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UNIVERSITY OF NEBRASKA COLLEGE OF AGRICULTURE
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Research Bulletin 157

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Previous to publication of this bulletin pasteurizer manufacturers were informed of its contents. Since that time the producers of pasteurizers A and B have endeavored to correct the operation of these pasteurizers to comply with the requirements of the milk code. New models have been submitted for investigation and the test results will be made available upon request.

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Portable Electric Home Milk Pasteurizers

A. E. Baragar [1] and P. A. Downs [2]

In an address before the American Society of Agricultural Engineers at Chicago, December 17, 1946, Schaenzer and Shiozawa *(1)* reported on two batch-type home pasteurizers and one in-the-bottle pasteurizer in terms of construction and method of operation. In a later paper, Trout and Bortree *(2)* concluded from bacteriological tests that these pasteurizers were satisfactory.

Just prior to the report of Trout and Bortree, staff members of the Dairy Department and Agricultural Extension Service of this college conferred with the senior author about making temperature-time tests on these appliances. A brief comment as to why this request was made may be of value in explaining the reason for this study. These appliances are labeled as pasteurizers, which implies that the products processed therein have been submitted to the process of pasteurization and thus the products can be called pasteurized. To dairymen the words 'pasteurization' and 'pasteurized' have the specific meaning defined in the U. S. Public Health Milk Code, item 16p, and it is this definition that was used as the basis for requesting temperature-time tests on home pasteurizers. This definition states that "the terms 'pasteurization,' 'pasteurized' and similar terms shall be taken to refer to the process of heating every particle of milk or milk product to at least 143° F. and holding at such temperature for at least 30 minutes, or to at least 160° F. and holding at such temperature for at least 15 seconds, in approved and properly operated equipment: Provided, that nothing contained in this definition shall be construed as disbarring any other process which has been demonstrated to be equally efficient and is approved by the state health authority." *(3)* It is stated further in item 16p that, in order to comply with these requirements, batch pasteurizers should be heated in such a way that the air space above the milk is 5° F. higher than the milk temperature *(4)*.

This requirement of higher temperature above the milk prompted the request for temperature-time tests for domestic pasteurizers. If necessary for large pasteurizers, it was believed such requirements might also apply to home pasteurizers. It was recognized that heretofore the milk code had been applied only to commercially pasteurized milk. However, since no known code containing a definition of pasteurization exists for home pasteurizers other than that in U. S. Public Health Bulletin 220, this was the standard chosen for checking the

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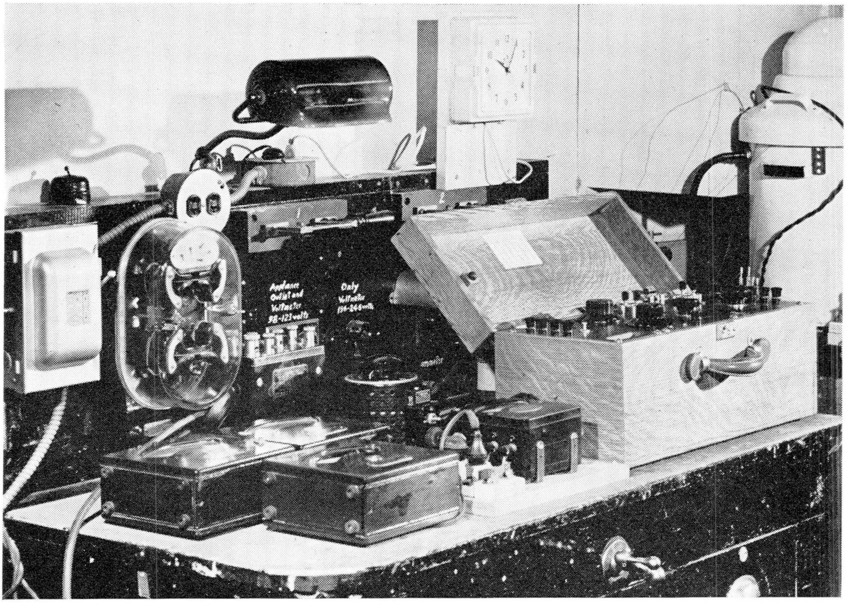

FIGURE 1.—Apparatus used for measuring energy and temperatures. It consists of voltmeters, ammeter, wattmeter, watt-hour meter, variable transformers and potentiometer.

pasteurizing ability of these appliances. The purpose of this investigation, therefore, was to determine whether the milk or cream contained in these pasteurizers and any milk which might be splashed on the sides of the container above the surface of the milk and on the lid would be maintained at a temperature of at least 143° F. for 30 minutes during the heating process, and if not, to determine how the pasteurizers could be modified to satisfy the requirements. As only physical measurements were necessary, the study was conducted by the Equipment Research Laboratory.

The pasteurizers studied, designated as A, B, and C, are shown in Figures 2, 4, and 6. Technical information regarding these appliances has been adequately reported by Schaenzer and Shiozawa *(1)* and Trout and Bortree *(2)* and will not be reported here. However, a brief explanation of the operation of the pasteurizers may be useful. The milk in pasteurizer A was heated directly by a 300-watt ring-type heater in contact with the bottom of the pail. Agitation of the milk was dependent upon the natural convection currents set up during heating. A thermostat in contact with the pail bottom regulated the heat. The milk in pasteurizers B and C was heated indirectly by a water bath. The water bath was heated by an immersion heater and the bath temperature was controlled by a thermostat that had its sensitive element in the water. During the operation of pasteurizer B, the water bath was heated to the pasteurizing temperature before the container of milk was placed in the bath. The milk in pasteurizer B was mechanically agitated. The milk in pasteurizer A had to be removed from the pasteurizer for cooling. Cooling was accomplished in pasteurizers B and C by replacing the hot water bath with flowing cold water. Pasteurizing time was regulated by automatic timers built into the appliances.

All temperatures were measured with copper-constantan thermocouples, properly shielded when necessary, connected to a Leeds and Northrup precision portable potentiometer. Cold junctions were maintained in a melting ice bath. In all tests, temperatures were measured only to within 0.5° F. The complete apparatus for testing is shown in Figure 1. For energy consumption measurements the voltage was maintained at 115 volts by using a manually controlled voltage regulator. The test board with accompanying electrical instruments used in this study has been described in a previous bulletin *(5)*.

PASTEURIZER A

(Direct Heating, Batch Type)

A series of tests was conducted on this pasteurizer "as received from the manufacturer" to determine temperatures in the milk and in the air space above the milk. Temperatures were taken at four locations in the fluid: (1) directly above the thermostat, (2) touching the side of the pail 3 inches below rim, (3) at the center of the pail 3 inches below the rim, and (4) at the surface of the liquid. One temperature was taken in the air space above the liquid. Preliminary tests showed that distilled water as well as milk could be used as a test fluid, so water was used in most of the development tests. Typical results for this pasteurizer "as received" are shown in Table 1. The thermostat disconnected the heater the first time at 51 minutes after starting. It was concluded from these data that sufficient convection currents were active to produce uniform heating, so in further tests the couple at the center of the pail was used to indicate liquid temperatures.

The pasteurizing temperatures shown in Table 1 were considered to be too high because the milk had a slightly scalded flavor, so the thermostat was readjusted for a lower cut-off temperature. Results are shown in Table 2. It will be noted that the air space temperature now reached 143° F. for approximately 12 minutes only. Here a question arose as to whether the air space temperature or some other temperature should be the controlling temperature for satisfying pasteurizing requirements. To answer the question a series of tests was made

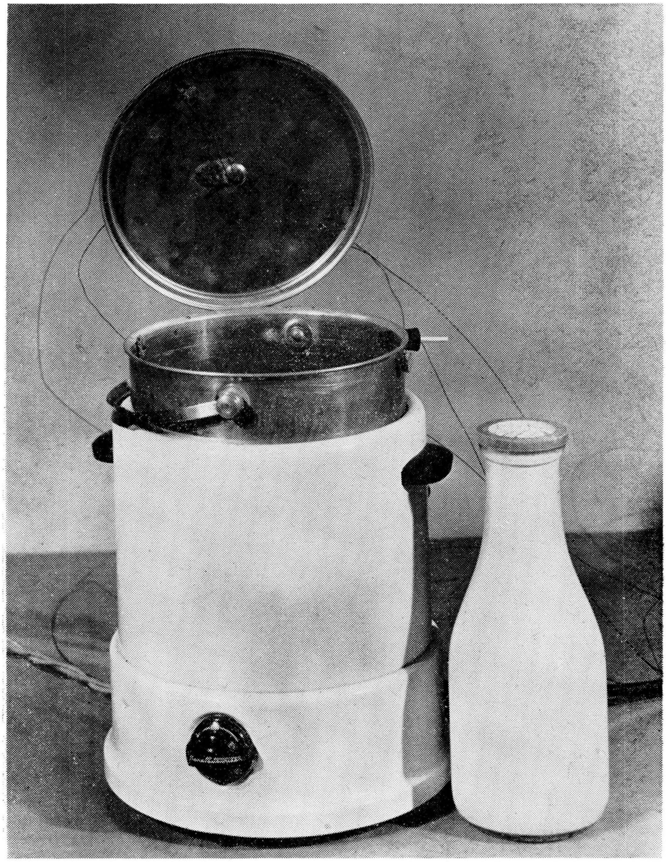

FIGURE 2.—Pasteurizer A, a direct heating, batch-type pasteurizer. There are two thermocouples on the lid and one on the side of the pail at the left. Size of the appliance may be compared with that of the quart bottle of milk.

using both a bare couple and a velocity thermocouple to record air space temperatures, and couples fastened to the cover and pail as shown in Figure 2 to measure container temperatures. From the results of these tests it was concluded that the critical temperatures, and hence the controlling temperatures were those on the lid. A heavy condensation on the lid during pasteurization also indicated that these lid temperatures were too low. It was evident that if this pasteurizer was to comply with Public Health code requirements a lid heater must be added. An additional reason for using a lid heater was to prevent the formation of a pellicle. According to Hammer *(6),*

TABLE 1.—*Pasteurizer A "as received." Heater regulated at 115 volts. Raw milk used as test fluid with temperatures as designated.*

Time	Temperatures: Center of pail	Touching side of pail, 3" below rim	Directly over thermostat	Surface of liquid on 1¾" radius	Space above liquid 1" from center	Time	Temperatures: Center of pail	Touching side of pail, 3" below rim	Directly over thermostat	Surface of liquid on 1¾" radius	Space above liquid 1" from center
Min.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Min.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
0	60	60	60	60.5	71	48	142	143	141	143	136
3	64	64	63	64.5	68.5	51	145.5	146	145.5	146	141
6	69.5	70	68.5	71	71	54	147	148	147	148	143
9	74	74	73	74	74	57	148.5	150	150	149.5	144.5
12	81	80.5	79	80.5	78	60	150	150	150	150	145.5
15	86.5	86.5	85	86.5	83	63	150	151	150	151	146
18	91	90.5	89.5	90	86.5	66	151	151.5	151	151.5	147
21	96	96	94	96	91	69	152	152	152	152	147.5
24	101	102	100.5	102	96.5	72	152	153	152	152	148.5
27	107	108	106	108	101	75	153	153	153	153	149
30	112.5	112	111	112	106.5	78	153	153	153	153	149
33	117	117	116	117	112	81	153	153.5	153	153	149.5
36	122	122.5	120.5	122.5	116	84	153	153.5	153.5	153.5	149.5
39	127	127	126	127	121	87	153	153.5	154	153	149.5
42	131	132.5	130.5	132	126	90	153.5	154	153.5	153.5	150
45	136	137	135.5	137	131	......	......	......	......	......	......

"The influence of pellicle formation on survival of organisms during pasteurization is of importance under practical conditions and pellicle development should be prevented by agitating the material or by heating and holding under conditions which prevent evaporation."

For experimental purposes, a 500-watt chromolox ring-type stove unit similar to the one shown in Figure 5 was fastened to the lid and covered with an aluminum cap. The modified pasteurizer is shown in Figure 3. Electrically the heater was connected to a Powerstat through

TABLE 2.—*Temperatures for pasteurizer A after thermostat was reset. Heater regulated at 115 volts. Raw whole milk used as test fluid.*

Time	Temperatures: Center of pail	Space above liquid	Time	Temperatures: Center of pail	Space above liquid	Time	Temperatures: Center of pail	Space above liquid
Min.	°*F.*	°*F.*	*Min.*	°*F.*	°*F.*	*Min.*	°*F.*	°*F.*
0	72.5	76.5	27	119	112	54	147	141
3	75.5	76.5	30	123.5	116	57	147.5	141
6	80.5	79	33	129	122	60	147.5	141.5
9	86.5	83	36	134	126	63	148.5	142.5
12	92	88	39*	139	131	66	149	143
15	97.5	92	42	142	135	69	149	143
18	103	98	45	143	137.5	72	149	143
21	108	102.5	48	144.5	139	75	149	143
24	113	106.5	51	146	140	78	149	143

* Thermostat operated first time.

FIGURE 3.—Pasteurizer A equipped with a lid heater, the terminals of which are shown at the left.

a wattmeter, voltmeter and ammeter. Lid heater energy input was regulated to produce a heat sufficient to insure pail and lid temperatures of at least 143° F. for 30 minutes for fluid quantities of from 2 to 4 quarts. Results are shown in Table 3. It will be noticed that the initial lid temperature for the heater-equipped lid with 4 quarts of water was considerably higher than room temperature. This occurred because the lid was not allowed to cool to room temperature following a previous test. For convenience in comparing data the time when the thermostat first operated was chosen as zero, hence the period preceding zero time denotes the preheating period and that one following zero denotes the pasteurizing interval.

Except for the cream test, there were at least 30 minutes during pasteurization that the liquid, pail, and lid temperatures were 143° F. or above when the lid heater was used. Apparently convection currents did not circulate as readily in the cream as in the milk and water and, consequently, the temperature above the thermostat must have been slightly higher than that indicated by the couple at the center of the pail. To provide sufficient pasteurizing time for cream, ten minutes should be added to the recommended time. This was done during the tests listed in Table 3, giving final temperatures of 148° F. in the liquid, 146° F. on the pail and 156° F. on the lid.

Without the lid heater a heavy condensation formed on the lid, but with the lid heater the cover was dry at the end of the pasteurizing period. Pellicle formation was also retarded by using the lid heater. When 2 quarts of liquid were used and the pasteurizer was equipped with the lid heater, a band of condensate was found around the top of the pail just the width of the portion of the pail exposed to the air. Below this band the pail was dry. No such condition was observed for 4 quarts of liquid. Hence, to prevent condensation on all portions of the pasteurizer it is suggested that the outer casing be raised as near the top of the pail as possible.

TABLE 3.—*Temperatures at various locations on pasteurizer A with and without lid heater. Time when thermostat first opened taken as zero time.*

Time	Temperatures in liquid, center of pail						Temperatures on lid			
							¾″ from center		3″ from center	
	4 qt. water, no lid heater	4 qt. water, 16-watt lid heater	4 qt. milk, 16-watt lid heater	4 qt. 40% cream, 16-watt lid heater	2 qt. water, no lid heater	2 qt. water, 16-watt lid heater	4 qt. water, no lid heater	2 qt. water, no lid heater	4 qt. water, no lid heater	2 qt. water, no lid heater
Min.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
48	......	......	52.5	......	......	......	......	......	......	......
45	......	......	55	45.5	......	......	......	......	......	......
42	70.5	......	61	47.5	......	......	70.5	......	70.5	......
39	72.5	77	66	52.5	......	......	71.5	......	71.5	......
36	77.5	80	72	56.5	......	......	74	......	76	......
33	82	85	78	61.5	......	......	78	......	80	......
30	88	90.5	83	67.5	......	......	83	......	85	......
27	92.5	96	89	73	......	......	87	......	89	......
24	98	101	95	80	......	......	92	......	95	......
21	103.5	106	101	86.5	78	75	96.5	77	99	77
18	108	112	107.5	92.5	83	81	101.5	78	103.5	79
15	113.5	116.5	112	100.5	95	91	105.5	85.5	109	87.5
12	119	122	118	107	105	101	111	95	114	96.5
9	123.5	127.5	123	114	115.5	112	114.5	104	119.5	106
6	128.5	132	129	121	127	122.5	121	115	123	117.5
3	134	138	133.5	127.5	139	132	125	123	128	123
0	137	141	138	132	144	142.5	128.5	132	131.5	133.5
3	139	142	141	135	145	146	131.5	135	134.5	135
6	141.5	143	142.5	138	146	146	132.5	136	135.5	136
9	143.5	145	143.5	140	147	147	134.5	137	137	136.5
12	143.5	145.5	144	141	148	147.5	134.5	138	137	138
15	144.5	146	145	142	147	148	137	137.5	138.5	137.5
18	145	146	146	143.5	148	148	138	137.5	139	138
21	146	147	146	144	148	148	138.5	138	139	138
24	146	147	146	145	147.5	149	138.5	138	139	138
27	146.5	147	146.5	145.5	148	149	139	137.5	140.5	137.5
30	146.5	147.5	146.5	146	148	149	139.5	138	140.5	138
33	146.5	148	146.5	146	148	149	139.5	138	140.5	138
36	146.5	148	146.5	147	148	149	139.5	138	141	138
39	146.5	......	146.5	147	.....	......	139.5	......	141	......
42	146.5	......	......	......	......	......	139.5	......	141	......

TABLE 3.—(*Continued.*)

Time	Temperatures on lid, 3″ from center				Temperatures on side of pail, ⅜″ from top					
	4 qt. water, 16-watt lid heater	4 qt. milk, 16-watt lid heater	4qt. 40% cream, 16-watt lid heater	2 qt. water, 16-watt lid heater	4 qt. water, no lid heater	4 qt. water, 16-watt lid heater	4 qt. milk, 16-watt lid heater	4 qt. 40% cream, 16-watt lid heater	2 qt. water, no lid heater	2 qt. water, 16-watt lid heater
Min.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
48	......	64	......	......	......	......	56	......	......	......
45	......	67.5	67	......	......	......	59	54	......	......
42	......	76.5	69	......	70.5	......	65	58	......	......
39	89	85	78.5	......	73	78	70.5	64	......	......
36	89.5	92	85.5	......	78	81	76	67.5	......	......
33	98	97	92	......	82	86	81	73.5	......	......
30	105	103	97.5	......	88.5	91	85.5	77.5	......	......
27	111	108.5	103	......	92.5	96.5	92	83	......	......
24	117	113	107.5	......	98	101	97.5	88.5	......	......
21	122	118	112	75	103	107	102.5	93.5	77	75
18	126	122	117	80.5	108	112	108	100	80	79
15	130.5	126.5	120.5	91.5	113	116.5	112	105.5	89	89
12	134	130	126	103	118.5	122	118	111.5	99.5	100
9	139	133.5	129	114	122.5	127.5	123	118	108	109
6	142.5	138	134	122	127	131.5	128.5	124	116.5	118
3	147	141	139	130	132	136.5	133	129	128	127.5
0	149.5	145	143	138	135	140	137	133	135	136.5
3	151	147	146	143	138	141	139	135.5	137.5	142
6	153	148	148	147	139.5	142	141.5	138	138	142.5
9	154	150	148	150	141	143	142	139	138.5	144
12	155	150.5	150	151	141.5	144	143	140.5	140.5	144
15	155	152	151.5	152	142	145	143.5	141	140	145
18	156	152.5	152	154	142.5	145	144	141.5	140	145
21	156	153	153	154	143	145.5	144	143	140.5	144.5
24	157	153	153.5	155	143.5	145.5	144.5	144	140.5	146
27	157	153.5	153.5	155	143.5	146	145	143.5	140	146
30	157	154	153.5	156	144	146	145	143.5	140.5	146
33	158	154.5	154	156	144	147	145	144	140.5	146
36	158	154.5	154.5	156	144	147	145	145	140.5	146
39	......	154.5	155.5	......	144.5	......	145	145	......	......
42	......	......	.....	......	144.5	......	......	......	......	......

PASTEURIZER B

(Water-Bath Heating, Batch Type)

Since the milk in pasteurizer B was agitated during pasteurization, a single couple immersed in the mid-plane of the container was used to measure milk temperatures. During the initial experiments air temperatures above the liquid in the throat of the pail were measured, but subsequent measurements showed that the controlling temperatures were those on the underside of the lid. Hence for the remaining tests temperatures were measured in the liquid, on the side of the pail either 1 inch or ⅝ inch from the rim, on the lid *either 2 inches or 4* inches from the center, and in the water bath.

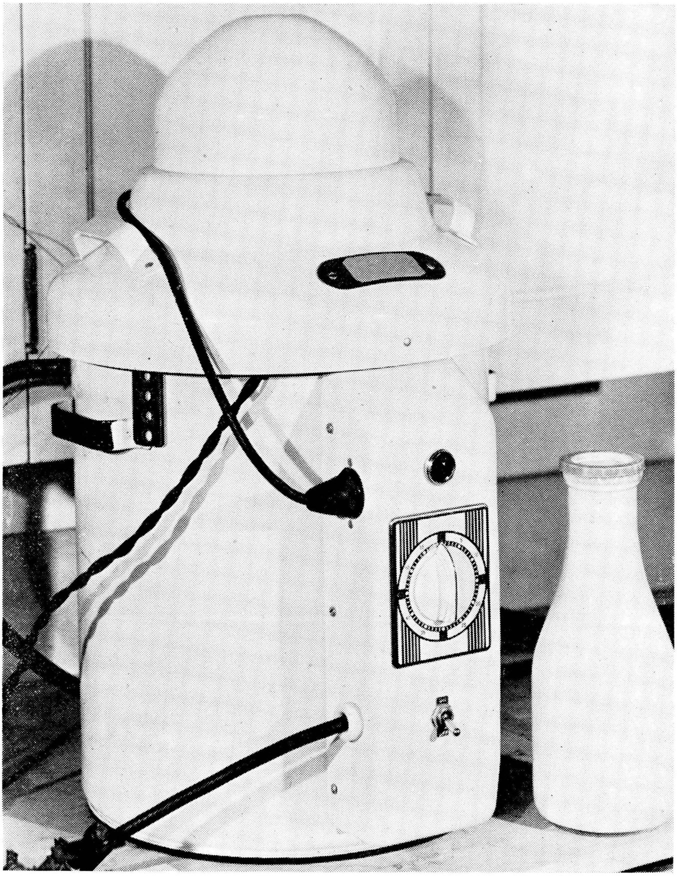

FIGURE 4.—Pasteurizer B, a water-bath heating agitator batch-type pasteurizer. The braided appliance cord leads to the lid heater. Size of the pasteurizer may be compared with that of the quart bottle of milk.

The initial experiments revealed that milk temperatures were above 143° F. for sufficient time to comply with Public Health code requirements for pasteurization, but when lid temperatures were measured at 2 inches from the center they were found to be less than 143° F. for the entire pasteurizing period. This was too low for milk splashed on the upper part of the pail and for the condensate on the lid. Results are shown in Table 4. Only data for the pasteurizing period are listed. It will be noticed that when only 7 quarts of liquid were being heated the temperature at the top of the pail decreased to below 140° F. The time for preheating the water bath depended upon whether the water for the bath was initially cold or warm. The time required to preheat cold tap water at approximately 63° F. through a temperature difference of 94° F. was about 30 minutes when the heating element was operated at 115 volts. For warm water initially at 114° F. and heated through 45 °F. temperature difference at 115 volts, the time required was approximately 16 minutes. This preheat period had no effect on the pasteurizing period because the pail of milk was not in the water bath during preheating. For the pasteurizer "as received" the thermostat disconnected the heating element at a bath temperature of 157–159° F. Immediately after the milk pail was immersed in the water, the bath temperature dropped 16° to 18° F., causing another period of heating.

To raise the temperatures of the upper pail and lid, an electric heater was added to the pasteurizer as shown in Figure 5. The input of this heater was controlled as described for the lid heater on pasteurizer A. With the lid heater in this position, satisfactory temperatures were attained for liquid, pail, and the inner portion of the lid; but the temperature on the outer portion of the lid was too low. This was indicated by a heavy condensation of water, drops of which could fall into the milk. Data for the lid heater as shown in Figure 5 are

TABLE 4.—*Temperatures at various locations on pasteurizer B "as received." Two gallons of water used as test fluid. Data are listed for pasteurizing period only.*

Time	Temperatures					
	Liquid, mid-plane of pail	Side of pail, 3½" below rim	Side of pail, 1" from rim	Air space, ½" above liquid	Lid, 2" from center	Water bath
Min.	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*
0	78	85	82	76.5	83.5	131
3	93.5	95.5	91.5	89	87	132.5
6	103	105	98.5	95	90.5	134
9	109	110.5	105	100	94.5	136.5
12	115	116	111.5	105.5	99.5	139.5
15	122	122.5	118.5	111.5	105	143
18	128.5	125.5	123.5	115.5	111	149
21	132.5	134	130	118.5	116	151.5
24	136	137	133.5	124	119.5	147
27	139	140	136.5	125.5	123	150
30	141	142	139	129	125	149
33	142.5	143	140	128.5	127.5	146.5
36	145	144.5	142	131	128.5	153
39	146	146	143	133	132	149
42	145.5	146.5	143.5	133	133	147.5
45	146.5	146	144	136	133	151
48	147	148.5	145	138.5	135	151.5
51	148	149	145.5	139.5	137	149.5
54	1 qt. of water removed from pail					
57	147	146	140	137.5	135.5	154.5
60	148.5	149	141	140	138.5	151
63	149	148	141	140.5	139.5	149.5
66	148	148	140	142.5	140.5	148

FIGURE 5.—Pasteurizer B equipped with a lid heater. The agitator is also shown.

listed in Table 5. This table shows that the pail temperatures were higher than necessary for compliance with Public Health code requirements.

As shown by the data in Table 5 better lid temperatures, spread over a greater area, were obtained by changing the heater as shown in Figure 5 so that it touched the lid. With the lid heater in this position the thermocouple used to measure lid temperatures was moved to the region over the water bath and consequently registered lower temperatures than those directly over the milk area. A comparison of lid temperatures obtained when water was used as a test fluid and no lid heater was used shows that during the last 30 minutes of the pasteurizing period the temperature averaged about 7° higher

TABLE 5.—*Temperatures at various locations on pasteurizer B with and without lid heater. Water, milk and 40 per cent cream used as test fluid. Data are listed for pasteurizing period only.*

Time	Temperatures in liquid				Temperatures on pail 5/8″ from rim				Temperatures on lid				
									Couple 2″ from center of lid		Couple 4″ from center of lid		
	8 qt. water, no lid heater	8 qt. water, 40-watt lid heater as in Fig. 5	8 qt. milk, 40-watt lid heater adjacent to lid	8 qt. 40% cream, 40-watt lid heater adjacent to lid	8 qt. water no lid heater	8 qt. water, 40-watt lid heater as in Fig. 5	8 qt. milk, 40-watt lid heater adjacent to lid	8 qt. 40% cream, 40-watt lid heater adjacent to lid	8 qt. water, no lid heater	8 qt. water, 40-watt lid heater as in Fig. 5	8 qt. water, no lid heater	8 qt. milk, 40-watt lid heater adjacent to lid	8 qt. 40% cream, 40-watt lid heater adjacent to lid
Min.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
0	65.5	73	70.5	55	69	73	72	68.5	74.5	121.5	72	118	138.5
3	93	98	93.5	79.5	99.5	116	105.5	122.5	79	116.5	89	121.5	122.5
6	105	111	107.5	96	103.5	118	111.5	123	83.5	118	94.5	123	121.5
9	114	119	115.5	105.5	110	124	115.5	123.5	88	119	95.5	124	122.5
12	121.5	126	125	115	115	131	126	124	92.5	123.5	99.5	127	124
15	127	131	129	122.5	121	135.5	132	128	98	126.5	102.5	129	126
18	133	134.5	136	129.5	127.5	137.5	139.5	132.5	104.5	129	108	132	129.5
21	137	139	140.5	135	131	139	142.5	137.5	108.5	132.5	109	134	132
24	141	144	142.5	139	135	148	145	142	113.5	138.5	114	135.5	133.5
27	143	145.5	145	141	139	150	147.5	143.5	118	141.5	114.5	137.5	135
30	145	146.5	146	143.5	140	151.5	149.5	145.5	121.5	143.5	115	139	137.5
33	146.5	149	146.5	145.5	142	153	150.5	147.5	123.5	146	115.5	141	138.5
36	146.5	149	148.5	146.5	142.5	154	151.5	148.5	126	149	118	142	139.5
39	146.5	149	149.5	146.5	142	154	153.5	149.5	127	150	120	143.5	141.5
42	148.5	150	149	148	143	155	153.5	150	128.5	151.5	120	144.5	142.5
45	149	150.5	149.5	149	143.5	156.5	153	150.5	129	153.5	121	145	143.5
48	149	150.5	149.5	149	144	156.5	153.5	151.5	129	156.5	122.5	145.5	144
51	149	149.5	150.5	149	144	156.5	154.5	151.5	130	156.5	123.5	146.5	144
54	149.5	150	151	149.5	145.5	156	154.5	151.5	131	158	124	147	145
57	150	151	150	150	146	157	154.5	151.5	132	159.5	125	147.5	146
60	149.5	151.5	150	150	146	158	154	152.5	132.5	160.5	125	148	146

at 2 inches from the center of the lid than at 4 inches from the center. If 7° were added to the lid temperatures for milk and cream (which were recorded 4 inches from the center of the lid while a lid heater was being used), it is evident that those temperatures would be above 143° F. throughout the last 30 minutes of the pasteurizing period and thus would satisfy Public Health code requirements.

During the lid heater tests various procedures were used in operating the lid heater. Starting the lid heater at the beginning of the pasteurizing cycle proved unsatisfactory because lid temperatures were on the borderline for compliance. When the lid was placed on the tank as in Figure 4 and heated during the preheat period, lid temperatures during pasteurizing were satisfactory but at the beginning of the pasteurizing period there was a heavy condensation on the lid and heater and at the end of pasteurization some condensate remained at the outer portion of the lid over the water bath. The best method of operation was to heat the lid heater in air during the preheat period. When this procedure was used the lid was still dry 21 minutes after the pasteurizing period began and was entirely dry at the conclusion of the test. It should be noted that when no lid heater was used there was a very heavy condensate on the lid at the end of the pasteurizing period.

The milk was cooled by running cold tap water into the water bath. This operation was controlled manually. The cooling time varied with the temperature of the inlet water, the rate at which it flowed and the quantity of milk being cooled. The greatest drop in temperature occurred in the first 5 to 7 minutes, during which time the milk temperature was reduced to about 86° F. for 7 quarts of milk and to about 77° F. for 4 quarts of milk. In 18 to 20 minutes the milk was brought to 56–60° F., which was near the temperature of the water bath.

PASTEURIZER C

(In-the-Bottle Type)

With this pasteurizer the milk was contained in capped quart bottles and the bottles were preheated with the water bath. Two thermocouples were used in each bottle, one at the center of the bottle and the other fastened to the face of the cap next to the milk with the hot junction exposed to the air above the milk. Both couples were secured to the cap with sealing wax. The milk level was adjusted for cold milk so that it was about ¾ inch from the cap and thus when it was expanded it did not touch the couple next to the cap. The thermocouple for the control bottle was wound around the thermostat sheath. Water bath temperature was determined at the center of the tank.

The results for this pasteurizer are listed in Table 6. The locations of the bottles as designated in Table 6 are shown in Figure 7.

The time necessary to bring the milk to the pasteurizing temperature varied from 51 to 60 minutes depending upon the initial temperature of the water bath. Initial milk temperatures were 50° F. and initial control bottle temperatures were 69 and 74° F. for the tests listed in Table 6. By pasteurizing time, however, the milk and control bottle temperatures were alike.

At the conclusion of the tests foam was found in several of the bottles including those having couples, but this foam was also heated by the water bath. It is evident from the data in Table 6 that adequate pasteurizing temperatures were maintained for a sufficient time for this pasteurizer to satisfy Public Health code requirements.

Cooling the milk was automatically accomplished at the end of the pasteurizing period by the action of a solenoid valve. As would be expected the cooling was slightly greater for the bottles on the inlet

TABLE 6.—*Temperatures in milk, under cap and in water bath for pasteurizer C. Data are listed for pasteurizing period only.*

Time	Temperatures										
	Bottle 1		Bottle 2		Bottle 4		Bottle 6		Control		Water bath
	Center of bottle	Under cap	Center of bottle	Under cap	Center of bottle	Under cap	Center of bottle	Under cap	With bottles 1 & 6	With bottles 2 & 4	
Min.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
0	141	144.5	143	143	143	143	142.5	144.5	142.5	143	147.5
3	143	145.5	144	144	143	144	144	145.5	143	144	146
6	143	146	145	144.5	145	144.5	144	146	144	144.5	147
9	144.5	146	145.5	145.5	145.5	145.5	145	146	144	145	146
12	144.5	146	146	145.5	145.5	145.5	146	146	144	145.5	147
15	146	146	147	146	147	146	146	146	145	146	146
18	146	146	147	146	146	146	146	146	145	146	147
21	146	147	147	146	146	146	147	147	145	146	147
24	146	147	147	146	147	146	147	147	145	146	148.5
27	147	147	148	146	148	146	147	147	146	146	147
30	147	147	147	145.5	147	145.5	147	147	146	145.5	148.5
33	147	147	147.5	147	147.5	147	147	147	146	147	147.5

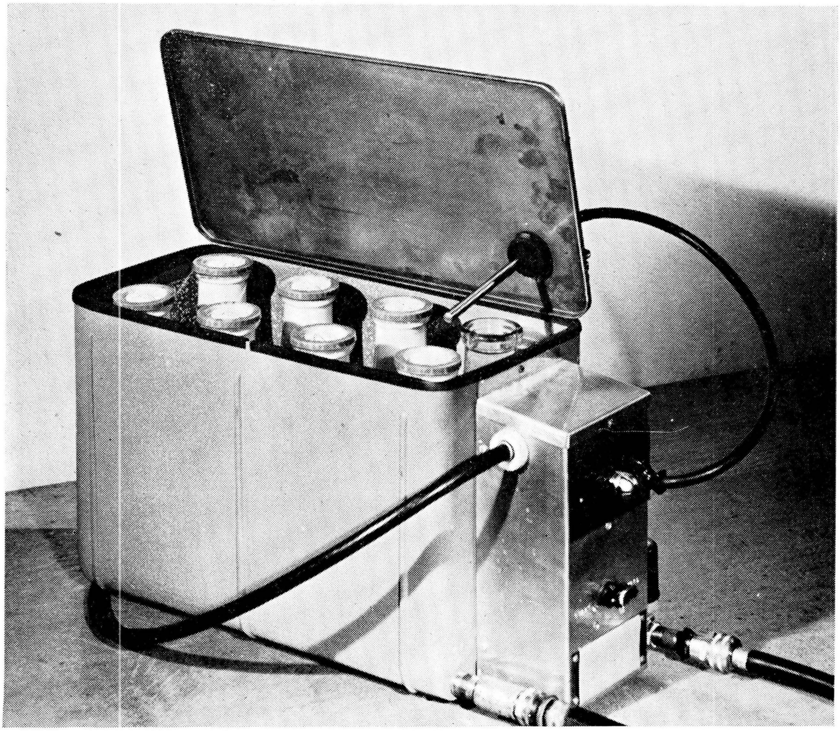

FIGURE 6.—Pasteurizer C, an in-the-bottle pasteurizer. The tank is filled with quart bottles of milk. The rod projecting through the cover is the thermostat element.

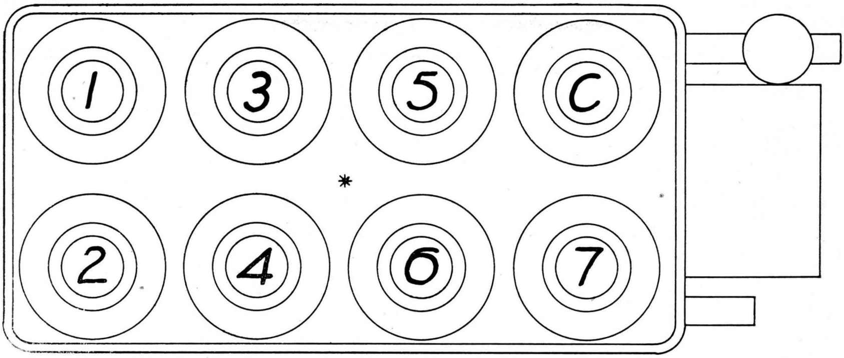

FIGURE 7.—Location and designation of bottles in pasteurizer C. Asterisk denotes location of water bath thermocouple.

side of the tank; however, actual temperature differences amounted to only 6° at the most. In 20 minutes the milk temperature was reduced to 72–78° F., under-the-cap temperature to 82–92° F., and water bath to 60° F. After 36 minutes the milk temperature was 62° F., under-the-cap temperature was 68° F., and water bath 60° F.

It should be noted that with pasteurizer C there should be no recontamination of milk at the end of pasteurization since the milk is bottled and sealed.

ENERGY CONSUMPTION

Although the manufacturer's watt rating of the heater for each pasteurizer would be known to the consumer it would be difficult to compute the energy consumption owing to the necessity of obtaining accurate "off" and "on" times for the thermostat action. To secure energy consumption data these pasteurizers were operated at a controlled voltage of 115 volts for the entire cycle with the energy being measured by a laboratory watt-hour meter. The watt ratings of the heaters were calculated from the data gathered and within experimental error the computed values agreed with manufacturers' ratings: namely 300 watts for pasteurizer A, 1250 watts for pasteurizer B and 1500 watts for pasteurizer C.

Average values of total energy that may be used for calculating operating cost are listed in Table 7. Also listed are total processing time and preheat time, the latter being taken as the time from the start of the test until the thermostat first operated to disconnect the heating element. As shown in Table 7, the addition of lid heaters to pasteurizers A and B would not add materially to the operating cost. For pasteurizer A the total energy listed in Table 7 would be maximum because when using the lid heater the thermostat "off-on"

TABLE 7.—*Heating time and energy consumption for pasteurizers A, B, and C.*

Pasteurizer	Quantity of liquid	Preheat time	Total time	Off / On	Volts	Amperes	Energy: Without lid heater	Energy: Lid heater *	Energy: Total with lid heater
	Quarts	*Min.*	*Min.*				*Watt-hr.*	*Watt-hr.*	*Watt-hr.*
A	4	43.85	83.6	3.69	115	2.63	275.6	22.3	297.9
A	4	49.75	90.0	2.84	105	2.42	267.5	24.0	291.5
B	7	29.00	97.0	1.31	115	10.84	1149.5	64.6	1214.1
B	7	18.00	78.0	1.01	110	10.44	860.0	52.0	912.0
B	4	14.50	76.5	1.40	110	10.44	738.0	51.0	789.0
C	8	52.50	136.5	4.63	115	13.20	1667.5	none	....

* Lid heater input, pasteurizer A, 16 watts.
Lid heater input, pateurizer B, 40 watts.

ratio increased to about 5.0, which means that the milk heater was using less energy during pasteurization than indicated for "no lid heater." Similar data were not secured for pasteurizer B.

It will be noted from Table 7 that pasteurizers A and B were operated also at 105 and 110 volts, respectively. In both cases a lower voltage showed no appreciable difference in pasteurizing temperatures even though the watt-rating of the heating unit for pasteurizer A was reduced by 16 per cent. At the lower voltage the "off-on" ratio simply became less, indicating that the heating element should be "on" for longer times when the voltage is lower than 115 volts. Thus the problem of line voltage drop would be of no importance until the voltage dropped to a value where the thermostat never would disconnect the heating element.

CONCLUSIONS

The temperature-time tests definitely show that pasteurizers A and B as pasteurizing equipment do not meet the requirements for pasteurization in so far as milk and condensation on the lids would not be at 143° F. or more for at least 30 minutes. If it is desired to have the equipment meet the accepted requirements governing pasteurized milk and cream, this can be easily accomplished by using a lid heater of suitable heat input.

A few bacterial counts were made as spot checks on several samples of pasteurized milk but the results were not retained for publication. For this study bacterial counts were not considered necessary because, as stated in item 16p of U. S. Public Health Bulletin 220, "It has been demonstrated that time-temperature combinations of 143° F. for 30 minutes and 160° F. for 15 seconds will, if actually applied to every particle of milk, devitalize all milk-borne pathogens."

With pasteurizer C "as received" and pasteurizers A and B as modified, every particle of milk will be at 143° F. for 30 minutes and thus these pasteurizers will fulfill the above conditions.

SUMMARY

Two batch-type and one in-the-bottle type home milk pasteurizers were investigated to determine whether they comply with U. S. Public Health code temperature and time requirements for pasteurizers.

"As received from the manufacturer" only the in-the-bottle pasteurizer satisfied the requirements. After the two batch-type pasteurizers were modified to include a lid heater for heating the lid adjacent to the milk and the upper exposed portion of pail these pasteurizers satisfied the requirements.

Energy requirements were determined for computing operating costs. At the same time low voltage was observed to have no effect upon pasteurizing temperatures and time during the pasteurizing period. The addition of lid heaters to the batch-type pasteurizers would not materially affect operation cost.

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