.76
10	14,100,000	14,200	99.89	28	176,000	11,400	93.52
11	24,700	5,780	75.59	29	97,000	8,350	91.39
12	75,000	28,000	62.66	30	230,000	5,500	97.61
13	126,000	1,720	98.63	31	124,000	1,500	98.79
14	4,100,000	2,410	99.94	32	450,000	11,400	97.46
15	76,000	3,550	95.32	33	3,950,000	3,520	99.91
16	8,100,000	1,660	99.98	34	985,000	18,400	98.13
17	18,900	710	96.24	35	190,000	9,300	95.10
18	24,000	10,900	50.41				
19	28,300	23,300	17.67	Average.	1,570,493	9,863	90.86

As may be seen from the table, the bacterial reductions were high as a rule, but there were exceptions. The average total count of the samples of raw milk was 1,570,493 and after pasteurization 9,863 bacteria per cubic centimeter. It is interesting to note that the percentage reductions averaged 90.86 per cent and ranged from 17.67 per cent to 99.98 per cent. When the latter reduction was obtained the raw milk contained 8,100,000 bacteria per cubic centimeter; when the minimum reduction was obtained the raw milk contained 28,300 bacteria per cubic centimeter. These results further substantiate the conclusion expressed in Bulletin 161, page 58 (3), that percentage bacterial reduction has no special meaning, since it is influenced by the number and kinds of bacteria in the milk when pasteurized. Considering the results as a whole, it is evident that low counts may be obtained by pasteurization in bottles.

While carrying on these experiments the following points were noted which are worthy of attention:

TEMPERATURE OF THE MILK DURING HEATING.

In the process of pasteurization it was found that the temperature of the milk in different parts of the bottle was quite different during the time the milk was being heated. Several experiments were made, heating water in sealed bottles to determine the differences in the top, middle, and bottom of the bottles. Three thermometers were inserted through a rubber stopper into a bottle so that the stems were at the top, middle, and bottom of the bottle, respectively. The bottles were then submerged in hot water at a temperature of from 145° to 146° F. and the temperatures of the water in the bottles were recorded.

Four pint bottles and four quart bottles were used. The averaged temperatures in the pint bottles are shown in figure 1. It will be seen from the curves that in a pint bottle with water at 50° F. submerged in hot water at about 145° F. it took 10⅘ minutes longer for the temperature in the bottom of the bottle to reach 140° F. after the top had reached that temperature and 4⅗ minutes longer for the temperature in the middle of the bottle. When the temperature in the top of the bottle was 140° F., in the bottom it was only 118° F.

The averaged temperatures of four quart bottles are shown in figure 2. When the temperature in the top of the bottle was 140° F., that in the bottom was only 127° F., and it took 9⅕ minutes longer for the temperature in the bottom to reach 140° F.

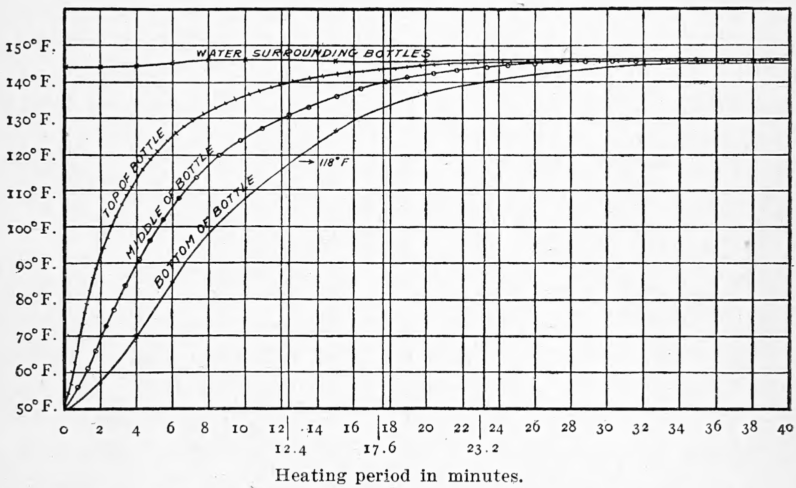

FIG. 1.—Variations in temperature in different parts of pint bottles of water during the process of pasteurization in the bottle.

It is evident that when pasteurizing in the bottle care must be taken to record the temperature in the bottom of a bottle and to date the holding period of 30 minutes from the time the bottom temperature has reached 145° F. In recording the temperature an accurate thermometer should be used, and it should reach to within one-half inch of the bottom of the bottle.

COOLING THE MILK AFTER PASTEURIZING.

After the milk is heated in bottles on a commercial scale it is cooled by replacing the hot water with cold and gradually changing the temperatures so as not to break the bottles. Upon cooling, the hot milk contracts and a partial vacuum is formed in the bottle when the caps are tight. It is recommended by the manufacturers of some of the patent caps that after heating the bottles be allowed to cool for a few minutes in air until the cap becomes concave, as this is said to hold the cap on tight and helps to make it water-tight. Obviously, it is of utmost importance that the caps be water-tight, since they are submerged in water during cooling, and if not tight the milk may become infected by polluted cooling water.

When bottles are submerged the ordinary cardboard cap is of no value for pasteurization in the bottle, since water will easily penetrate during cooling. This makes it necessary to use some form of patented cap, of which both specially treated cardboard and metal caps are on the market. It is almost needless to state that if the edge of the bottle is chipped or otherwise imperfect almost any seal cap will not be water-tight during the cooling. Imperfect bottles must not be used. It is claimed by the manufacturers of patented seal

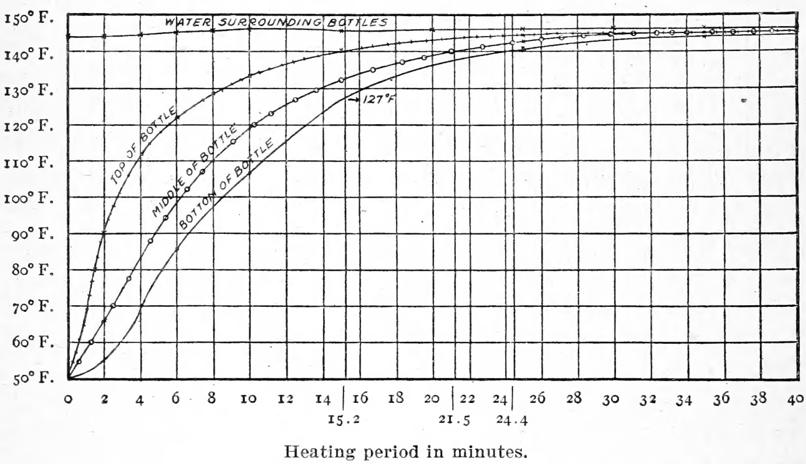

FIG. 2.—Variations in temperature in different parts of quart bottles of water during the process of pasteurization in the bottle.

caps that they are tight on perfect bottles. It would be advisable, however, for the dairyman to test the tightness of his caps by the following method: Fill the milk bottle with a 0.05 per cent solution of barium chlorid ($BaCl_2$). The barium-chlorid solution should be made up with distilled water, since the sulfates present in ordinary water will cloud the solution. Cap the bottles in the usual way with a seal cap and heat to 145° F., submerge, and cool in a 10 per cent solution of magnesium sulfate ($MgSo_4$).

If any of the magnesium sulfate leaks into the bottle during cooling the barium-chlorid solution will become cloudy, owing to the formation of barium sulfate, which is insoluble. This test is very delicate and will show even a slight leak. Both these chemicals may be obtained at any drug store. *Since barium chlorid is poisonous, after testing bottles in which it has been used care must be taken to* *wash the bottles thoroughly in order to remove the barium solution. Care must also be exercised to keep the chlorid solution from all edible products about the plant.*

ADVANTAGES AND DISADVANTAGES OF PASTEURIZATION IN BOTTLES.

From a bacteriological standpoint the advantage of pasteurization in bottles lies in the fact that reinfection after pasteurization is usually prevented. In the ordinary methods of pasteurization there is a great opportunity for infection from coolers and in bottling. Of course the proper handling in the ordinary method of pasteurization reduces and may prevent subsequent reinfection, but the possibility still remains.

It is the general opinion that the process of pasteurization in bottles also effects a great saving in milk by doing away with the loss in evaporation over the coolers and with the loss in milk which adheres to the apparatus in the process of pasteurization. Undoubtedly this saving is quite a considerable factor. There may also be a saving in the expense of machinery and in the interest on the capital invested, but it is not the province of this paper to discuss the financial aspect of this process.

On the other hand, in a plant where pasteurization is now performed in the ordinary way, it would be necessary to install an entirely new equipment for this system of pasteurization in the bottle. When bottles are heated and cooled by submerging in water perhaps the greatest disadvantage is the cost of water-tight caps. This item of expense is important, since it may increase the cost of pasteurization as much as one-fifth of a cent per bottle. Whether the saving in milk losses is sufficient to overcome this added expense can be determined only by the actual operation of a milk plant. In some processes of pasteurization in the bottle ordinary caps can be used, as the bottles of milk are heated and cooled by a spray of water, and the tops of the bottles are protected by metal coverings.

MACHINERY FOR PASTEURIZING MILK IN BOTTLES.

Pasteurization in the bottle has been practiced on a commercial scale in many different ways since water-tight caps made it possible to heat milk in bottles by submerging in water. When this process of pasteurization was first practiced the bottles, with water-tight caps, were placed in tanks and heated, held, and cooled by changing the water. This method, while satisfactory on a small scale, was hardly practical in large plants. Several types of machines have been invented, which make the process continuous. One of these machines is shown in figure 3. The machine consists of a large tank divided into two compartments and two smaller tanks. These contain water at different temperatures. Bottle-holding frames are carried through these compartments on an endless chain in the manner shown in the drawing. The raw milk is bottled and capped with water-tight caps, then placed on the bottle-holding frames of the machine on the loading end. The bottles of milk are then carried through the preheating compartment into the pasteurizing compartment where they remain for about 30 minutes. From the pasteurizing tank the bottles are carried to the cooling tank, then to the refrigerating tank, after which they are removed from the machine. The process is continuous, the bottles of milk being loaded at one

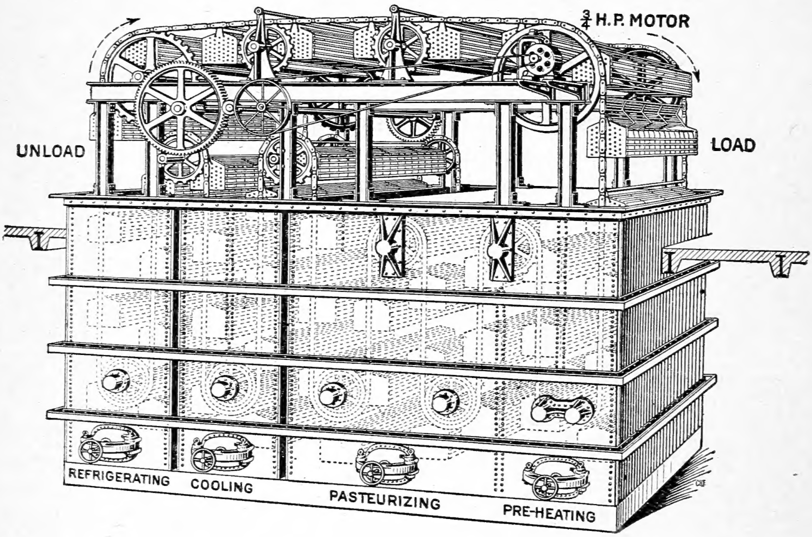

FIG. 3.—Machine for continuous pasteurization of milk in bottles. The bottles have water-tight caps and are conveyed on an endless chain through water compartments of various temperatures.

end, heated, held, and cooled, then unloaded at the other end of the machine. The temperature of the water in this machine is automatically controlled.

There are other machines on the market which differ in the manner in which the bottles are carried through the tanks of water, but the principle is about the same.

In other types of pasteurizers the bottles are not submerged in water and consequently water-tight caps are not necessary. The bottles of milk are heated and cooled by sprays of water and ordinary caps are used and protected from water by a metal covering. One of this type of in-the-bottle pasteurizers is shown in figure 4. The crates of raw milk are placed on an endless traveling conveyor which passes through the machine and returns under it. The bottom of the machine is divided into several compartments and each compartment is filled with water for supplying the machine when in operation. The top of the machine is a flooding pan divided into compartments corresponding to those in the bottom of the machine. Pumps draw the water from the lower compartments and force it into the corresponding top sections, from which it returns in the form of a shower through perforated bottoms. The process is repeated with the same water. As the crates of milk pass through the machine they pass through showers of water at different temperatures and are heated to the pasteurizing temperature, then held and finally

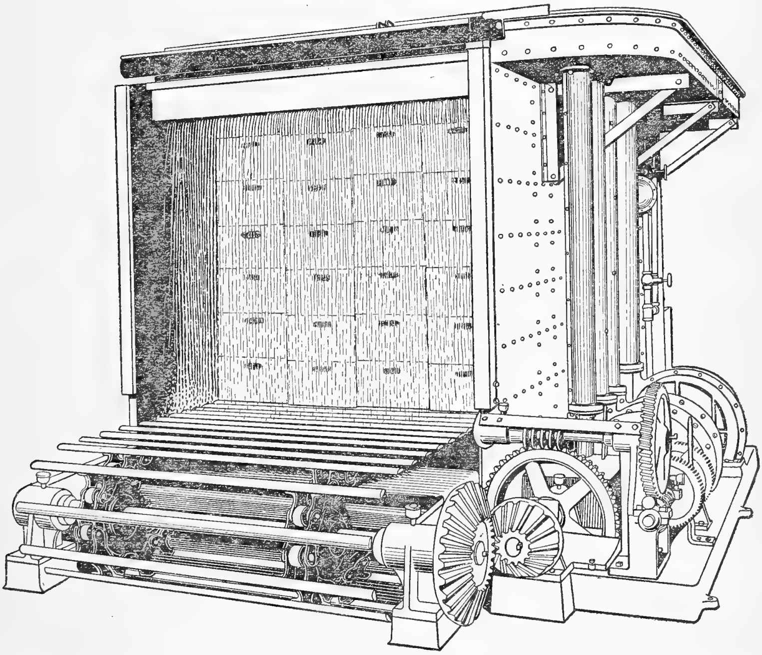

Fig. 4.—Another type of continuous machine in which the bottles of milk have ordinary caps and are passed through showers of water at various temperatures.

cooled. The tops of the bottles are protected from water by metal caps arranged as shown in figure 5. This frame of metal caps covers the top of each bottle in the crate.

The pasteurizing section of the machine is located in the center with the preheating and cooling section at each end. The preheating and cooling sections are connected by channels, because the cool milk entering the machine has a tendency to cool the water and the hot milk emerging from the pasteurizing section has a tendency to heat it. The temperature of the water in the pasteurizing section is automatically maintained.

In figure 6 is shown another type of in-the-bottle pasteurizer which is so arranged that bottles of milk may be heated with ordinary

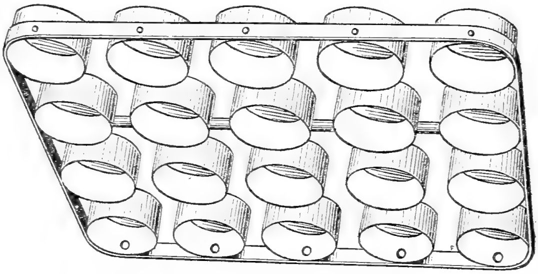

FIG. 5.—Metal caps in frame for protection of bottles as operated in machines shown in figures 4 and 6.

caps. The pasteurizer is made of sheet metal and contains racks which hold crates of bottles. The tops of the bottles are covered with metal caps of the type shown in figure 5. The crates of raw milk covered with metal caps are placed on the racks in the pasteur-

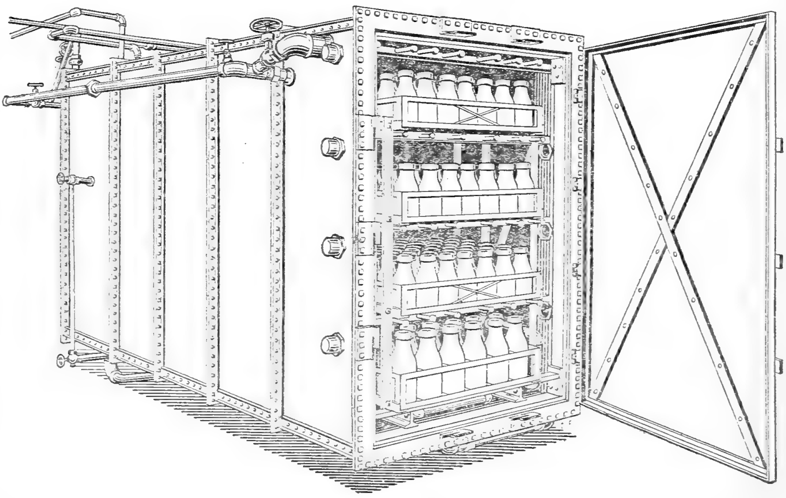

FIG. 6.—A pasteurizing machine in which paper-capped bottles are protected by metal caps, and heating and cooling are done, respectively, by circulation of hot and cold water.

izer and heated by means of hot water which is forced against the bottles. The water is circulated by means of a pump and is used continuously. After the milk has reached 145° F. it is held for 30 minutes and then cooled. Cooling is accomplished by replacing the hot water by cold, while for low temperatures a special set of cooling pipes is supplied. The temperature of the heating water can be automatically controlled.

METHOD OF PASTEURIZING MILK IN BULK AND BOTTLING WHILE HOT.

For the pasteurization of milk in bulk a double-walled cylindrical tin tank with a capacity of about 3½ gallons was used. The con-

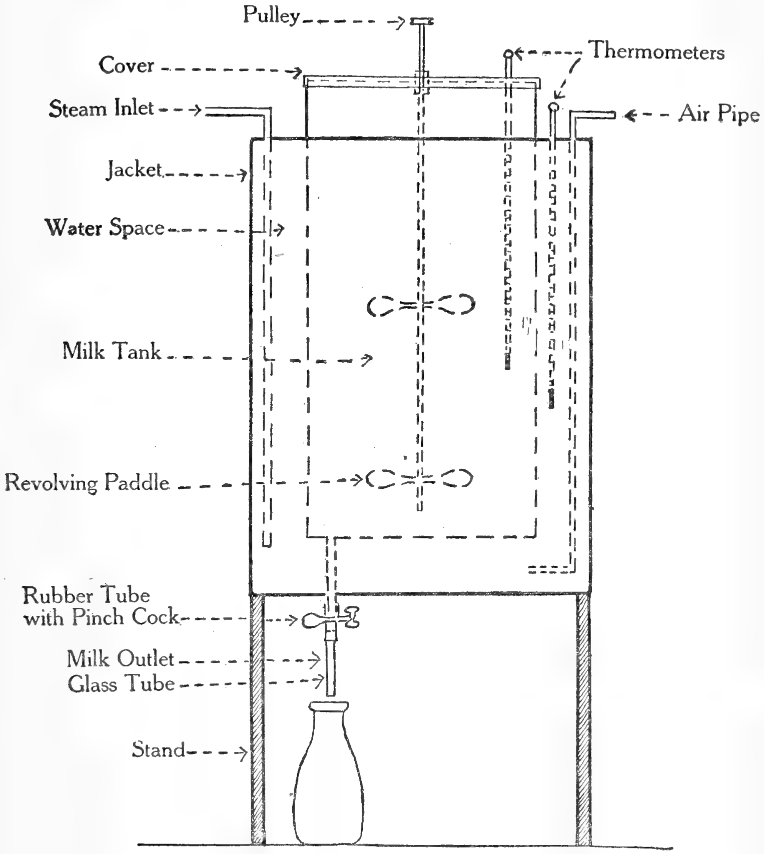

FIG. 7.—Apparatus for pasteurizing milk and bottling while hot.

struction of this tank is shown in figure 7. Raw milk was placed in the milk tank, where it was heated by hot water in the outer jacket. The surrounding water was heated by a steam jet and constantly agitated by blowing in a small amount of air. During the heating the milk was agitated by a paddle supported by the cover of the milk tank. The water in the jacket was kept at a temperature of about 146° F. The milk was held at a temperature of 145° F.

for 30 minutes and then drawn off while hot through the outlet pipe into hot milk bottles which had been steamed 2 minutes. As stated before, this method of bottling milk while hot was suggested in Circular 184 of the Bureau of Animal Industry (5), but the suggestion then was to bottle hot milk in cold bottles. In this work it seemed advisable to bottle directly into hot bottles, as it makes it possible to steam the bottles and fill them before infection can take place. Also, this method eliminates the possibility of breaking bottles. While working on this process of bottling milk hot it has been found that a similar process was apparently patented several years ago, but, so far as known, it has never been used to any extent. This process as described by de Schweinitz (7) consisted in pasteurizing the milk at temperatures from 160° to 180° F. and placing it while hot in a sterilized milk jar or fruit jar with a flap top. Special paper caps were used. The jars of milk were cooled by being placed in troughs of iced water.

COMPARISON OF BACTERIAL REDUCTIONS IN MILK PASTEURIZED IN BOTTLES AND MILK PASTEURIZED IN BULK AND BOTTLED WHILE HOT.

Since it has been shown earlier in this bulletin that excellent bacterial reductions may be obtained by pasteurization in bottles, a question of great importance arises as to whether or not as good results can be obtained by pasteurizing milk in bulk and bottling while hot.

A series of 22 samples of raw milk was pasteurized by both processes at 145° F. for 30 minutes. Part of the milk was pasteurized in bulk in the pasteurizer shown in fig. 7 and bottled hot in hot bottles which had been previously steamed for two minutes. In all these experiments the bottles were capped with ordinary paper caps, no precautions being used in capping by hand. Another portion of the same raw milk was pasteurized in bottles. Both samples of pasteurized milk were examined bacteriologically while hot in the bottles.

In the first series the bottles in which the milk was pasteurized directly were washed with hot water and washing powder immediately before they were filled with raw milk.

TABLE 2.—*Comparison of bacterial reductions in milk pasteurized in unsteamed bottles and in pasteurized milk bottled while hot in steamed bottles.*

Sample No.	Raw milk (bacteria per c. c.).	Milk pasteurized at 145° F. for 30 minutes.			
		Hot pasteurized milk in hot steamed bottles.		Milk pasteurized in washed but unsteamed bottles.[1]	
		Bacteria per c. c.	Percentage reduction.	Bacteria per c. c.	Percentage reduction.
2	58,000	1,160	98.00	1,630	97.18
3	63,000	220	99.65	1,070	98.30
4	5,100,000	8,400	99.83	11,800	99.76
5	580,000	8,300	98.57	8,000	98.62
6	5,900,000	6,000	99.90	15,600	99.74
7	99,000	610	99.38	980	99.01
8	7,400,000	6,300	99.91	7,100	99.90
9	191,000	2,000	98.95	7,600	96.02
10	14,100,000	7,000	99.95	14,200	99.89
11	24,700	4,550	81.58	5,780	75.59
12	75,000	3,000	96.00	28,000	62.66
13	126,000	1,440	98.86	1,720	98.63
14	4,100,000	2,470	99.94	2,410	99.94
15	76,000	1,400	98.16	3,550	95.32
16	8,100,000	1,620	99.98	1,660	99.98
17	18,900	760	95.97	710	96.24
18	24,000	800	96.66	10,900	50.41
19	28,300	7,050	75.09	23,300	17.67
20	80,000	1,360	98.30	2,010	97.48
21	160,000	1,830	98.86	29,500	81.56
22	151,000	3,200	97.88	12,500	91.72
23	81,000	6,800	91.60	9,800	87.90
Average	2,115,268	3,467	96.50	9,083	88.34

[1] Bottles were washed clean in hot water, but not steamed, before they were filled with raw milk.

The results of the bacteriological examinations are shown in Table 2. It will be seen that the average count of the raw milk was 2,115,268 bacteria per cubic centimeter. After being pasteurized in bulk and bottled hot in hot steamed bottles the average count was 3,467 bacteria per cubic centimeter, while the average count when pasteurized in bottles was 9,083 bacteria per cubic centimeter. Comparing the percentage of bacterial reductions, it will be noted that the average reduction of the milk bottled hot was 96.50 per cent and only 88.34 per cent in the milk pasteurized in bottles. In 19 of the 22 samples the bacterial count was lower in milk pasteurized in bulk and bottled hot. In many cases the count was much lower, as may be seen by comparing samples 4, 6, 7, 12, and 18. This difference is particularly striking in sample 21, in which milk pasteurized in bulk and bottled hot showed a count of 1,830, and some of the same milk pasteurized in a bottle for the same time and at the same temperature contained 29,500 bacteria per cubic centimeter.

In the belief that this marked difference might be due to the fact that the bottles were steamed in the first case and unsteamed when the milk was pasteurized directly in bottles, another series of samples was pasteurized in which both bottles were steamed for two minutes in order to eliminate this factor of possible infection. The result of these experiments are shown in Table 3.

TABLE 3.—*Comparison of bacterial reductions in milk pasteurized in steamed bottles and in pasteurized milk bottled while hot.*

Sample No.	Raw milk.	Milk pasteurized at 145° F. for 30 minutes.			
		Hot pasteurized milk in hot steamed bottles.		Milk pasteurized in steamed bottles.[1]	
	Bacteria per c. c.	Bacteria per c. c.	Percentage reduction.	Bacteria per c. c.	Percentage reduction.
24	24,900	380	98.47	570	97.71
25	94,000	860	99.08	2,200	97.66
26	305,000	21,800	92.85	55,800	81.70
27	235,000	5,400	97.70	7,600	96.76
28	176,000	2,200	98.75	11,400	93.52
29	97,000	5,900	93.91	8,350	91.39
30	230,000	6,300	97.26	5,500	97.61
31	124,000	920	99.26	1,500	98.79
32	450,000	4,200	97.47	11,400	97.46
33	3,950,000	4,320	99.89	3,520	99.91
34	985,000	11,800	98.80	18,400	98.13
35	190,000	7,500	96.06	9,300	95.10
Average	571,766	5,965	97.46	11,295	95.48

[1] Bottles were steamed two minutes, and cooled before they were filled with raw milk.

It will be seen that the results again were in favor of the milk pasteurized in bulk and bottled while hot. Of the 12 samples in the experiment 10 showed lower counts than when the milk was pasteurized in the bottles.

The average count of the raw milk was 571,766 bacteria per cubic centimeter. After pasteurization in bulk, followed by bottling hot, the count was 5,965, and a portion of the same milk pasteurized in bottles averaged 11,295 bacteria per cubic centimeter. In several of the samples the count in the milk pasteurized in bottles was very much higher than in the same milk pasteurized in bulk and bottled hot. The explanation of these marked differences is not known. While minor differences are always within the limits of the errors of bacteriological methods, the great differences found in many cases can not be explained in this manner.

PREVENTION OF BOTTLE INFECTION BY BOTTLING HOT MILK AND BY PASTEURIZATION IN BOTTLES.

Since the process of pasteurizing milk in bulk and bottling while hot enables the use of hot, steamed bottles which can be directly filled with hot milk, it should be expected that there would be no contamination added to the milk during bottling.

To determine this point eight samples of milk were pasteurized in bulk and bottled hot in hot, steamed bottles. The bacteriological results are shown in Table 4, column A. Two steamed and cooled milk bottles for each sample were inoculated with equal amounts of sour milk. One of these infected bottles was then steamed for two minutes and filled with hot pasteurized milk and the other contaminated bottle not heated was filled with some of the same pasteurized milk, which had been previously cooled in a sterile bottle. An examination of Table 4 shows, when the figures in columns A and C are compared, that the infectious material added to the bottle was entirely destroyed by the method of bottling, at least so far as bacteriological methods can detect, since any marked increase in column C would show infection. Column B shows the bacterial counts obtained by putting cold pasteurized milk into infected bottles. From these results it is evident that the process of bottling hot pasteurized milk in hot, steamed (two minutes) bottles entirely eliminates the factor of bottle infection, which may often be serious in the ordinary processes of pasteurization on a commercial scale.

TABLE 4.—*Destruction of bottle infection during the process of bottling hot pasteurized milk.*

Sample No.	Raw milk.	Hot pasteurized milk in hot steamed bottles.	Cold pasteurized milk in cold infected bottles.[1]	Hot pasteurized milk in steamed infected bottles.[1]
		A	B	C
	Bacteria per c. c.	*Bacteria per c. c.*	*Bacteria per c. c.*	*Bacteria per c. c.*
24	24,900	380	6,400,000	460
25	94,000	860	5,600,000	600
27 [2]	235,000	5,400	1,330,000	4,800
28	176,000	2,200	1,510,000	2,400
29 [2]	97,000	5,900	235,000	4,100
30 [2]	230,000	6,300	355,000	5,800
31 [2]	124,000	920	305,000	950
35 [2]	190,000	7,500	....	8,800

[1] Bottles had been previously infected with several cubic centimeters of sour milk.
[2] Bottle infected with old, sour, pasteurized milk.

The question naturally arose as to whether or not pasteurization in bottles would destroy infection in bottles specially infected before being filled with raw milk. To determine this point nine samples of milk were pasteurized which had been previously steamed and cooled. The results are shown in Table 5. One bottle for each sample was steamed, cooled, infected with several cubic centimeters of sour milk, and filled with some of the original raw milk. Samples were then plated from this bottle to show the extent of the infection, the results of which may be found in column B of the table. The bottle of infected raw milk was capped with a seal cap and the milk pasteurized directly in the bottle. Plates were made directly after the heating and the bacteriological results are shown in column C. Any increase in the counts in column C over those in column A shows the amount of infection introduced by placing milk in an infected bottle. It is evident that in only two samples, Nos. 28 and 35, was the infection entirely destroyed.

TABLE 5.—*Destruction of bottle infection during the process of pasteurization in bottles.*

Sample No.	Raw milk.	Milk pasteurized in clean previously steamed bottles.	Bottles infected with sour milk and filled with raw milk.	Milk pasteurized in infected bottles.
		A	B	C
	Bacteria per c. c.	*Bacteria per c. c.*	*Bacteria per c. c.*	*Bacteria per c. c.*
24	24,900	570	3,700,000	2,090
25	94,000	2,200	3,300,000	6,200
27[1]	235,000	7,600	760,000	9,500
28	176,000	11,400	650,000	11,000
29[1]	97,000	8,350	530,000	20,000
30[1]	230,000	5,500	645,000	20,900
31[1]	124,000	1,500	400,000	28,600
35[1]	190,000	9,300	230,000	9,600
36[1]	38,000	5,600	92,000	17,700

[1] Bottle infected with old, sour, pasteurized milk.

It is quite possible that infection from unclean bottles might become a serious factor in bottle pasteurization. When one considers that in pasteurization in the bottle the bacteria which are left are either heat-resistant vegetative cells or spores, it is easy to see that if a large number are left in a bottle and it is again filled with milk and pasteurization again performed in the bottle these same bacteria will again survive and increase the number left. It is advisable to steam the bottles at least two minutes before filling with milk for pasteurization in the bottles.

COOLING MILK WHICH HAS BEEN BOTTLED HOT.

When a water-tight cap is used it is, of course, possible to bottle the milk while hot and cool by submerging in cold water, but experiments have been made with a process by which the milk may be cooled in bottles capped with ordinary cardboard caps. Briefly stated, the process consists in exposing the hot bottled milk to an air blast. The air-blast system is used at present in the hardening rooms in ice-cream plants, but, so far as known, this system has never been applied to the cooling of milk.

Several experiments were tried on a laboratory scale which gave promising results. When a bottle of hot milk is allowed to cool in still air a film of warm air forms about it which can move away only by convection, and, naturally, the cooling process is slow. If some means were provided for moving the film of warm air and forcing cool air against the bottle, heat would constantly be given up with more rapidity by the milk and the cooling process hastened. In figure 8 are shown the temperatures in three bottles of milk cooled for 30 minutes in air. One bottle was cooled in still air at 77° F., one was cooled in an air blast from an electric fan at a temperature of 77° F., and one was cooled in still air at 35° F. At the beginning of the cooling the temperature of the milk was about 145° F. As will be seen from the curves, after 30 minutes' cooling the temperature of the milk in the bottle cooled in still air at 77° F. was about 127.5° F., while that of the milk cooled in an air blast at 77° F. was about 102° F. It is noted that by cooling in an air blast for 30 minutes

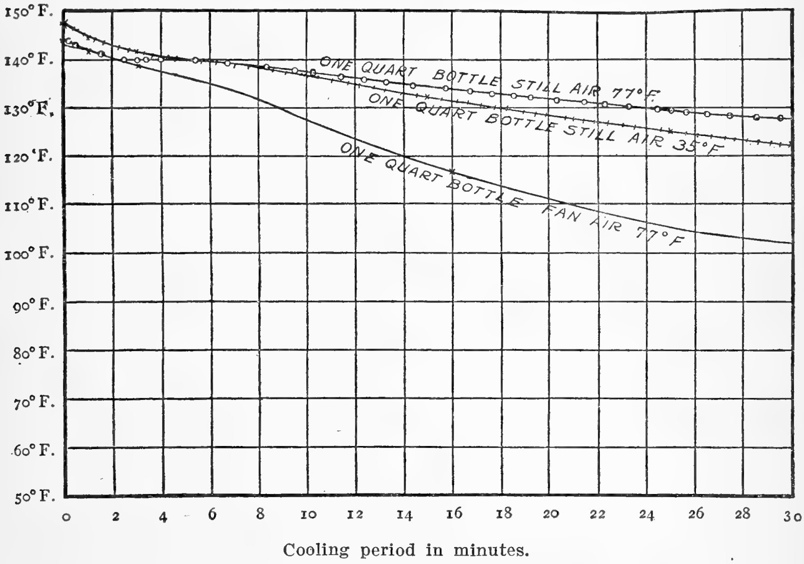

FIG. 8.—Effect of cooling a quart bottle of milk in still air and in an air blast.

there was a reduction in temperature of about 25.5° F. in excess of that obtained under the same conditions in still air. The temperature curve of the milk in the bottle cooled in still air at 35° F. follows closely that of the milk cooled in still air at 77° F. It is also interesting to note that after cooling for 30 minutes in still air at 35° F. the temperature was 122° F., while that of the milk cooled in an air blast at 77° F. was about 102° F., a difference of 20° F.

Since these experiments indicated that hot bottled milk might be cooled more rapidly by using a blast of cold air, another experiment was conducted in which one quart and one pint bottle were cooled in still air which averaged 39.4° F. and another set in an air blast the temperature of which averaged 44.3° F. The blast of cold air was obtained by placing an electric fan in a refrigerator. The fan delivered air at a velocity of about 1,250 feet per minute. The temperature curves in figure 9 show the results of this experiment. The temperatures of the hot milk at the beginning of the cooling ranged from 140° to about 143.5° F. in the different bottles. It will be seen from the curves that five and one-half hours were required for the temperature of the quart bottle of milk in still air to reach 50° F., while the milk in a quart bottle in an air blast was cooled to 50° F. in a little over two hours. The milk in the pint bottle cooled in still air reached a temperature of 50° F. after about three and one-half hours, while only one and one-half hours were required to cool the milk in the pint bottle which was in a blast of cold air.

From these results there can be no doubt as to the value of an air blast for cooling bottles of hot milk, at least as compared with still air as a cooling medium. As these experiments were made on single

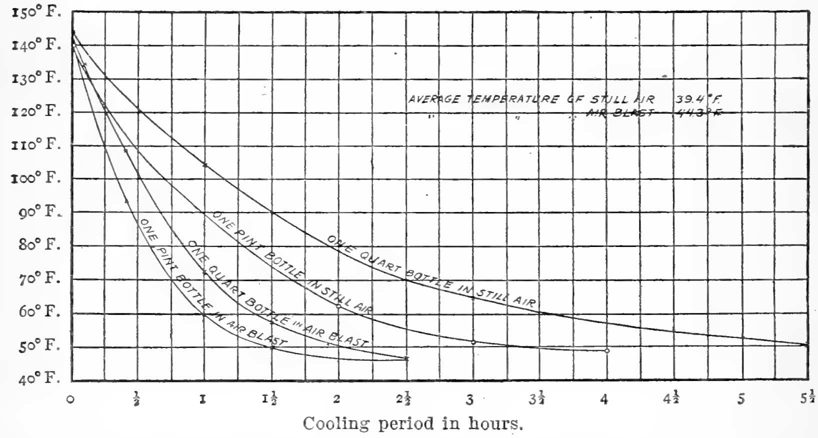

FIG. 9.—The cooling of pint and quart bottles of hot milk in still air and in an air blast at refrigerator temperature.

bottles it was thought advisable to try cooling several crates of bottled hot milk by an air blast. Specially constructed skeleton-frame steel crates were used, so as to allow a free circulation of air.[1] Milk was pasteurized at 145° F. for 30 minutes and bottled hot in ordinary milk bottles by the aid of a hand bottle filler. The bottles were then capped with the ordinary cardboard caps and placed in crates. Four crates were used in these experiments, two filled with quart and two with pint bottles. The two crates which contained quart bottles were placed in a refrigerator room one above the other, and directly back of them were placed the two crates of pint bottles one above the other. The air blast was generated by a 16-inch desk

[1] Mr. John T. Bowen, of this division, assisted in this work.

fan, which gave an air velocity of about 1,250 feet per minute. The fan was placed about 2½ feet in front of the pile of four crates directly facing the crates with quart bottles. Temperatures were taken in two quart bottles, one in the front and the other in the back row. In this experiment the crates were cooled in a refrigerator room, the temperature of which varied from 40° to 44° F. The results of this experiment are shown in figure 10, together with the results of a similar experiment in which the crates were cooled in an air blast at a temperature of about 76° F. for a period of 2¼ hours. The crates were then placed in a refrigerator and the cooling continued, a blast of air with a temperature of about 41° F. being used. The curves in figure 10 show the averaged temperatures of two quart

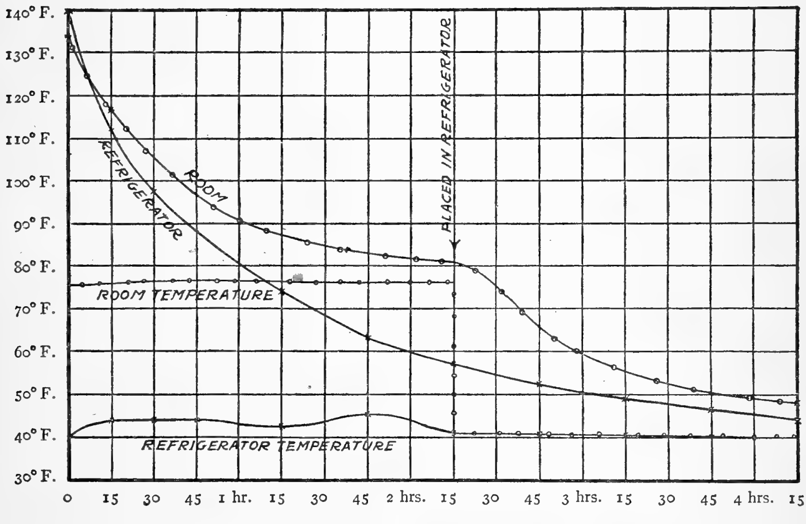

FIG. 10.—Effect of cooling crates of bottled hot milk in an air blast at different temperatures.

bottles. It will be seen from curve A that about 3 hours and 7 minutes were required to cool the milk in quart bottles from 140° to 50° F. when cooled in a blast of cold air during the entire period. A comparison of curves A and B shows that it took only about 45 minutes longer to cool to 50° F. the milk in bottles exposed to an air blast at room temperature for the first 2¼ hours. It is interesting to note that curves A and B follow each other fairly closely during the first 30 minutes of cooling. These results suggest that the cooling of hot pasteurized bottled milk may be accomplished by cooling with an air blast at ordinary room temperature and completed by cooling in a blast of cold air in a refrigerator room. The greater the number of heat units which can be removed from the milk by an air blast at room temperature the cheaper the cost of cooling, since refrigeration would be saved and about the only cost would be the operation of a blower.

These experiments, although by no means conclusive as to the value of this method of cooling by an air blast on a practical scale, since many complications may arise in the practical application, indicate great possibilities for such a system.

THE EFFECT OF QUICK AND SLOW COOLING ON THE BACTERIAL FLORA OF THE MILK.

It is believed that any system of pasteurization in which the milk is not cooled immediately after heating will be looked upon with suspicion and will excite comment. It has always been supposed that immediate cooling was an indispensable part of the process of pasteurization, first, because sudden changes in temperature were believed to have a destructive effect on the bacterial cells, and second, because it has been supposed that bacteria left after pasteurization would immediately begin to grow unless the milk was cooled at once.

As stated earlier in this bulletin, it was shown in Bulletin 161 (3) that sudden cooling played no part in the destruction of bacteria. There remains, therefore, one question to be answered, How quickly must pasteurized milk be cooled in order to check bacterial growth?

From the writers' former studies of pasteurization it seemed apparent that the bacteria which survived heating were somewhat weakened or at least did not begin to grow as might theoretically be expected. These observations naturally gave rise to the idea that pasteurized milk might be cooled directly in bottles by a cold air blast, provided the cooling period did not extend over a few hours.

In order to obtain data on this question 10 samples of milk were pasteurized and bottled hot in steamed bottles. Two bottles for each sample were cooled as follows: One bottle was cooled within half an hour in ice water and placed in a refrigerator at 45° F. for 17½ hours; the other bottle was cooled slowly at room temperature for 4 hours and placed in a refrigerator at 45° F. for 14 hours. At the end of that time each bottle of milk was 18 hours old; one was cooled quickly and had been at 45° for 17½ hours; the other had been cooled slowly and had been at 45° for probably a very short time, because, although it had been in the refrigerator for 14 hours, the milk was warm when placed there, and cooling in still air is a slow process. Both bottles after the 18-hour cooling period were allowed to stand at temperatures of from 75° to 86° F. for a period of 6 hours. The bacterial results are shown in Table 6.

TABLE 6.—*Number of bacteria per cubic centimeter in pasteurized milk bottled hot, cooled quickly and slowly, and subsequently held at room temperature.*

Method of cooling.	Sample No.										Average of 10 samples.
	1	2	3	4	5	6	7	8	9	10	
Bacteria in the raw milk....	95,000	176,000	176,000	97,500	97,500	......	450,000	......	985,000	38,000	264,375
Bottle No. 1, cooled quickly:											
Directly after pasteurization................	600	1,870	1,570	5,900	5,900	22,900	890	4,800	8,300	5,500	5,823
After one-half hour in ice water and 17½ hours at 45° F........	1,000	[1] 2,050	[1] 2,370	......	......	16,600	1,700	2,500	8,900	5,200	5,040
After 6 hours at 86° F....	......	5,750	8,400	6,600	5,900	......	......	......	[2] 9,600	[2] 5,200	6,908
Bottle No. 2, cooled slowly:											
Directly after pasteurization................	860	1,320	1,220	5,900	5,900	21,800	890	5,400	7,500	6,500	5,729
After 4 hours at room temperature and 14 hours at 45° F........	500	1,180	5,520	......	......	12,300	2,200	715	9,800	5,200	4,678
After 6 hours at 86° F....	......	5,800	6,100	3,700	3,700	......	......	......	[2] 8,900	[2] 5,300	5,583

[1] Held at 45° F. for 21 hours in place of 18 hours. [2] Held at 75° F. instead of 86° F.

As may be seen from Table 6, bacterial counts were made of the raw milk on each bottle directly after pasteurization, at the end of the 18-hour cooling period, and again after the milk had been at room temperature for six hours. The bacterial results obtained showed that there was no more increase in the pasteurized milk cooled slowly than in similar milk cooled within half an hour and held at low temperatures for 18 hours. Neither was there any difference in the bacterial numbers even after milk cooled by both processes had been removed, after 18 hours' cooling, and allowed to stand for six hours. The various counts from 10 samples have been averaged and are given in the last column in order to show more plainly the effect of the two systems of cooling on the bacterial numbers in milk. It will be seen that the average bacterial counts of the milk cooled slowly are even lower than those of milk cooled quickly. While this difference is probably an experimental error, it is evident that bacterial growth in the pasteurized milk was not increased by the slow-cooling process.

The writers do not wish to convey the idea that pasteurized milk need not be cooled at all. The cooling of any milk is absolutely essential in order to restrain bacterial growth, and the fact should be emphasized that the process of cooling pasteurized milk slowly does not dismiss the cooling process but simply makes use of a slower cooling process than is in use at present.

In order to show, respectively, the effect on the bacterial content of cooling quickly, cooling slowly, and not cooling to low temperatures at all, three experiments were made. Milk was pasteurized in bulk and three steamed and hot quart bottles were filled with the hot milk. One bottle was cooled in iced water in half an hour to 50° F. and refrigerated at 45° F. Another bottle was cooled in a blast of air at room temperature for half an hour during which time the temperature dropped from 145° to about 100° F. The milk was then allowed to stand at a temperature of from 100° to 80° F. for five hours, after which it was placed in a refrigerator at 45° F., where it cooled slowly in still air. The remaining bottle was cooled for half an hour in an air blast at room temperature and allowed to remain at a temperature of about 75° F. through the entire experiment. The results of these experiments are given in Table 7.

TABLE 7.—*Effect of different methods of cooling on the bacterial content of pasteurized milk.*

Method of cooling.	Sample No.		
	1	2	3
	Bacteria per c.c.	*Bacteria per c.c.*	*Bacteria per c.c.*
Raw milk	9,050,000		11,900,000
Bottle No. 1, cooled quickly:			
Directly after pasteurization	6,450	2,110	8,500
Held at 45° F. for 22 hours	5,050	1,720	28,400
Held at 75° F. for 6 hours	4,800	2,340	76,500
Held at 75° F. for 24 hours	1,370,000	885,000	
Bottle No. 2, cooled slowly:			
Directly after pasteurization	7,150	2,580	11,900
Held at 75° F. for 5 hours	6,100	1,600	29,000
Held at 45° F. for 17 hours	6,200	2,400	192,000
Held at 75° F. for 6 hours	9,600	2,740	348,000
Held at 75° F. for 24 hours	2,760,000	850,000	
Bottle No. 3, cooled at room temperature:			
Directly after pasteurization	4,950	2,180	8,500
Held at 75° F. for 5 hours	6,850	2,890	25,000
Held at 75° F. for 22 hours	700,000	2,420,000	83,400,000
Held at 75° F. for 28 hours	2,750,000	13,400,000	269,000,000
Held at 75° F. for total of 66 hours	460,800,000		

A study of the table shows that there was no increased bacterial growth with samples 1 and 2 caused by holding the pasteurized milk for five hours after bottling hot, even though the temperature during that period ranged from 100° to 80° F., which is the most favorable temperature for bacterial development. With sample 3 there was an increased growth over that in the milk cooled quickly. It must be remembered that these experiments represent extreme conditions in slow cooling, but the fact is apparent that the cooling process should not extend over five hours. The effect of not cooling milk to low temperatures is plainly shown in the table by a comparison of the bacterial counts with those of milk cooled both quickly and slowly. It is believed from these experiments that it is possible to cool hot bottled pasteurized milk by a blast at room temperature followed by a blast of cold air without any more bacterial development than would take place if the milk were immediately cooled, provided the milk is cooled to 50° F. gradually within five hours. This is not made as a definite statement, because different results may, of course, be obtained when milk is thus cooled on a commercial scale.

Again let the fact be emphasized that pasteurized milk or raw milk must be kept at low temperatures after cooling in order to check bacterial development.

THE CREAM LINE AND FLAVOR OF PASTEURIZED MILK COOLED BY VARIOUS METHODS.

In the consideration of the process of bottling hot pasteurized milk followed by slow cooling it is of practical importance to know what effect such a process will have on the cream line and flavor of the milk. Several experiments were made to determine the effect on these points. Milk was pasteurized, and hot 500-cubic-centimeter graduated cylinders were filled with hot milk up to the 500-cubic-centimeter mark. Together with the cylinder of hot pasteurized milk one cylinder was filled with raw milk and one with pasteurized milk which had been cooled to 50° F. in 15 seconds' time by running through a coil immersed in brine. The method of cooling the hot cylinders of pasteurized milk was varied considerably, as may be seen from Table 8. After holding the milk for 24 hours at 45° F. the numbers of cubic centimeters of cream were read off directly from the graduations on the cylinder. This method, of course, gave a very accurate means of determining the effect of heating and cooling on the cream line; in fact it was too accurate, since considerable differences in the cream line by this method of measurement were not apparent in bottled milk.

TABLE 8.—*Cream-line experiments with raw milk and milk pasteurized at 145° F. for 30 minutes.*

Experiment No.	Process.	Cubic centimeters of cream in 500 c. c. cylinder after 24 hours' refrigeration at 45° F.
1	Raw milk	64.5
	Pasteurized milk:	
	Cooled quickly in 15 seconds to 50° F. and held in refrigerator at 45° F.	64.5
	Cooled slowly in air blast for 45 minutes and placed in refrigerator at 45° F.	65.0
	Held above 105° F. for 3 hours, cooled in ice water, and placed in refrigerator at 45° F.	64.5
2	Raw milk	65.0
	Pasteurized milk:	
	Cooled in 15 seconds to 50° F. and placed in refrigerator at 45° F.	62.5
	Cooled slowly in air blast for 1½ hours and placed in refrigerator at 45° F.	52.5
	Held above 100° F. for 1½ hours and placed in refrigerator at 45° F.	52.5
3	Raw milk lost	....
	Pasteurized milk:	
	Cooled in 15 seconds to 50° F. and placed in refrigerator at 45° F.	83
	Cooled slowly for 30 minutes in air blast, cooled quickly in brine, and placed in refrigerator at 45° F.	85
	Held above 100° F. for 3 hours, cooled quickly in brine, and placed in refrigerator at 45° F.	90
4	Raw milk lost	....
	Pasteurized milk:	
	Cooled in 15 seconds to 50° F. and placed in refrigerator at 45° F.	75
	Cooled slowly in air blast for 2½ hours, cooled in ice water, and placed in refrigerator at 45° F.	69
	Held above 100° F. for 2½ hours, cooled in ice water, and placed in refrigerator at 45° F.	75
5	Raw milk	80
	Pasteurized milk:	
	Cooled in 15 seconds to 50° F. and placed in refrigerator at 45° F.	68
	Cooled slowly in air blast for 2 hours and placed in refrigerator at 45° F.	55
	After cooling in air blast for 2 hours the milk was cooled quickly in brine to 50° F. and placed in refrigerator at 45° F.	62
	Held above 100° F. for 5 hours and placed in refrigerator at 45° F.	55
	After holding above 100° F. for 5 hours the milk was cooled quickly in brine to 50° F. and placed in refrigerator at 45° F.	62

A study of the results in Table 8 shows that the cream-line formation is a variable factor. Sometimes it was reduced by pasteurization even when the milk was cooled to low temperatures within 15 seconds, and at other times there was no difference. In some experiments the cream line was slightly less on milk cooled slowly and again it was slightly higher. Throughout the experiments on pasteurized milk bottled hot in ordinary milk bottles a good clear cream line was obtained. When milk stood at temperatures above 80° F. for several hours without agitation some of the melted butter fat rose to the top of the bottle and on cooling formed a small lump of butter. This was not observed, however, when the cooling process was begun immediately after bottling, even though the cooling was gradual.

As to the effect on the flavor of the milk, it may be said that there was no more effect than that produced by milk pasteurized and cooled rapidly, except in instances where the milk was held above 100° F. for several hours, as was the case in some of the experiments, in which a slightly more pronounced cooked taste was noticeable in the milk.

In this connection attention is called to the fact that these results hold only for milk pasteurized at 145° F. and can not be applied where higher temperatures might be used, as it is possible that with higher temperatures different results might be obtained.

BOTTLES TO BE USED IN THE PROCESS OF BOTTLING HOT PASTEURIZED MILK.

It is obvious that a quart bottle filled with milk at 145° F. will not contain a full quart when the milk has cooled to 50° F., owing to the contraction during cooling. Several experiments which were made to determine the loss in volume during cooling showed a shrinkage in a quart bottle which averaged about 18.40 cubic centimeters. Assuming a quart of milk to be 946.35 cubic centimeters, that volume at 145° F. would therefore contract to about 927.95 cubic centimeters when cooled to 50° F. If a quart bottle is filled with milk at 145° F., it will be 18.40 cubic centimeters, or 0.62 of an ounce, short of 1 quart when cooled to 50° F. To overcome this shortage bottles of a slightly larger capacity should be used when filled with milk at 145° F. A bottle should be of sufficient size to hold 1 quart of milk measured at 50° F. which has been heated to 145° F.

PROCESS OF BOTTLING HOT PASTEURIZED MILK UNDER COMMERCIAL CONDITIONS.

Having discussed the various steps in the process of bottling hot pasteurized milk, the possible application of this process of commercial conditions may be outlined.

Milk can be pasteurized by the ordinary holder system at 145° F. for 30 minutes. It can then be bottled hot in special oversized milk bottles of the ordinary type and capped with ordinary sterile caps. Before being filled the bottles can be steamed for two minutes by running the crates inverted on a conveyer over steam jets. The bottles would then go through the bottling machine in a hot condition and would be practically sterile. The crates of hot bottled pasteurized milk can then be cooled by stacking in a refrigerator room and blowing cold air through the crates. In the cold season outside air can be used for cooling, and in the warm season refrigerated air can be circulated through the crates.

This process can be modified. The hot milk can be held in the bottles at 145° F. instead of in a tank, and the crates of hot pasteurized milk can be cooled by spraying with cold water instead of air.

From the results of experiments with air cooling on a small practical scale started in 1913, it is believed to be entirely practical to cool hot bottled milk by means of forced-air draft. The results of this work are being prepared for publication in the near future.

Since the process of bottling hot pasteurized milk has not as yet been worked out for practical use, it is impossible to state definitely all its advantages and disadvantages. However, from laboratory experiments alone certain advantages are plainly shown. From a sanitary standpoint one great advantage of the process of bottling hot pasteurized milk in hot bottles lies in the fact that bottle infection is eliminated. From a commercial standpoint there is also an advantage, because of the reduction of milk losses on the cooler caused by adherence of milk and by evaporation. Ordinary cardboard caps may be used in this system, since they do not have to be water-tight, which is obviously a point of great advantage so far as cost is concerned.

At the present stage of this work it is impossible to state how the cost of air cooling will compare with the ordinary methods in practice, but it is believed that there will be no more expense involved.

The length of time required for cooling is perhaps the greatest disadvantage of this process, and yet this would be of no consequence except in plants where the milk is delivered immediately after pasteurization. In the majority of milk plants the milk is pasteurized in the morning or afternoon, placed in refrigerators, and delivered early the next morning. Consequently in most plants it would make little difference whether the cooling process was performed quickly or slowly.

SUMMARY.

1. The process of pasteurization in the bottle, using a temperature of 145° F. for 30 minutes, causes satisfactory bacterial reductions.

2. Bottles should be steamed at least two minutes before being filled with milk in order to destroy heat-resistant types of organisms which might survive the pasteurizing temperature and thereby increase the bacterial count.

3. Care must be taken to record the temperature in the bottom of the bottle during the heating process. When milk at an initial temperature of 50° F. is heated in bottles without agitation in water at about 146° F. the temperature of the milk in the top of the bottle will reach 140° F. about nine minutes before that in the bottom. The temperature of the milk during the process of pasteurizing in the bottle should be recorded by placing a thermometer in a control bottle with the bulb of the thermometer about one-half inch from the bottom. The milk should be heated for 30 minutes at 145° F.

4. When bottles are heated and cooled under water care should be taken not to use bottles with chipped or otherwise imperfect tops, since the seal caps may allow leaks during the process of pasteurizing. It is advisable for the users of patented seal caps to assure themselves that the caps are water-tight, since leaking caps may cause dangerous infections, particularly if the cooling water is polluted.

5. The process of bottling pasteurized milk while hot in hot steamed bottles causes equally good bacterial reductions as does pasteurization in bottles. Even with the same length of exposure of 30 minutes and the same temperature of 145° F. the bacterial reductions are often much greater than those produced by pasteurization in bottles.

6. In the process of bottling hot, bottle infection is eliminated, even when several cubic centimeters of old, sour milk are added to bottles before filling. The two-minute steaming period to which the bottles are subjected before filling with hot milk is sufficient to destroy the contamination, at least so far as bacteriological methods can detect.

7. Laboratory experiments indicate that milk may be pasteurized, bottled hot, capped with ordinary cardboard caps, and cooled by a blast of cold air.

8. It is probable that if milk is cooled from 145° to 50° F. within five hours no more bacterial increase will take place during the slow cooling than would take place if the milk were cooled immediately to 50° F. Whether or not this will be true under commercial conditions can be determined only by future experiments.

9. So far as the laboratory experiments indicate, when milk is heated to 145° F. for 30 minutes, the bottling of the hot pasteurized milk followed by slow, gradual cooling has no more appreciable

effect on the cream line or flavor of milk than the ordinary process of pasteurization. This is true of cooling periods of less than five hours' duration.

10. Since milk contracts on cooling, a quart bottle filled with milk at 145° F. does not hold a full quart when the milk is cooled to 50° F. It is about 0.62 of an ounce short. Therefore slightly oversized bottles should be used.

11. The advantage of the process from the commercial standpoint are: (1) That bottle infection can be eliminated; (2) that milk losses are saved, owing to evaporation over the cooler; and (3) that ordinary cardboard caps can be used. The principal disadvantage is that the air-cooling process requires several hours. This, however, would be a disadvantage only in the few plants where milk is delivered directly after pasteurization.

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