



DESIGN, OPERATION AND EFFICIENCY
OF A PRODUCER SIZE ELECTRO-PURE
HIGH-TEMPERATURE SHORT-TIME
PASTEURIZER

Thesis for the Degree of M. S.
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Theodore Joseph Mucha
1948



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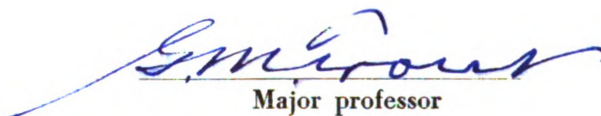
Design, Operation and Efficiency of
a Producer Size Electro-pure Pasteurizer.

presented by

Mr. Theodore J. Mucha

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of the requirements for

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Major professor

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DESIGN, OPERATION AND EFFICIENCY OF A PRODUCER SIZE ELECTRO-

PURE HIGH-TEMPERATURE SHORT-TIME PASTEURIZER

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PURE HIGH-TEMPERATURE SHORT-TIME PASTEURIZER

by

Theodore Joseph Mucha

A THESIS

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Design, Operation and Efficiency of a Producer Size Electro- pure Pasteurizer

INTRODUCTION

Within the past few years, the strides made toward acceptance of high-temperature, short-time pasteurization have been greater than at any other time in its history. Much of the responsibility for the delay in development and acceptance of this system of pasteurization, can be attributed to the fact that accurate, sensitive, controlling devices were not perfected until recently. Obviously, accurate controls are necessary if the temperature of the milk products is to be maintained within the desired limits; that is, sufficiently high to destroy all pathogens in the products and yet not so high as to alter appreciably the original characteristics of the milk.

Michigan now has a law which makes high-temperature, short-time pasteurization legal. This law not only states the time and temperature required but also stipulates that "acceptable equipment must be used."

Likely many types of short-time pasteurizers will find their way to the dairy market. Some of these may not be acceptable under Michigan's new law.

All of the pasteurizers on the market today are designed for large dairy plants since they are made to handle from a minimum of 1300 pounds per hour to 20,000 pounds per hour. However, these pasteurizers may be either steam or electrically heated.

The electrically heated and operated units may be suitable for the small producer who desires to process milk and milk products on his own dairy farm, but the capacities of the present ones are too great.

A small producer size, electric pasteurizer has been designed and built by the Electro-pure Division of the Ex-Cell-O Corporation, Detroit, Michigan. This pasteurizer was originally designed to handle 500 pounds of milk per hour.

Due to the fact that an immediate need exists for a small high-temperature, short-time pasteurizer on the dairy farm since steam generally is not economically available, it seemed desirable that a detailed study be made of the producer size Electro-pure pasteurizer recently designed.

Scope of Investigation

The investigation, involving large sample, long-time runs, extending over a period of 15 months, covered the following general areas: (a) the design of the machine; (b) various temperature regulating devices; (c) methods of operation; (d) comparison of the pasteurization efficiency of the Electro-pure pasteurizer with that of a commercial steam operated high-temperature machine; (e) comparison of the pasteurization efficiency of the same Electro-pure pasteurizer with that of a commercial holder installation and, (f) bacteriological, physical and chemical properties of the milk throughout the entire study.

REVIEW OF LITERATURE

1. Early development of electric pasteurizers

The chronological development of the high-temperature short-time pasteurizer goes back as far as 1896 at which time the first high-temperature short-time pasteurizer was invented by Thiel, (anonymous 1938). Weigmann (1893) described Thiel's apparatus as follows: "It consisted of (a) an outer cylinder of tinned steel with a wooden jacket, (b) an inner corrugated cylinder closed at the bottom and made of tinned copper, and (c) a hat shaped hood covering both cylinders. Between the outer and inner cylinder was a space for steam heating. A spiral agitator was attached at the top." This pasteurizer did not remain on the market for any length of time.

Jensen, in 1901, (Anonymous 1938) developed a type of "flash" pasteurizer which lacked sufficient controls and, therefore, was not considered a success.

Beattie (1916) worked with a pasteurizer between the years 1913 and 1916, which employed electricity as the source of heat. The nature of the electricity was a high frequency alternating current ranging between 2500 and 6000 volts. The apparatus consisted of a horizontal "lethal" tube of glass through which milk flowed continuously, passing through copper electrodes, one at the middle and one at each end.

Anderson and Finkelstein (1919), studied high-temperature short-time electrical pasteurization using a machine which consisted of copper electrodes mounted inside porcelain cups. As the milk passed through a series of these cups the electrical circuit was completed by the milk, the resistance of which was such that heat was generated. The temperature of

the pasteurization process was 155° F. which was reached by flowing milk preheated with steam to 104° F. over electrodes in the cups. Again, a high voltage of 2300 was employed. The amperage used on this copper electrode heater was 14 and the frequency 25.

The high voltages were not only dangerous but also expensive. However, Anderson and Finkelstein (1919) concluded from their experimental work that "Modifications in construction must be made before the machine can be considered a commercial success." They also pointed out that an improved temperature control was needed to assure uniform heating and to divert milk which had not been raised to the proper temperature.

Harding (1921) reported that these porcelain cups, Electro-pure pasteurizers were in commercial operation in a milk plant located in Stamford, Connecticut and also in Columbus, Ohio as early as 1914. As a result of the findings of Anderson and Finkelstein (1919), this form of pasteurizer did not remain on the market for any length of time.

Yale (1933) reported that the next form of Electro-pure pasteurizer was one in which the milk was heated by a 60-cycle alternating current of 230 volts instead of by the higher voltage previously used. This pasteurizer, using milk preheated by steam to 130° to 145° F., further heated the milk to 160° F. This temperature caused a valve to open, thus permitting the milk to leave the machine. The pasteurizer was studied by Robinson (1923) and Harding (1930) of which reports will be made later.

Yale (1933) stated that the Pennsylvania Department of Health investigated the Electro-pure process of pasteurization in the year 1926. They worked with a pasteurizer which was superior to all others since it contained two important improvements, namely (a) constant level tank in-

stalled to maintain a uniform head on the circulating pump and (b) an automatic Bristol's temperature controller added to control the speed of the milk thereby regulating the temperature at which the milk was treated. They determined the rate of flow of milk through the system and found that it took from 33 to 41 seconds to fill a 5-gallon milk can.

The holding time, or length of time required for the milk to pass from the heated outlet to the cooler inlet, was not determined. However, it was calculated to be from 3 to 4 seconds. This was essentially a "flash" pasteurizer.

Dahlberg (1932) graphed the data of North and Park (1927), Margardt and Dahlberg (1931) relative to the time and temperature necessary to render the milk safe yet preserve the creaming ability. The semi-logarithmic graph showed that 160° F. for 15 seconds provided a safety factor of 5 seconds; while 142° F. for 30 minutes allowed a safety factor of 20 minutes.

A similar form of Electro-pure pasteurizer was studied by Ogden, Carpenter and Curran (1924). The New York State Public Health Council appointed representatives to study this machine which was installed in the Cornell University Dairy Department. The machine operated as follows: The cold raw milk was pumped through the regenerator while the hot pasteurized milk, flowing on the other side of the plates, was cooled. The raw milk entering was heated to about 120° F. while the hot milk was cooled to about 90° F. From the regenerator the 120° F. milk flowed through the filter cloth and flowed on up through the heater which consisted of two carbon electrodes separated by two pieces of glass. A hand operated micrometer valve, placed ahead of the heater was the only piece of equipment which con-

trolled the temperature of the milk. This form of control proved to be inadequate since the holding time also changed as the rate of flow changed which resulted in overholding of the milk since the maximum flow as set by the valve had to be at least 15 seconds. Any position other than maximum opening caused the milk to be overheld.

Up to this time inadequate controls did not effectively maintain the exposure time of the milk or amount of heat generated by the passage of electricity into the milk. Therefore, it was rightfully called "flash" pasteurization.

From the year 1927, high-temperature short-time pasteurization began to develop rapidly.

The next form of Electro-pure pasteurizer was studied cooperatively in 1927 by the New York State Department of Health and the New York City Department of Health with the United States Public Health Service as reported by Yale (1933). The unit studied was a standard commercial machine which contained an automatic thermo-electric device for stopping the milk pump if the temperature of the heated milk dropped below the desired safe temperature point. The length of the milk piping leading from the heater to the cooler inlet was twice as long as the one studied by the Pennsylvania State Health Department (Yale 1933). Thus the length of the pipe from the heater to the cooler section was 14 feet. The holding time between the heater outlet and the cooler inlet ranged between 11.1 and 19.7 seconds.

As a result of extensive research by both the United States Public Health Service and Pennsylvania Department of Health the State of Pennsylvania was the first to adopt and accept high-temperature short-time electrical pasteurization. This was in the year 1927, exactly 15 years after

the process was introduced into the United States from England (anonymous 1938).

Weinreich (1945) stated that in England, the Ministry of Health stipulates 162.5° F. for 15 seconds as high-temperature short-time pasteurization.

Miscor (1943) pointed out that the 15-second holding time (with a temperature of 71.1° C.) was chosen because it was a convenient holding time, that is, "long enough for controls to respond, yet short enough to permit a continuous flow."

Weinreich (1945) further stated that Germany has the most complicated requirement for short-time processing which consists of: combined heating from 165-169.7° F. in seven seconds, holding at 169.7° F. for one second, cooling to 162.5° F. in five seconds and holding five more seconds. Scandinavian countries designated 162.5° F. for 15 seconds as low-temperature pasteurization, while 176° F. to 185° F. for a few seconds as high-temperature processing.

From these time-temperature requirements of foreign countries it is evident that the high-temperature short-time processing is much more rigorous than that required for the same processing in the United States.

Holland and Dahlberg (1940) plotted at various time and temperature combinations, the percentage destruction of E. coli, destruction of phosphatase, and extent of cream line reduction. From their results they concluded that heating milk to 170° F. without any holding would give them all the desirable characteristics of pasteurization standards.

The following is a description of the equipment used with the Electro-pure pasteurizer of a few years ago. This material was obtained

from a private "Compilation of Studies and Tests on the Electro-pure Process" a copy of which was obtained from the Ex-Cell-O Corporation, Pure-Pak Division, Detroit, Michigan. The apparatus consisted of a (a) supply or surge tank for holding the raw milk; (b) regenerative cooler; (c) multiple speed motor driven milk pump; (d) milk filter; (e) electric heating chamber, and (f) electric control switchboard.

Besides these were thermostatic controls, miscellaneous equipment, and instruments for automatic operation, emergency shutdown, and for making temperature recordings of pasteurization.

The main units, with the exception of the electric heating chamber, consisted of standard pasteurizing equipment.

The electrical heater was the main unit for heating the milk to the desired temperature, and consisted of a rectangular vertical chamber 24 inches high and 3 inches by 4 inches inside cross section. Two sides of the chamber were composed of carbon electrodes separated by hard rubber insulators so arranged as to hold the electrodes 3 inches apart. The rubber insulators formed the other two sides of the chamber.

In the operation of this equipment, the milk was drawn by means of the pump from the supply tank and through the upper half of the regenerative cooler. In this regenerator the cold raw milk at approximately 40° F. (4.4° C.) passed upward through the inside of the pipes where it was gradually heated to approximately 125° to 130° F. (51.6° to 54.4° C.) by heat exchange with the treated hot milk which came from the electric heater and flowed down over the outside of the regenerator tubes. This interchange of heat units reduced the amount of heating in the electric heater and also the amount of cooling in the entire process. The static pressure of the raw milk flowing within the regenerator tubes was purposely made to

be below atmospheric pressure, which surrounded the outside of the same tubes, so that in case of any leaks in the tubes there would be an inward flow of treated milk into the raw milk, instead of the raw milk flowing in to the pasteurized milk and contaminating it.

From the uppermost coil of the regenerator where the milk had attained a temperature of approximately 125° to 130° F. (51.6° to 54.4° C.), the milk was drawn by the pump and forced through the twin filter. The latter was designed to remove all foreign matter such as dirt, etc., which sometimes found its way into the milk. A fine mesh filter cloth (50 threads to the inch) effected this removal as the milk passed through. The apparatus was equipped with two filters, one of which could be taken out of service temporarily for cleaning, without interfering with continuous operation of the process.

From the filter the milk passed over to the treating chamber where in passing upwardly, it was subjected to the action of an alternating current (60 cycles) at 220 volts between electrodes. Here the temperature of the milk was raised to any predetermined value for which the machine was set to operate. One hundred and sixty degrees Fahrenheit (71.0° C.) was the usual commercial practice.

Leaving the electric heater, the milk passed over to the top portion of the regenerative cooler. Here it spilled down and over the outside of the tubes, giving up its heat to the raw milk within the tubes until it reached the brine cooled tubes in the lower half of the regenerative cooler. In this lower half of the cooler, the milk was finally cooled to approximately 36° to 38° F. (2.2° - 3.5° C.). The temperature of the milk leaving the electric heater was dependent upon the rate of flow of the milk stream

passing up between the electrodes. Since the flow of electric current, which passed transversely through the column of milk between electrodes, was dependent largely upon the electric conductivity of the milk which within the usual operating range was practically constant, it would be apparent that the lower the velocity of milk and the longer the exposure to the electric current flow, the hotter the milk would become, and vice versa. The rate of flow was dependent upon the pump speed. With the apparatus set for any predetermined temperature, the operation was absolutely automatic by means of the thermostatic control devices connected with and regulating the speed of the motor driving pump. Any operation tending toward too high a temperature was offset by a speeding up of the pump motor and any tendency toward too low a temperature was met with a slowing down of the pump motor.

If, for any reason, the temperature of the treated milk fell below the lowest tolerable value for which the apparatus was set, the control devices cut off instantly the electric supply circuit to the pump motor, thereby stopping the pump and the flow of the milk.

2. Present types of high-temperature short-time pasteurizers

There are two types of high-temperature short-time pasteurizers on the market, one employing electricity as the source of heat and control; the other utilizing steam to heat the milk and compressed air as the controller activator.

The pasteurizer with the electric heating unit is made up of a constant level raw milk tank, a positive pump, plate regenerator, carbon electrode heating chamber, holding tubes or sections, diversion valve, indicating and recording thermometers.

The heating chamber consists of a two foot section made up of glass on two sides and carbon electrodes on the other two sides. The inside of the chamber is three inches wide and four inches long. The electrodes in this chamber are three inches apart. At each end are porcelain insulators which prevent the electricity from grounding on the metal parts of the machine.

Palmer (1944) described the Electro-pure equipment, other than the heater, which makes up the large, commercial high-temperature short-time pasteurizer as follows:

"1. The ballast tank, which regulates the flow of raw milk to the unit from the supply tank, insures a constant head on the milk pump."

"2. Attached is another driven positive type milk pump which sucks the raw milk through the regenerator and pushes it through the rest of the system at a steady constant flow."

"3. A tubular holding section designed and engineered to accomplish the required holding period. This is located between the heating chamber and the diversion valve."

"4. A diversion valve consists of a long "tooled" stem, with a ground head at one end and a restriction four inches away from the same end. It is operated by an electrical magnetic coil mounted at the top of the diversion valve."

"5. Located between the diversion valve and the cooler is a set of plates so constructed as to allow cold, raw milk to be warmed by the pasteurized hot milk going to the cooler. This flow diversion valve is controlled by a recording thermometer located at the farthest end of the holding tube."

Filbert (1945) pointed out that the reason dairymen are anxious to adopt high-temperature short-time processing was because 80 percent of the heat was recovered and therefore 80 percent less refrigeration was needed. He stated that:

"40° F. raw milk ... regenerator ... 80 percent recovery since raw milk is preheated to 138° F."

"162° F. pasteurized ... regenerator ... 80 percent recovery since the pasteurized milk is cooled to 64° F. before it enters the cooler."

Palmer (1944) noted that this type of valve was introduced by H. S. Fielder in 1927, but was not used with high-temperature short-time equipment until 1939 when the contact thermometer was discarded. This thermometer controlled the milk pump rather than the direction of the flow as the diversion valve does.

Olsen (1946) gave a complete description of operation of controlling instruments used with the steam type installations. The operation of these instruments and the source of heat energy are the only differences between the two types of pasteurizers.

Olsen (1946) explained the usual controlling instruments as follows:

"A. A mercury-in-glass indicating thermometer located in the milk line between the end of the holder tube and the flow diversion valve. This thermometer unlike similar instruments used for 30 minutes holding systems has a very open scale with a range of 135° to 165° F. and is graduate in one-half degree divisions."

"B. A steam pressure controller, for maintaining a constant supply of steam to the diaphragm valve of the water temperature control under conditions of forward flow."

"C. A temperature controller for maintaining the circulating water at the correct value."

"D. A safety thermal recorder which serves three functions:

- (a) Provides record of temperatures of milk leaving the holder tubes; (b) electro-pneumatically actuates flow diversion valve; and (c) records whether flow diversion valve is in forward flow or diverted flow position, depending on whether bulb of safety thermal limit recorder is above or below the desired cut-out temperature."

Weinreich (1945) reported that since 1937, 75 percent of the milk processed in Europe was pasteurized in high-temperature short-time equipment.

Gillespie (1944) outlined the maintenance and operation of steam pasteurizers. He recommended that a routine maintenance schedule should be followed prior to daily runs to check the accuracy of the pasteurizing equipment so that it would operate efficiently throughout the processing of the dairy products.

Weinreich (1945a) pointed out that no difference existed between the two types of pasteurizer as to efficiency of pasteurization, because of the source of heat. From his description it appears that the steam high-temperature short-time pasteurizer is much like the Electro-pure short-time equipment except for the source of heat used.

5. Checking equipment:

The method for checking the lag of thermometers and the setting of the flow diversion valve is explicitly described in the "Milk Ordinance and Code", Bulletin 320, United States Public Health Service.

Hall (1945) stated that Newton's Law of Cooling should be applied to figure the lag of a thermometer when it is in a surrounding of a different temperature than itself, the formula being:

$$\frac{dR}{dt} = \frac{1}{\lambda} (R-T)$$

t = Time in seconds

T = Temperature of surroundings

R = Thermometer reading

λ = Lag constant of thermometer

The checking of holding time is accomplished by two methods, namely, the color method and the "sol-u-bridge" method, which is preferred.

Rishoi (1946) stated that the method of injecting color solutions into the holding section and the 1-second interval sampling at the end of the holding tube for presence of the dye was too "sluggish" for accurate results. He recommended the use of the "sol-u-bridge" and a stop watch since electrical responses were better than the physical stimuli of the color appearance.

Rishoi (1946) described a "home-made sol-u-bridge" using a galvanometer and a double throw switch. With this he used the second hand of his wrist watch and found that it gave him fairly accurate results.

Weber (1946) compared the "sol-u-bridge" and the galvanometer assembly and discovered the difference to be immeasurable.

Helt (1945) calculated the volume of the holder tube and converted this to rate of flow per hour.

Cohn (1946) illustrated some of the problems he encountered in checking high-temperature short-time equipment. He points out the problems that arose and the subsequent solutions he applied to them.

Ball (1945) stated that the preheating time should not be overlooked in comparing 145° F. for 30 minutes to 160 to 161° F. for 15 to 16 seconds since as much as 50 percent of bacterial reduction is ac-

accomplished during this period. The total time involved in processing canned foods was considered in the sterilization process and therefore we should consider it in the pasteurization process.

Hiscox and Davis (1943) concluded that the margin of safety was not yet established accurately for the temperature, time combination of 160 to 161° F. for 15 seconds, because laboratory equipment was lacking which could reproduce the rate of heating and the short holding of commercial units.

4. Cleaning of equipment

Calcium, albumin and other constituents of milk treated by high-temperature short-time pasteurization develop a deposit (milkstone) which is difficult to remove.

Moore (1945) stated that the type of deposit present on short-time equipment was quite different in composition from that encountered on holder pasteurizers. He spoke of a double treatment milkstone remover which is now universally adopted. With these treatments brushing is seldom necessary since the deposits are removed very efficiently by pumping the cleaning solutions. The cleaners are composed of wetting agents, compounds which have flocculating and peptonizing properties. One of the cleaners is acidic in nature, while the other is basic.

Trout (1946) concluded that it apparently made no difference which treatment was first, the alkaline or acid, as some workers used the acid treatment while others used the alkaline treatment first, with equal success.

Bell and Sanders (1944) reported that the formation of milkstone in a high-temperature short-time heater was greatly decreased by preheating milk, skim milk and whey.

5. Sterilization of equipment

Prior to introducing any milk into the pasteurizing equipment it is imperative that the entire apparatus should be sterilized.

Cavanagh (1946) stated that the common practice of sterilization is carried on by circulating hot water at a temperature of 180° or 190° F. for five to fifteen minutes through the complete system and then to fill the system with chlorine-water solution, allowing the solution to stand about five minutes when it is forced out by the first run of milk. Another method, he advised, was to sterilize by using hot (180° - 190° F.) water only and allowing it to circulate about fifteen minutes. He recommended the inspecting and checking of equipment be made while circulating the hot water or sanitizing solution. During this temperature checking, it was advisable to check the sanitary pipe joints for leaks, especially on the milk suction side as a leakage would considerably upset pump performances.

Foley (1934) stated that after the equipment was sterilized and inspected, the raw milk was allowed to flow into the system via constant level tank. The cold, raw milk was "sucked" into the system and during the pasteurization process cooled the out-going pasteurized milk. This part of the process is called "regeneration."

Getchel (1935) working with electric pasteurizers, found that after the milk was preheated it should be "pushed" instead of "sucked" into the heater section, if a constant volume and uniform holding is to be maintained.

Filbert (1945) stated that plate heat exchangers have been foremost in the rapid adoption of high-temperature short-time pasteurization in that they allow the movement of milk in a thin film at a rapid velocity and thus have the milk at the critical heat for a minimum length of time.

Putnam (1945) believed that the reason high-temperature short-time processing was so successful was because of the flow diversion valve as well as the regenerative feature.

Button (1940) realized the progress that was being made in the design and use of automatic controls on high-temperature short-time equipment. He believed that automatic controls should be installed on holder equipment.

The physical and chemical changes brought about as a result of high-temperature short-time pasteurization have been observed and studied by many workers.

6. Effect on acidity

Anderson and Finkelstein (1919) checked raw and Electro-pure treated milk for titratable acidity and found that after 24 hours the raw milk showed a high acidity, while the treated milk showed a slight decrease in acidity. The raw milk curdled after 24 hours and had a "pin-holed" appearance, while the treated milk remained normal. After 48 hours, the acidity of the treated milk increased to the point where the milk curdled; this curd unlike the raw milk curd was normal in texture and appearance.

High-temperature short-time pasteurization is more efficient in preserving the original vitamin content of milk. Holmes et al. (1945) pasteurized some milk in a stainless steel vat which they assayed. They made this study to determine whether there was any reduction of vitamin content due to short-time pasteurization. They obtained the following results:

Vitamin	Type of milk	
	Raw	Pasteurized
Ascorbic acid	16.4 mg/L.	16.6 mg/L.
Riboflavin	1.5 mg/L.	1.5 mg/L.
Thiamin	0.36 mg/L.	0.35 mg/L.

In another experiment, Holmes et al. (1943) assayed some milk, treated by the holder method, for vitamin content and found the following:

Vitamin	Type of Milk	
	Raw	Pasteurized
Ascorbic acid	19.7 mg/L.	15.9 mg/L.
Riboflavin	1.5 mg/L.	1.43 mg/L.
Thiamin	0.33 mg/L.	0.30 mg/L.

Millenky and Brueckner (1941) found milk which had been pasteurized by the high-temperature short-time method after 5-days storage, had a higher ascorbic acid than that processed by the long hold method.

7. Effect on cream line

The cream line on a bottle of standard milk is an important selling point since the customer believes that the volume of cream is a measure of "richness" or butter-fat content of the milk. Therefore, the dairyman will be anxious to buy and use only processing equipment which will maintain this cream line until the attitude of the customer changes.

Skelton and Sommer (1944) found that there appeared to be no difference in the manner in which the cream layer forms on raw milk as compared with pasteurized milk.

Hanner (1916) studied the creaming ability of milk and found the fat packs together more so at room temperatures than at ice water temperatures. He says that the difference in specific gravity on the fat and the serum at the two said temperatures accounts for the shallower cream line at room temperatures.

Plumb (1893) and others, indicated that for best results of creaming, the milk sample should be placed in ice water during the rising period.

Kilbourne (1922) reported that temperature of pasteurization effected creaming ability since he observed wide ranges in cream layer formation. He thought this was due to natural causes or inadequate temperature controls. He recommended 142° F. for 30 minutes as the pasteurization standard.

Dean (1927) found that the amount of cream rising on milk pasteurized by a continuous flow electrical process (using a standard piece of commercial equipment) was compared with that rising on the same lots of milk pasteurized by the vat with circulating water as the heating media. The average for six trials gave cream volumes as follows:

Pasteurized by electricity 14.5 percent
 Pasteurized by vat method 13.0 percent
 Raw milk (no treatment) 15.3 percent

Price (1922) reported that creaming was injured at 145° F. if held for 30 minutes. He advocated 142° to 145° F. for 30 minutes as a standard pasteurization.

Anderson and Finkelstein (1919) concluded that the Elektro-pure process in no way interfered with the cream line in milk treated at 70° C.

8. Effect on flavor

MacCurdy and Trout (1940) found that high-temperature short-time processing produced milk which not only had a higher initial score but also kept a higher score than the holder (aerated and nonaerated) treated after 3 days storage. They reported as follows:

Treatment	: 0 Days Storage		: 3 Days Storage	
	:	Score	:	Score
Raw	:	21.80	:	20.99
Holder:	:		:	
Aerated	:	21.81	:	21.34
Nonaerated	:	21.86	:	20.43
High-temperature short-time	:	22.16	:	21.56

They also noted that less oxidized flavor was encountered in high-temperature short-time pasteurized milk.

Sharp, Trout and Guthrie (1936) explained that the effect of high temperatures of pasteurization in retarding the development of oxidized flavor and the destruction of ascorbic acid could be explained by assuming the destruction of enzymes, which if present accelerated these changes, and that these enzymes survived pasteurization at 145° F.

Although Quinn and Burgwald (1933) found that the high-temperature short-time pasteurization imparted less "cooked" flavor to the milk than did the holder method, it must not be overlooked that "cooked" flavor is more apt to develop if controls are only slightly off which would allow temperatures to go a little above pasteurization temperatures since the safety range is shorter than in holder pasteurization.

Gould and Sommer (1939) attributed cooked flavor to the formation of sulfides which occur when milk is subjected to sufficiently high temperatures or to other changes occurring simultaneously with this formation.

Marquardt and Dahlberg (1934) showed that heated flavor was imparted to cream more readily than to milk. They separated and churned the cream and found that heated flavor was associated with fat more than with the serum.

Dahlberg, et al. (1941) studied "quick time" pasteurization and found that the milk heated to 169° F. to 177.5° F. was of slightly better quality. The exposure time above 140° F. was from 5 to 24 seconds. They concluded also that 170° F. with a controlled rate of heating is a good possibility for future pasteurization times.

Pasteurization reduces the bacterial flora in milk and thereby increases the time prior to putrefaction and off flavor development provided the milk is stored at low temperatures.

Sherman, et al. (1933) found that pasteurized milk showed a lower percentage of growth when stored at 32° F. (0° C.) than raw milk.

Anderson and Finkelstein (1919) found that high-temperature short-time pasteurized milk had good keeping qualities for about 5 days at 5 to 10° C. (41-50° F.) which are commercial storage temperatures.

Pasteurization is not above the maximum temperature for treatment of milk for cheddar cheese production. Phillips (1928) found that a maximum flash temperature of 168° F. may be used in heating the milk for the manufacture of cheddar cheese. Higher temperatures gave a weak body and texture, a scorched flavor and sometimes allowed a bitter flavor to develop.

2. Effect on chemical composition

Overman (1945) found that the ash content of milk was lower between May and October and that lactose was highest during the summer.

Matsuo (1929) studied effect of heating on constituents of milk and found that (a) casein fraction increased; (b) albumin decreased to a mere trace, and that (c) globulin decreased by 50 percent.

Bell (1925) found that comparable amounts of calcium and phosphorus were removed from solution at 170° F. He heated raw skim milk 30 minutes and obtained samples at 10° intervals between 150° F. and 212° F.

Magee and Harvey (1926) suggested that heat changes the calcium salts of milk from a soluble to a colloidal form. Ferric hydroxide ($\text{Fe}(\text{OH})_3$) was used and the results showed no reaction with the "denatured" calcium.

Gould (1946) found that sulfhydryl groups were formed in milk which was heated to 158° F. through 212° F. The groups were antioxidants and re-

sisted subsequent oxidation.

10. Effect on phosphatase

The phosphatase test is used today to determine proper pasteurization procedures.

Key and Graham (1926) developed the phosphatase test.

Gilcreas and Davis (1926) substituted color standards and expressed amount of phosphatase as mg. of phenol per 0.5 ml. of milk. The maximum amount of phenol considered as pasteurized milk was 0.037 mg.

Holmquist (1932) used a modified Key and Graham phosphatase test, incubating the samples for 24 hours.

Buck (1942) found a thermophilic organism which survived pasteurization and which produced phosphatase in the pasteurized milk which when tested for presence of phosphatase was naturally positive. This implied erroneously that the milk was not properly pasteurized.

Sommer (1946) pointed out that the greater presence of ascorbic acid in high-temperature short-time treated milk caused the phosphatase to react more completely and thus a darker blue color resulted.

11. Effect on total bacteria content

The ability of a pasteurizer to destroy all pathogenic bacteria and at the same time reduce the nonpathogenic population, is more important than physical or chemical changes it imparts to the milk. Therefore, the percentage reduction of bacteria as well as the final count of the treated milk is of value when evaluating the efficiency of any pasteurizer.

Carpenter (1929) found that it did not make any difference as to the source of heat used in pasteurization since heat produced by an electric current effectively destroyed tubercle bacilli found in raw milk.

Stone (1909) studied the influence of electricity on micro-organisms and found that high voltages were lethal, while low voltages were stimulating to the organisms.

Anderson and Finkelstein (1919) found that the percentage of bacterial reduction was at least 99.7 percent. The raw milk samples of the first series of the test were excellent containing only 150,000 organisms per milliliter. This milk was pasteurized down to 12,000 organisms per milliliter. When the milk was poor to begin with, (12,000,000) the milk pasteurized down to 135,000 colonies per milliliter.

There are two schools of thought as to the reason for such efficiency in reducing the total bacterial population in milk.

Beattie and Lewis (1925) worked with electrical pasteurization and believed that the organisms were killed by the electrical current since the temperature of the treatment was lower than the thermal death points of the organisms.

Galpi (1931) found that there was another factor other than heat which was involved in Elektro-pure pasteurization. He found that bacterial spores were more efficiently destroyed in his electrical pasteurizer than in the holder trials even though the temperature of either treatment was not lethal.

Tracy (1932) demonstrated by passing an alternating current through grape juice containing yeast cell suspensions that a pronounced killing took place even though the temperature of the exposure was only 42° C. (107.6° F.).

Anderson and Finkelstein (1919) believed otherwise for they said that "The destruction of bacteria in the Elektro-pure process is apparently due to the heat produced by the electric current rather than to the electric current itself."

Sanderf (1938) did some work which agreed with the finding of Anderson and Finkelstein.

1.2. Effect on thermodurics

Fabian (1942) defines the thermoduric bacteria as those that withstand either of the pasteurization temperatures, 145° F. for 30 minutes or 160° to 161° for 15 seconds.

Both the "long hold" and short-time pasteurization exposures are abnormal temperatures for the thermoduric organisms. It seems logical to expect high thermoduric counts in high-temperature short-time treated milk since the exposure to this abnormal temperature is only a few seconds. However, Hammer and Treut (1928) worked with yellow cocci which they isolated from dairy products and found them to withstand temperatures of 80° C. for 30 minutes.

Fay (1927) stated that if the flora is resistant to pasteurization the possible destruction during pasteurization is nil. Therefore, the problem of "pin-point" colonies on plated milk samples indicates that producers are negligent in proper sanitation and that they should practice better housekeeping otherwise this milk would not be pasteurized down to legal limits especially if it were processed in high-temperature short-time equipment.

Hileman (1940) reviewed the literature on thermoduric bacteria found in pasteurized milk.

Fabian (1942) stated that more thermodurics are apt to be found in the high-temperature short-time process than in the holder process.

Yale and Kelly (1933) concluded that high-temperature short-time pasteurization was not as efficient in reducing bacterial counts of milk as was the holder method. This was due to the fact that the bacterial flora was of a resistant nature.

Tiedeman and Swanner (1940) reported that counts were higher with high-temperature short-time equipment than with long holding (vat) treatments because of thermophilic contamination of the milk utensils.

Some have tried to "pin down" the source of these organisms. The source is still greatly undetermined as these organisms are found everywhere.

Detterer (1943) pointed out that the source of the thermophilic organisms in milk could be traced to the producer.

O'Daniel (1942) checked the producers with the idea of reducing thermophilic organisms in the milk. He was able in this way to increase the pasteurization efficiency by nine percent.

Levowitz (1945) found, in average herds, that the mean thermophilic population was three thousand per milliliter. This was not the case in certified herds, however.

Jensen and Bertree (1946) were more specific for when they studied the milking machine and its inflations with the idea of determining the most suitable method of washing and sanitizing it, they found that by frequent boiling of the rubber inflations in a strong alkali (lye or sodium hydroxide) it was possible to reduce the total thermophilic population to a standard which was desirable.

Robertson, et al. (1923) studied pasteurizing equipment and found that *B. subtilis*, *B. cereus*, *B. mesentericus*, and *B. vulgaris* could be isolated from dirty equipment showing milkstone formation.

Hileman (1941) reported that certain species of micrococcus caused high bacteria counts in milk pasteurized by high-temperature short-time equipment. These organisms were most often thermophiles and could be isolated from dirty, neglected milking equipment, especially milking machines.

Hucker (1928) found a prolific number of micrococci in pasteurized milk samples. He found that most of the thermoduric organisms found in milk are the micrococci.

Curran and Evans (1945) found that heat activated spores of the resistant organisms and thus upon standing such milk would increase in count, especially if the milk was a 145° F.

Myers and Pense (1941) worked up a simplified procedure for the laboratory examination and control of raw milk supplies.

Morris (1943) found that the resazurin test alone was a good method for determining the number of thermoduric organisms.

Wainess (1941) stated that now that high-temperature short-time pasteurization was being used more and more, laboratory controls must also be brought up-to-date since ordinary laboratory tests used today are not efficient to detect thermoduric organisms in raw milk supplies. He recommends the resazurin test for quick, economical laboratory control.

Breed (1928) favored the microscope to supplement plate counting when checking producers for thermodurics.

Mallmann, et al. (1940) proposed a maximum acceptable number of 40,000 thermoduric organisms, as detected by the microscopic technique, in producer's milk.

Breed (1928) found that the causes for high thermoduric and thermophilic counts are: (a) repasteurization; (b) temporary "tie up" of pasteurized milk (143° F.); and (c) hotwalls used in powdering milk processes.

Robertson (1927a) concluded that young, rapidly growing or adolescent cells are more susceptible than the older cells to the killing action of high temperatures. As the temperatures used approached the thermal death points of the organisms, the degree of killing at any one age

is greater and extends over a longer period of time. If the greatest efficiency of pasteurization of milk or canning of foods is desired then heat should be applied to the product before the microorganisms have passed the accelerative growth stage.

13. Effect on thermophiles

Robertson (1927) cited 447 references on thermophiles and thermodurics and gave an excellent review on the subject.

Mudge (1930) made a fine study of the life cycle of a thermophilic organism.

Brannon and Prucha (1927) found that in pasteurized milk (62.5° C.) high counts were due to nonspore forming organisms. This was not conclusive for they felt that further investigation should be made.

Tanner (1944) pointed out that thermophilic bacteria survived temperatures as high as 75° C. (167° F.).

Robertson (1927a) isolated species of thermophiles and thermoduric organisms from milk and found that their rate of growth, except for *S. thermophilus* ^{was} relatively slow at temperatures ranging between 20° C. through 37° C.

Breed and Prickett (1929) reported that some thermophiles isolated from milk were found to be liquifiers, alkali producers, and others produced acid. They felt that thermophiles are not connected with insanitary practices. The thermophiles are not considered to be pathogenic and therefore are not a health hazard, only a dairy plant nuisance.

Fabian (1942) stated that more problems with thermophiles are apt to arise in holder pasteurization than in high-temperature short-time processing.

14. Effect on coliform organisms

Coliform organisms have the ability of fermenting the lactose in milk. Their presence in raw milk is of no significance since pasteurization kills virtually 100 percent of these organisms, (Finkelstein 1919).

McCrady, et al. (1932) used the coliform organisms in pasteurization efficiency studies and found that some survived pasteurization.

Ayers and Johnson (1924) studied Escherichia coli and found that at 135° F. for 30 minutes the "majority" were killed while at 150° F., or above, for 30 minutes exposure he obtained the "absolute" death point or 100 percent kill.

Beavens (1930) examined 100 pasteurized milk samples and found that 32 percent of them contained Escherichia-aerobacter organisms. He found the majority thermal death point of Escherichia coli to be 144° F. for 30 minutes.

Stark and Patterson (1936) reported that of 505 cultures studied they found that less than one percent survived 145° F. for 30 minutes. They concluded that coliform organisms in pasteurized milk were due to post-pasteurization contamination, and may, therefore, be an excellent method of checking the efficiency of pasteurization. This was especially true in high-temperature short-time processing since this method virtually destroys all of the organisms.

Dahlberg (1946) found that if one out of three desoxycholate agar plates or one out of three brilliant green bile tubes, were positive, it did not necessarily mean that the sample was positive for E. coli; he duplicated results only when two out of the three plates or tubes were positive.

Speck (1947) plated some milk samples which he innoculated with E. coli and which were heated to 140° F. for 50 minutes. Other samples were treated at 140° F. for 55 minutes. Small red colonies appeared on the desoxycholate lactose agar, which were less than one millimeter in diameter, on the 50 minute plates, while no colonies were evident on the 55 minute treatment. M. freundreichii was the organism isolated from the 50 minute exposure plates, since the E. coli did not survive the 140° F. for 50 minutes. Speck concluded that this organism might be employed as the test organism for proper pasteurization.

High-temperature short-time pasteurization is a safe method of processing since the Tubercle bacillus is destroyed during processing.

Holmquist (1932) found Tubercle bacillus was killed at 160° F. in 11 seconds.

Anderson and Finkelstein (1919) stated that "the Electro-pure machine does not affect appreciably the physical and chemical properties of milk, reduce the total bacteria count satisfactorily and at the same time destroys nearly all lactose fermenting, Endo positive organisms in raw milk."

Robinson (1923), Dowd, et al. (1943), and Erwin (1945) studied high-temperature short-time pasteurization and found favorable results.

Devereaux (1929) after working with Electro-pure pasteurization, concluded "that the convenience and simplicity of the machine and the efficient manner in which it reduces bacterial populations and destroys pathogenic organisms in milk without altering the taste or creaming ability of milk make the Electro-pure process one worthy of farther consideration by the producer, the consumer, and the investigator of dairy products."

EXPERIMENTAL PROCEDURE

A. PASTEURIZATION EQUIPMENT

1. Description The high-temperature short-time pasteurization was conducted throughout this study with a new model of an electric pasteurizer which was called "producer size" since it was designed for the small producer. The parts used, listed in Table 1, are designated with corresponding letters as shown in Figure 1.

Table 1. A list of parts that comprised the original
pasteurizer

:	
<u>Identification :</u> <u>Name of Part</u>	
A	Tri-clover centrifugal pump
B	Electro-pure heater
C	Thermal thermometer
D	Metering valve
E	Holding section
F	Mercury thermometer
G	Recording thermometer cable
H	Solenoid (electric coil)
I	Flow diversion valve
J	Recording thermometer (volt meter upper left)
K	Foreward flow pipe
L	Diverting flow pipe
M	Agitator
N	Surface cooler
O	Container for pasteurized milk
P	Raw milk surge tank valve
Q	Raw milk surge tank

Figure 1 shows the original installation which consisted of the necessary heating and cooling parts but which lacked efficient controls.

The list of the parts comprising the original "producer size" pasteurizer are described as follows:



Figure 1. Showing the original Electro-pure, producer size pasteurizer.

a. Surge tank The surge tank (Q) was 4 feet in diameter and about 3 feet deep. It was made of stainless steel metal and had a capacity of 50 gallons. A 2-inch outlet was located on the side and near the bottom of the tank.

b. Piping All piping was made of stainless steel metal with tin soldered flanges and ferrals. The pipes were 1 inch in diameter with the exception of the holding tube which was originally 2 inches in cross section.

c. Valves The surge tank valve (P) was made of white metal and was an ordinary two way type. The flow control valve (D) was also made of white metal. A groove was made in the valve in such a manner that milk flowed even when the valve was placed in the off position. This valve was the only source of temperature control in the original installation. Nine positions, spaced equally apart, were set on a wooden scale and mounted on the outside of the valve. The gallons per minute were determined in the various valve positions, both in diverted and forward flows.

d. Pumps The first pump (A) used was a tri-clover single speed centrifugal pump, which is standard in the dairy plants. The revolutions per minute were determined. This type of pump operated by a 110 volt single phase motor. The second pump tried was a centrifugal type and was identical except that its speed was adjustable by means of a variable speed drive pulley. The third pump (not shown in Figure 1) studied was a Waukesha positive pump, driven through a variable speed drive. This pump proved desirable and efficient and therefore was retained in the redesigned producer size pasteurizer.

e. Agitator This temporary agitator (M) was part of the original equipment. It was installed to keep the cream portion of the milk well

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agitated and mixed throughout the milk so accurate cream line determinations could be made of the treated samples.

f. Heater section The heater (B) was 6 inches long and was made of two flat, carbon electrodes mounted opposite each other with two pieces of glass, 1 inch thick and 4 inches wide, separating them. The inner area of the chamber was 12 inches, since the size of the rectangle cross-section was 4 inches by 3 inches. These carbon electrodes and the glass sections were clamped together with flat pieces of metal bolted together. Above and below the heater were sections of porcelain which insulated the electrodes from the rest of the machine. Small rubber tubing, which can be seen on the floor in back of the panel in Fig. 1, supplied the water needed to cool the electrodes. This tubing led into a pipe so arranged that water flowed down the back side of the two carbon electrodes. The function of this water was to cool the carbons and to wet the carbon surfaces so that even distribution of the electrical energy resulted.

Two leads were located in back of the heater. These entered the heater from the back of the panel and were attached to a knife switch located on the back frame of the panel board. This smaller heater, of the two tried, required 240 volts, 60 cycles and 50 amperes in order that the milk would be rapidly heated to the desired temperature.

After several runs and some equipment modification a 14-inch heater was installed, which differed only in the length from the 6-inch heater. This required the changing of the voltage to 210 volts since the 14-inch heater would use more than 10 kilowatts per hour. This would overload the line, not only in the Dairy Building but also in the rural areas which might adopt this pasteurizer.

g. Thermometers All thermometers used were installed in the original machine. Thermometer (C) was used to indicate the position at which the valve was set. The thermal thermometer was kept at 130° F. until all of the raw milk was preheated (by diverting milk) to a temperature which would give an exit temperature of 130° F. or slightly higher.

The valve position was then restricted so that the milk would go fairly rapidly into forward flow. This valve was never changed to a position which would show 165° F. or above on the thermal thermometer. Thermometer (F) was a mercury in glass type which was calibrated from 140° F. to 212° F. in $\frac{1}{2}$ -degree intervals with minimum spacings of 1/8 of an inch. This was used to check the operating temperature of the pasteurizer and the diversion valve was set according to this "master" thermometer. The thermometer was mounted on the exit end of the holding section. Thermometer (J) was a Taylor recording thermometer with a temperature and a diversion flow pen operating on the chart. Actuation took place at 125° F. A voltmeter was located in the upper left corner. The inside of the recorder had both the pen arm adjustment and the flow diversion cut-in and cut-out adjustment. The cable from the recorder extended under the panel section to the top of the holding tube or section where it was mounted near the mercury thermometer.

h. Solenoid valve The solenoid labeled (H) in Figure 1 was made up of a wound coil with a square core to which was attached a square rod with a swivel end. The swivel end was attached to the end of the diversion valve. The coil had wires leading to the recording thermometer which were attached to a cut-in switch, which in turn was activated by the setting of the recording thermometer. The solenoid and recording thermometers were both operated by a 110-volt alternating current.

QUESTION 1

1. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
2. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |

3. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
4. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
5. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
6. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
7. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
8. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
9. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
10. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |

QUESTION 2

1. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |
2. The following table shows the number of people who attended a concert in each of the five years from 2010 to 2014.
- | Year | 2010 | 2011 | 2012 | 2013 | 2014 |
|------------------|------|------|------|------|------|
| Number of people | 1200 | 1500 | 1800 | 2000 | 2200 |

i. Diversion valve The stem of the diversion valve consisted of a long "tooled" piece of metal which had a restricting washer mounted in such a way as to cause restriction only in forward flow position. This allowed the milk to be heated more rapidly since it slowed up the flow of the milk leaving the milk in the heater for a longer period of time.

j. Cooling section An 18-inch by 24-inch tin coated copper surface cooler was installed on a suitable frame which made it portable. This cooler used tap water as the refrigerant. This refrigerant was capable of cooling the milk down from 161° F. to 54° F. (71.1° C. to 12.2° C.).

k. Switches Three switches were required with this equipment. The one on the left of the electrical conduit (Figure 1), was the pump switch; the one on the right operates the recording thermometer and voltmeter. The third switch (not shown in Figure 1) is the main switch located on the back of the panel control. This is the heater switch.

l. Electrical controls

(1) Paddles Two paddles, made of rubber pressed onto a steel shaft, were tried. These were placed into the heater section and mounted in such a way as to allow the paddle to be manually operated in a pivoting manner, by a handle located on top of the heater and attached to the steel shaft. Each of these paddles were used separately and each was different. One had a solid rubber facing tapered at the sides and at the end and was 1½ inches wide and 14 inches long. The second was six inches from the bottom. These paddles were used since it was found that electrical input could be controlled easier than the flow of the milk since the electrical input does not affect the holding time while the rate of flow does.

(2) Sliding box A phenolic resinous box was constructed so that it would snugly but loosely fit into the heater. Three holes (5/8 inches in diameter) were drilled and a shaft was mounted in the center of the block. The box moved up and down between the electrodes with the movement of the steel shaft.

(3) Resistance stabilizer The stabilizer was made of a section of ordinary pipe which was cut from an ordinary pipe, 1 inch in diameter. Around this was a heavy number 8 wire coiled in such a manner as to leave two open ends. A cut-in and cut-out relay was attached to the open end of the coil and this in turn was cut into the heater circuit; the other end of the coil wire was attached to the main line. The stabilizer would cut in and out every ten to fifteen seconds, as was evident on the second voltmeter attached to the resistance section. The extent of cut-in and cut-out was determined by the thermostat setting. As is indicated on the recording thermometer chart, the stabilizer controlled the temperature to within one degree of the 161° setting. The stabilizer was not part of the original equipment and was installed much later in the experiment when other means failed to control the temperature rise.

m. Holding section Two different holding sections were used, one with the centrifugal pumps and the other with the positive pump. The difference was in the cross-section of the two tubes. Each modification or equipment substitution was made after several trial runs were made to determine the type of change needed.

2. Checking equipment

a. Revolutions per minute The revolutions per minute of motors and pumps tested were made with a tachometer and a stop watch.

The tachometer was a thumb type with a removable rubber nipple on the end for setting on end of shafts. The scale on the tachometer was divided into 100 parts which were divided in 10 parts which in turn were divided into 10 parts. Thus the smallest reading was 1 revolution per minute.

The stop watch was a Cenco (Swiss) make which had its seconds divided into one-fifths of a second. Two workers were required for the determinations of revolutions per minute, since it was necessary to watch the number of times the revolving bead traversed around the scale. The revolutions were clocked for 1 minute intervals. The number of times the bead traveled around the scale multiplied by 100, plus the fraction of 100, timed for 1 minute, constituted the revolutions per minute of the mortar or pump tested.

b. Checking accuracy of thermometers The mercury and recording thermometers were checked according to methods outlined in "Milk Ordinance and Code" Bulletin 220, United States Public Health Service.

The floating thermometers in the raw tank or the thermal thermometer were not checked. However, their respective temperatures were compared to the mercury thermometer when immersed in hot water, a sufficient time being allowed for thermometers to equalize.

c. Holding time determinations The holding time was determined by observing an electrical impulse. A "sol-u-bridge" was made using a galvanometer, double throw knife switch, number 12 insulated copper wire, resistance call of salt and rubber stoppers with a piece of copper and iron wire pierced through them. The pierced rubber stoppers with the wires through them constituted the probes, one of which was mounted in place of

the mercury thermometer; the ether was placed in a special apparatus. The special apparatus was made identical to that in Figure 1, located between the lower end of the holding tube and the metering valve, except that a small nipple was welded to the side. Thus the probes were located just above and immediately below the holding tube. Two leads were connected to each probe, the other ends of the leads were connected to the galvanometer through a double switch. This made two complete circuits, one being at each probe. The thermal thermometer was removed and a nut with a brass washer was used to hold down a 1/8 inch thick rubber diaphragm. This diaphragm was easily pierced with a 20 gauge needle attached to a 50-milliliter syringe. Saturated salt solution was made using ordinary table salt. A Genco (Swiss) stop watch, graduated in 1/5 seconds, was used to time the interval between the galvanometer deflections.

Water was placed in the raw milk surge tank to its fullest capacity. The milk pump was started and the water was allowed to flow for a time (five minutes or more). The syringe, with the 20 gauge needle attached, was filled with saturated salt solution, then the point of the needle was forced through the rubber cord diaphragm. The operator of the stop watch noted the galvanometer deflections while another operator injected the salt solution. As the salt solution passed the first probe, the deflection of the galvanometer was noticed and the stop watch was started and the knife switch thrown to the other circuit. The deflection in the galvanometer was again noted when the salt solution passed the second probe at which time the timing was stopped. The time interval between the galvanometer deflections constituted the holding time.

The holding time was tried with various valve positions which were calculated in gallons per minute.

d. Determination of gallons per hour processed The gallons per hour were determined by weighing the milk that was pumped through the pasteurizer and over the cooler in a given time.

A 2 $\frac{1}{2}$ -gallon milk can was weighed without the cover. The milk flowed through the heater and holding tube on out the flow diversion valve (forced shut) and through the forward flow pipe and finally over the cooler for sometime before the weighed can was placed and the timing started. A steady flow continued for some time before the can was placed under the delivery spout below the cooler. The timing was started simultaneously with the placing of the weighed can under the spout. The milk was allowed to flow for five minutes before the can was removed and weighed. The initial weight (weight of the can) was subtracted from the final weight. The final weight was multiplied by 12, since 5 minutes is a twelfth of an hour. The product of this multiplication constituted the pounds that the pasteurizer was able to process in a period of one hour.

e. Power input determinations An ammeter was used to determine the kilowatt consumption per hour of operation. The amperage consumed never exceeded 50 at any time but was less than 50 during initial preheating periods.

The kilowatt consumption was determined by the following formula:

$$KW = \frac{V \times A \times PF}{1000}$$

When KW = kilowatts
 V = volts
 A = amperes
 PF = power factor

Note: In this instance, since the load is non-reactive, the
power factor = 1.

f. Checking of the cut-in and cut-out temperature of the solenoid

The temperature registered on the mercury thermometer was the criterion for the cut-in and cut-out temperature of the solenoid which in turn controlled the position of the flow diversion valve.

This was done according to the methods outlined in "Milk Ordinance and Code" Bulletin 220, United States Public Health Service. If the cut-in temperature was too low or too high then the adjusting "wheel" located inside of the Taylor recording thermometer was adjusted until the desired cut-in temperature (161° F.) and the cut-out temperature (161° F.) were obtained.

B. PROCEDURE OF PASTEURIZATION

1. Milk supply

a. College Creamery Milk used in the initial runs and in the runs of final testing of the producer size pasteurizer, was obtained from the College Creamery in ten-gallon cans. The College Creamery obtained its milk from its own producers or from a local dairy. Later, when the machine controls were redesigned and perfected, comparisons of efficiencies with those of vat (holder) pasteurization and a large commercial high-temperature short-time pasteurizer were made.

The milk that was used for comparison of efficiency of pasteurization with the holder was obtained by the following method: A 200-gallon vat was filled to capacity, and after sufficient agitation, a 30- to 40-gallon sample was obtained. The sampling pail used was washed and then sanitized with 200 p.p.m. or more available chlorine solution. Rubber gloves were worn to minimize possible contamination while sampling. After the 30- or 40-gallon sample was taken, a small, sterile sampler was used to obtain

sufficient sample for bacteriological and phosphatase test. The bacteriological samples and phosphatase samples were placed in test tubes and stored in ice water until analyzed.

b. Local creamery The milk that was used for the studies of relative efficiencies of the small experimental Electro-pure pasteurizer and a large commercial, steam-heated, high-temperature short-time pasteurizer, was obtained by exchanging 40 gallons with a local dairy which had the large commercial unit installed recently. This gave a representative sample since the 40 gallons obtained was from the same supply tank that feeds the surge tank of the commercial pasteurizer. The 40 gallons was immediately shipped to the College Creamery where it was pasteurized. Samples were taken of the milk treated in the commercial short-time pasteurizer for bacteriological, creamline, phosphatase, and flavor studies.

2. Washing All parts of the machine were disassembled and washed prior to making a run. Each section of equipment was washed and brushed with water at 120 to 130° F. (48.8 to 55.5° C.). Suitable detergent or soap was used to give washing properties for ease of milk film removal. After washing the sections and parts, warm water was used to rinse the equipment. The equipment was then allowed to drain dry. When dry, it was assembled.

3. Sanitizing When the equipment was assembled, as shown in Figure 1, cold water was hosed into the surge tank and sufficient HTH, or other chlorine bearing compound, added to give at least 200 p.p.m. of available chlorine. This was allowed to circulate for about 10 to 15 minutes by pumping. While the chlorine water was circulating, the end of the diversion flow pipe was stoppered with the palm of the hand to force the sanitizing solution through the forward flow pipe and over the surface cooler. When

the 15 minutes were up, warm water with a temperature close to 140° F. was added to the surge tank after the chlorine water was drained. This warm water not only rinsed the chlorine out but also warmed the piping and other equipment of the pasteurizer.

4. Operation Raw milk in ten-gallon cans was dumped into the surge tank. This tank fed the centrifugal pump which pumped the milk through the whirlpool agitator located on the bottom of the heating unit, and forced it on up to the top of the heater. At the top of the heater (to the left) was located a thermometer which registered the temperature of the preheated milk. This temperature was 130° F. (55.5° C.), while the milk was diverting and warming in the raw milk surge tank. This operation continued until the temperature of the milk in the raw milk tank reached 80 to 100° F. (26.6 to 37.7° C.). After the raw milk in the surge tank was up to the required preheated temperature the metering valve was closed to retard the flow through the heater to such an extent that the milk was heated from 80 to 100° F. on up to 161° F. From the heater, on past the thermal thermometer, and the metering valve, the milk entered the holding tube whose volume was such that 16 seconds were required for the milk to pass through it. The milk leaving the holding tube passed the mercury thermometer, which registered the temperature in one-half degree gradations from which it simultaneously passed the recording thermometer cable. The temperature recorded by the recording thermometer either caused the milk to be diverted or passed on to forward flow depending on whether its temperature was above or below 161° F. This was accomplished since the recording pen arm was set in such a manner that when a certain set temperature was reached, (160° F.), contacts closed, causing the solenoid to close the diversion valve. This forced the milk to fill up the diversion chamber and spill out into the

forward flow pipe from which it flowed down over an 18 by 24 inch surface cooler. The refrigerant in the surface cooler was ordinary tap water which cooled the milk from 161° F. to 54° F. (71.1° C. - 12.2° C.)

C. PROCEDURE OF SAMPLE TESTING

1. Chemical

a. Acidity The acidity of the milk, before and after treatment, was determined by pipetting 9 milliliters of milk into a white porcelain cup after which five drops of phenolphthalein was added. This mixture was then titrated with Nafis reagent (N/10 sodium hydroxide) to a faint pink color. The graduations were then read and the readings were the percent of lactic acid.

b. Phosphatase The phosphatase test was made by following the field test method as outlined in "Standard Methods for the Examination of Dairy Products," 8th edition, 1941.

2. Physical

a. Cream line The milk samples for this determination were left in ice water from the time they were taken until they were read. Samples were obtained from the raw supply tank, diverted flow outlet and at the outlet below the surface cooler. The raw milk samples were heated to 100 to 120° F. (37.7 to 48.8° C.) momentarily to repack the fat globules, otherwise a larger cream line would be observed in the pasteurized samples. All samples were placed in 100 milliliter graduated cylinders with a little alcoholic suspension of Sudan III dye. Rezasurin was found to be equally good in differentiating the cream line on 24 hour settings. Cotton plugs were placed on the cylinders to observe cream plug formation. These were then

stered in the refrigerator at 40° F. Samples were most always read at 24 hours but occasionally at 48 hours.

b. Flavor The flavor of the raw and treated samples was determined by the dairy staff members who did the tasting and criticizing. No attempt was made to actually give each sample a particular score. The pasteurized milk was tasted throughout the various runs for any off-flavors that might have developed during processing.

3. Bacteriological

a. Total count Total counts were made on all samples by the dilution method. After the dilutions were made samples were plated by use of a pipette. After the required amount of sample was placed into the petri dishes (obtained from the media room) the agar was poured. The media used was standard tryptose glucose extract with sterile skim milk added at the rate of 2 milliliters per 200 milliliters of medium. No skim milk was added to agar which was poured into plates having dilutions of 1/10 or less since sufficient milk was already present in these dilutions. After these plates hardened they were inverted and incubated at 37° C. (98.6° F.) for 48 hours. After the 48 hour incubation period the plates were counted.

b. Thermoduric Thermoduric organisms were those which survived pasteurization temperatures. Practically all of the thermoduric organisms appeared as pin-point colonies on tryptose glucose extract medium after 48 hours of incubation at 37° C. The method of plating was the same as outlined in "Standard Methods of Milk Analysis," 8th edition, 1941.

c. Thermophilic For the thermophilic and thermoduric studies samples were obtained from producers who were known to have a prolific amount of these organisms in their milk due to poor practices. These were pasteurized

in the same manner as regular normal milk. The samples were plated and treated as outlined in "Standard Methods of Milk Analysis", 8th edition, 1941. The plates were incubated at 56° F. for 48 hours after which they were read. Growth at 56° F. indicated thermophilic organisms.

d. Coliform Tests for number of coliform organisms were made by plating dilutions and pouring the plates with desoxycholate agar which is selective of coliform organisms. Desoxycholate plates were prepared by introducing 1 ml. or .1 ml. quantities of milk into the petri dishes and pouring the plates. After the medium had solidified a second layer of three to four milliliters of desoxycholate was poured on the surface to prevent development of atypical colonies. The red colored colonies, appearing between the two layers of desoxycholate after 18 to 20 hours incubation, were considered to be the coliform organisms.

RESULTS

A. PASTEURIZATION OF SALINE SOLUTION USING ORIGINAL EQUIPMENT

1. Time required to heat water to pasteurization temperatures.

Since experience in operating the producer size Electro-pure pasteurizer was desired, water instead of milk was pasteurized. A metering valve, which controlled the flow of the water was the method of temperature control in the first runs. Salt (an electrolyte) was added at the rate of 80.5 grams per 20 gallons of water. This made a 0.21 percent saline solution which exhibited the same conductivity as milk when placed in the path of the heater electrodes. The original saline solution temperature was 58° F. The voltage varied from 203 to 205 volts during the first six runs. A 6-inch heater was used. Table 2 illustrates the time required to preheat the saline solution prior to going into forward flow.

Table 2. Rate of preheating of saline solution prior to forward flow when using 203 volts

Elapsed time (Minutes)	: Temperature of saline solution in vat (° F.)		
	: Trial 1	: Trial 2	: Trial 3
0	: 71	: 57	: 65
10	: 82	: 66	: 74
20	: 93	: 75	: 85
30	: 103	: 85	: 94
40	: 115	: 94	: 104
50	: 124	: 104	: 112
60	: 133	: 113	: 121
70	: 143	: 122	: 131
80	: 154*	: 130	: 140
90	:	: 138	: 149
95	:	: 142*	: 153*

*Forward flow.

In the second part, the focus is on the classification of transactions. It explains how different types of transactions should be categorized into specific accounts, such as sales, purchases, and expenses. This classification is crucial for the preparation of financial statements and for the analysis of the company's performance. The document provides examples of how to classify various types of transactions, such as cash sales, credit sales, and purchases on account.

The third part of the document deals with the recording of transactions in the accounting system. It describes the process of debiting and crediting accounts to record a transaction. It explains the double-entry system, where every transaction is recorded in two accounts, one as a debit and one as a credit, to ensure that the accounting equation remains balanced. The document also discusses the importance of using the correct accounting entries and the need for careful attention to detail in the recording process.

Finally, the document touches upon the preparation of financial statements. It mentions that the recorded transactions are used to prepare the income statement, balance sheet, and statement of cash flows. These statements provide a comprehensive overview of the company's financial position and performance over a specific period. The document stresses the importance of accurate recording and classification of transactions to ensure the reliability of these financial statements.

Journal Entry				
Date	Particulars	Debit	Credit	
2023-01-01	Opening Balance			
	Cash		1000	
	Accounts Receivable	500		
	Inventory	300		
	Accounts Payable		200	
	Equity		1000	
2023-01-05	Sales			
	Cash		200	
	Accounts Receivable	100		
	Sales Revenue		300	
2023-01-10	Purchases			
	Inventory	150		
	Accounts Payable		150	
2023-01-15	Expenses			
	Rent Expense	50		
	Utilities Expense	20		
	Cash		70	

The data indicate that entirely too much time was required to pre-heat the saline solution to a temperature which would permit forward flow of the saline solution. When the saline solution in the surge tank was heated sufficiently high to permit forward flow, about 142 to 155° F., the pasteurizer then was able to bring the temperature up to the required 160° F. Thus, it would seem that the original voltage was entirely too low to permit successful operation of the pasteurizer.

2. Effect of an increased voltage on time required to heat saline solution to pasteurization temperatures

Two transformers, each having a load capacity of five kilowatts, were installed to step up the voltage from 205 to 240. Together they allowed a load of 10 kilowatts per hour to be consumed with no overloading of the power lines. The data are presented in Table 3.

Table 3. Rate of preheating of saline solution prior to forward flow when using 240 volts

Elapsed time (Minutes)	: Temperature of saline solution in vat (° F.)		
	: Gallons processed per minute		
	: 0.6	: 0.8	: 0.9
0	: 68	: 73	: 68
5	: 84*	: 86	: 77
10	: 96*	: 96	: 86
12	: --	: 102*	: --
15	: 102*	: 102*	: 90*

*Forward flow.

These data show that the preheating time was only five minutes prior to forward flow when the tank temperature was 68° F. and the machine was pasteurizing 0.6 gallons per minute. The raw tank temperature kept rising while the saline solution was in forward flow, this being due to a leak

in the flow diversion valve. The data show also that more time was required to preheat the saline solution prior to forward flow temperature when 0.8 gallons were pasteurized, even though the initial saline solution temperature was higher, (Table 3).

3. Influence of change in rate of flow on holding time

Since changes in valve positions resulted in a corresponding change in the gallons per minute processed, it seemed desirable to note the effect on the holding time. The data are presented in Table 4.

Table 4. The holding time of pasteurization is influenced by the position of the valve

Valve Position	Holding time (seconds)			
	Trial 1	Trial 2	Trial 3	
1	33.2	33.6	33.6	
2	29.0	29.2	29.0	
3	25.4	25.6	25.6	
4	22.4	22.4	22.4	
5	21.3	21.4	21.6	
6	19.2	19.2	19.4	
7	18.2	18.0	18.2	
8	17.2	17.4	17.0	
9	16.0	16.2	16.3	

4. Influence of changes in pump head on changes in holding time

When a recheck of holding time was made a two second difference was noted even though conditions were the same in both runs, except the water level in the raw tank. Therefore, it was thought that head pressure on the centrifugal pump caused this difference. Table 5 illustrates the holding time differences due to changes in head pressure on the pump.

Table 5. Changes in holding time due to head pressure
changes on the centrifugal pump

Valve position (number)	:	Holding time (seconds)		:	Difference in holding time (seconds)
	:	Low head	High head	:	
9	:	18.0	16.0	:	2.0
9	:	18.6	16.2	:	2.4
9	:	18.6	16.3	:	2.3
9	:	18.8	16.0	:	2.8

5. Comparison of holding times as determined with a commercial sol-u-bridge
with the holding times found with a home-made sol-u-bridge

A home-made sol-u-bridge, as described by Rishoi (1947), was compared to a commercial model RD5, manufactured by Industrial Instruments, Inc., Jersey City, New Jersey. The results of holding time determinations by the home-made apparatus and with the RD5 instrument are given in Table 6.

Table 6. The comparison of holding time determinations
made by the home-made sol-u-bridge with the
RD5 commercial sol-u-bridge

Valve position (number)	:	Holding time (seconds)		:	Differences in holding time determination
	:	Determined by sol-u-bridge Home-made	RD5	:	
1	:	32.3	33.3	:	-1.0 seconds
2	:	31.0	29.1	:	1.9 "
3	:	26.1	25.4	:	0.7 "
4	:	23.5	22.4	:	0.8 "
5	:	22.8	21.4	:	1.4 "
6	:	20.8	19.2	:	1.4 "
7	:	18.2	18.1	:	0.1 "
8	:	17.2	17.4	:	-0.2 "
9	:	17.0	16.1	:	0.9 "

The data indicated that the response in the home-made sol-u-bridge was slower in all but two positions, those being practically the two extreme positions.

6. Revolutions per minute of single speed centrifugal pump

The speed of the centrifugal pump was determined. The data are presented in Table 7.

Table 7. The revolutions per minute made by the tri-clover single speed centrifugal pump

Number of revolutions	:	Seconds clocked	:	Revolutions per minute
	:		:	
790	:	30	:	1580
800	:	30	:	1600
1595	:	60	:	1595
805	:	30	:	1610

The speed of the tri-clover pumps was relatively fast. With such speeds and recirculation of milk for 15 minutes, churning might be expected to take place.

7. Revolutions per minute of single speed agitator

The speed of the milk agitator was determined. The data are recorded in Table 8.

Table 8. Revolutions per minute made by the milk agitator

Revolutions per minute	:	Minutes clocked
	:	
20	:	0.5
30	:	0.5
62	:	1.0
60	:	1.0
80	:	1.0

The revolutions per minute of the agitator were 20 (Table 8). This relatively slow speed was insufficient to cause churning.

8. Influence of directions of flow on the capacity of the pasteurizer

The gallons per minute processed was determined in both the forward and diverted flows while in the same valve position. Data obtained are in Table 9.

Table 9. A comparison of the volumes delivered at the same valve positions while the system was in diverted and forward flows

Flow direction :	Position : of valve :	:	:	:	Difference in quantity : at same position
:	:	:	mls./min. :	gals./min. :	:
Diverted :	1 :	:	2380 :	.629 :	580 ml.
Forward :	1 :	:	1960 :	.518 :	
Diverted :	2 :	:	2870 :	.759 :	620 ml.
Forward :	2 :	:	2250 :	.595 :	
Diverted :	3 :	:	3400 :	.883 :	950 ml.
Forward :	3 :	:	2550 :	.674 :	
Diverted :	4 :	:	3700 :	.978 :	1,000 ml.
Forward :	4 :	:	2700 :	.714 :	
Diverted :	5 :	:	4360 :	1.152 :	1,460 ml.
Forward :	5 :	:	2900 :	.765 :	
Diverted :	6 :	:	5100 :	1.35 :	2,040 ml.
Forward :	6 :	:	3060 :	.814 :	
Diverted :	7 :	:	5940 :	1.57 :	2,690 ml.
Forward :	7 :	:	3250 :	.859 :	
Diverted :	8 :	:	7260 :	1.92 :	3,910 ml.
Forward :	8 :	:	3350 :	.886 :	
Diverted :	9 :	:	7660 :	2.03 :	4,260 ml.
Forward :	9 :	:	3400 :	.899 :	

It can be seen from the data presented in Table 9 that the volume of milk treated per hour depended on the position of the valve. The rate of flow in forward direction varied from that in diverted direction by as little as 580 mls. to as much as 4,260 mls. which represented a difference in volume of 29.3 to 125.2 percent respectively. This meant that the saline solution (or milk) was retained in the heater 1/7 to 2 times as long as when in diverted flow, even though the valve position and voltage

[illegible]

er heat input was not changed. Therefore, the temperature of the saline solution (er milk) should be expected to rise rapidly, depending on valve position, when the pasteurizer suddenly goes into forward flow.

The recording chart (Figure 2) shows that the above deduction was correct since the temperature rose continually after the saline solution went into forward flow. A restriction caused by a washer being welded on to the stem of the diversion valve formed a collar which slowed up the flow when the saline was in forward flow.

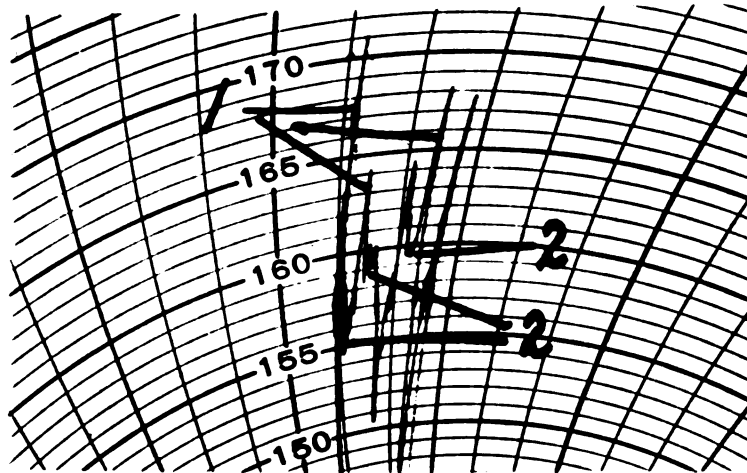


Figure 2. Showing the rapid rise in temperature after the saline solution went into forward flow.
1. Forward flow 2. Diverted flow

B. PASTEURIZATION OF MILK USING ORIGINAL EQUIPMENT

1. Operation

Data obtained on the operation of the machine when milk was used are given in Table 10.

Table 10. A typical run using the original equipment,
240 volts, and milk

Elapsed time : (minutes)	Temperature of milk tank (° F.)	Direction : of flow	Valve position
0	68	: Diverted	: 6.0
5	78	: Diverted	: 6.0
10	85	: Forward	: 4.5
15	85	: Forward	: 5.0
20	84	: Diverted	: 5.5
25	90	: Forward	: 6.0
30	92	: Forward	: 7.0
35	92	: Forward	: 7.5
40	91	: Diverted	: 6.0

The data show that the valve control was not adequate enough since the flow of the milk would change quicker than the operator could respond to the changing temperatures. This lag in response to temperatures caused the milk to go from diverted to forward and so on until the valve position was set just right by trial and error. After 10 minutes of forward flow the milk diverted; then after going back in forward flow, the milk diverted again after 15 minutes of pasteurizing.

2. Creaming ability

The cream line was determined since butter granules appeared in the raw milk tank after milk had been in forward flow. The amount of cream line reduction that took place due to churning action is shown in Table 11.

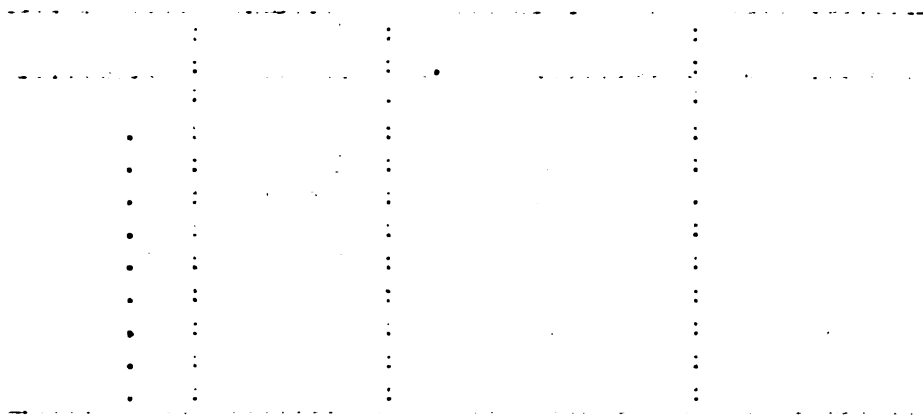


Table 11. The creaming ability of the processed milk testing 3.6 percent butterfat

Sample number	: Treatment : (°F.)	: Time : (Min.)	Cream volume		
			: Milliliters	: Percent	: Percent Reduction
1	: 68	: 0	: 16.0	: 100.0	: 0.0
2	: 130	: 5	: 15.0	: 93.8	: 6.2
3	: 160	: 10	: 8.5	: 53.1	: 46.9
4	: 161	: 15	: 8.0	: 50.0	: 50.0
5	: 163	: 20	: 8.0	: 50.0	: 50.0
6	: 165	: 25	: 8.0	: 50.0	: 50.0

3. Flavor

Flavor determinations were made on samples of the milk taken throughout the entire run. Cooked flavor was found in samples which were treated at 165° F. or higher. The samples treated at 160° to 163° F. were excellent in flavor.

4. Acidity of milk

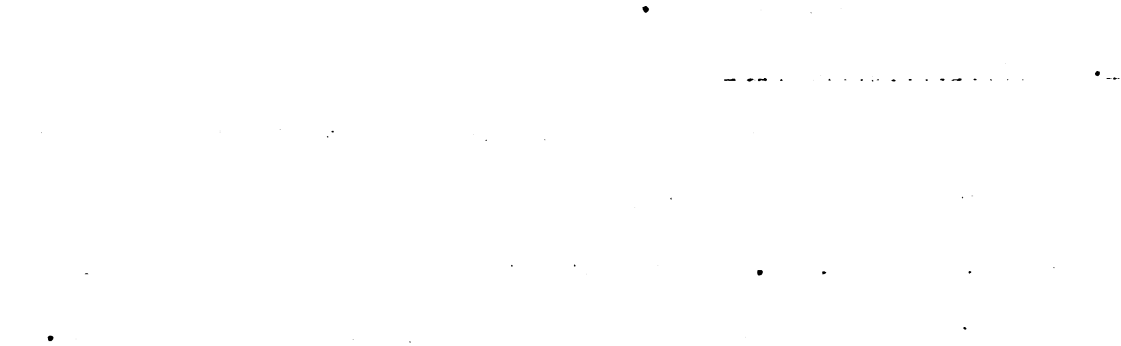
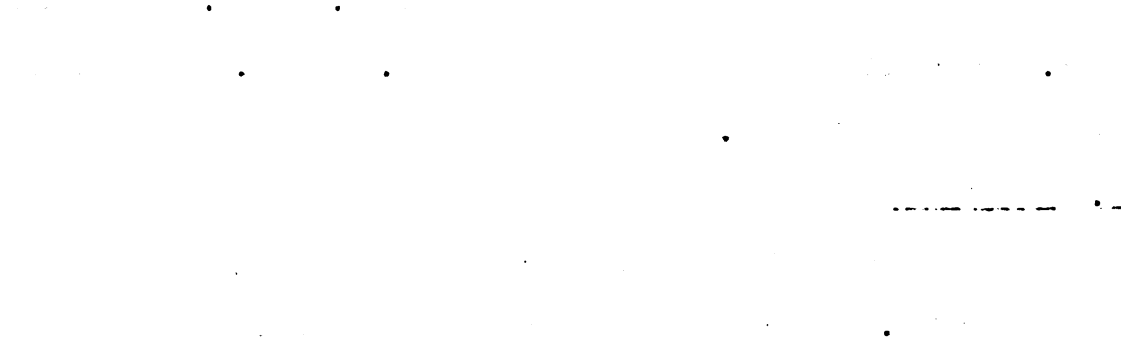
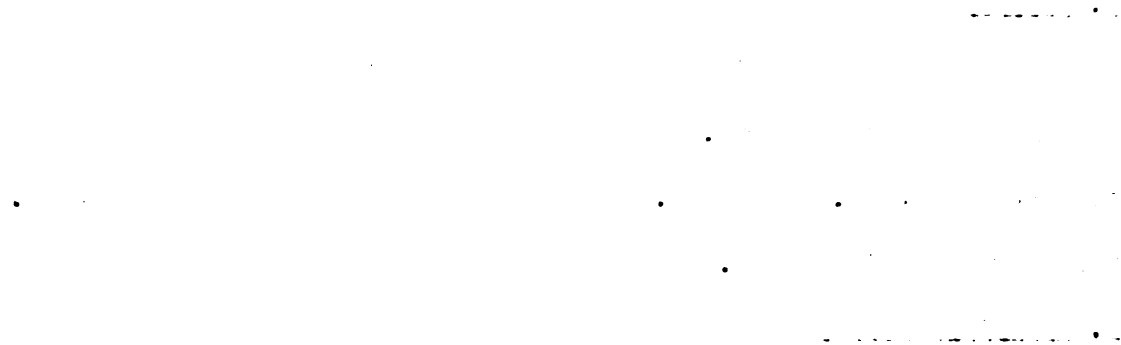
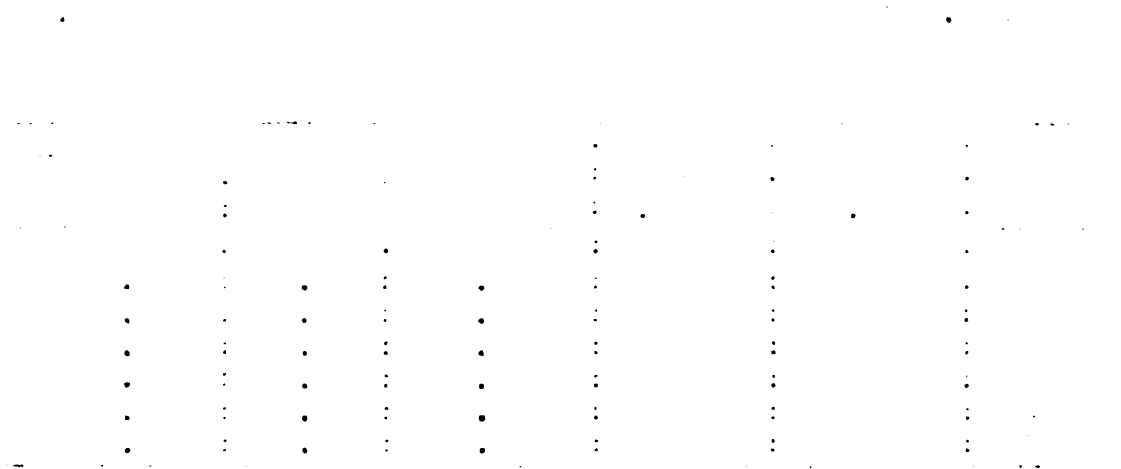
Only samples which had an acidity of 0.15 to 0.18 percent were used. The acidity of the milk dropped from 0.002 to 0.01 percent as a result of pasteurization.

5. Phosphatase

All pasteurized samples were negative since they all tested less than two units. The raw milk samples tested more than five units and were therefore definitely positive.

6. Bacteriological tests

Bacteriological tests were made but were not reported here since the temperature controls were not perfect at the time these runs were made. There was, however, 99.9 percent reduction in bacteria population but this is not significant since there was definitely signs of overholding.



C. PASTEURIZATION OF MILK SUBSTITUTING A VARIABLE

SPEED PUMP IN THE ORIGINAL EQUIPMENT

1. Operation

The operating equipment was similar except the speed of the pump was varied. Speeds of 1080, 1266 and 1520 revolutions per minute were tried.

When the pump was set to revolve at 1080 and 1266 revolutions per minute, the operation had to be stopped since the temperature of the milk could not be controlled.

2. Creaming ability

Table 11 illustrated that as much as 50 percent creamline was reduced during pasteurization. It was also stated previously that butterfat granules appeared in the surge tank while the milk was in diverted flow. The speed of the pump was thought to be the cause of this loss due to churning action. Table 12 illustrates the extent of creamline loss when the speed of the pump was slowed down to 1520 revolutions per minute.

Table 12. Creaming ability of milk when determinations using variable speed pump set at 1520 revolutions per minute

Sample number	: Treatment :		Time : Operating:	: Cream volume		
	: temperature:			:	:	Percent
	: (° F.)	:	(Min.)	: Milliliters:	Percent :	Reduction
1	: 62	:	0	: 13.0	: 100.0	: 0.0
2	: 130	:	5	: 12.5	: 92.3	: 7.7
3	: 160	:	10	: 7.5	: 57.8	: 42.2
4	: 163	:	15	: 7.0	: 53.9	: 46.1

3. Flavor

The flavor of the milk was determined from time to time during processing. Cooked flavor was found in practically all of the pasteurized

samples. This was thought to be caused by the increase in holding time due to the fact that the variable speed pump was set to make 270 less revolutions per minute.

4. Acidity

The acidity of the milk was lowered due to pasteurization. This was the same as in the previous trials. All milk which tested 0.19 percent or more was not used.

5. Phosphatase

The phosphatase test showed five units or more for the raw samples and more than two but less than five units in the diverted samples. All of the samples obtained while the system was in forward flow had a phosphatase test of less than two units. Thus the raw and diverted samples had a positive phosphatase while the pasteurized samples had a negative phosphatase.

6. Bacteriological tests

Bacteriological tests are not recorded even though aseptically taken milk samples were plated, since the cream line reduction was as severe as in the previous runs.

D. PASTEURIZATION OF MILK USING A WAUKESHA POSITIVE PUMP

AND AN ELECTRICAL CONTROL PADDLE

1. Substituting new equipment in original pasteurizer

Previous tests proved that varying the flow of the milk was not a satisfactory method of controlling the treatment temperature. It was, therefore, thought that a more constant control could be had by varying the electrical input. This was done by installing a pivotally supported paddle having its axis at the intersection of the diagonals drawn between the corners of the chamber. By a control handle externally of the chamber the

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paddle was turned parallel to the faces of the electrodes, thus resulting in greatest shielding and minimum power input or it was turned at right angles to the electrodes resulting in minimum shielding and maximum power input.

The paddle was mounted in the 14-inch heater which was installed and which necessitated changing of the voltage back to 205 volts.

A clamp type ammeter was attached around the incoming electrical power line. The position of the paddle was marked 1-10, the ammeter showed the greatest power consumption when the paddle was set at 10.

A Waukesha positive pump was installed in the redesigned equipment. The reason for the substitution was to obtain a constant volume at all times. The pump was adjusted to deliver milk at a rate that it would take 16 seconds for the milk to pass through the holding tube.

With the new equipment being substituted in the original equipment, the variable speed pump, the thermal thermometer, and the metering valve were removed. The Waukesha positive pump replaced the variable speed pump; a 212° F. indicating thermometer replaced the metering valve, and a plug was placed in the place of the thermal thermometer.

2. Holding time

The holding time was determined, using the same equipment as was used in the previous determinations with the equipment shown in Figure 3. The speed reducer attached to the Waukesha pump was adjusted by turning a round shaft which stuck outside of the housing. The holding time was taken and the adjustments made until the required 16 seconds retention was had. Since only one position was now available, due to the removal of the metering valve, no table was prepared to show the holding time determinations.

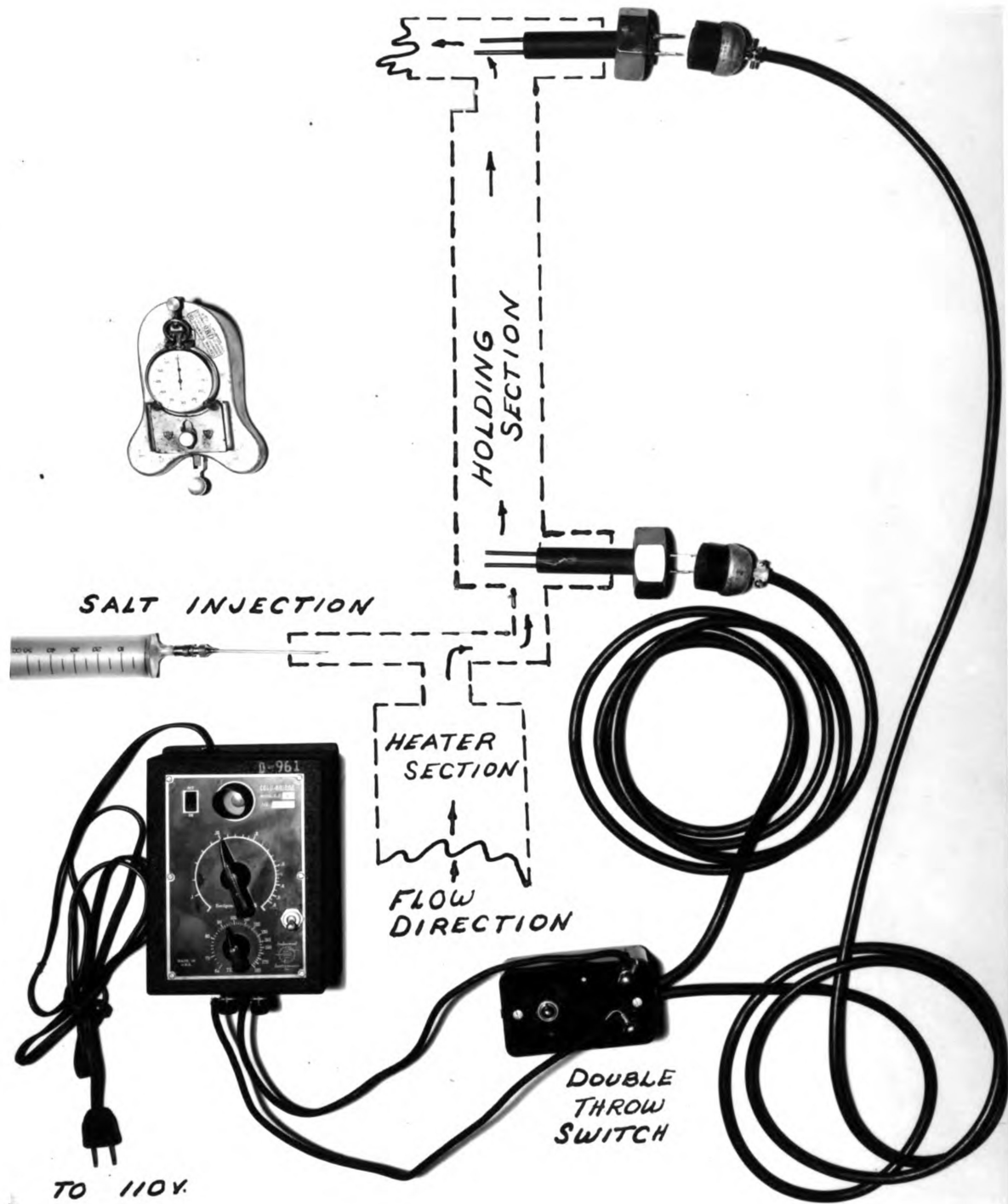


Figure 3. The electrical hook-up and instruments used to determine the holding time.

3. Pounds per hour processed

The pounds of milk processed per hour was found by weighing the milk pasteurized during a five-minute period and multiplying by 12. The machine was found thus to pasteurize 357 pounds of milk per hour.

E. PASTEURIZATION OF MILK USING REDESIGNED EQUIPMENT

WITH THE PADDLE AS THE ELECTRICAL CONTROL

1. Operation

Since the metering valve was discarded, the method of operation was changed entirely. The operation of the machine was as follows: After the machine was washed, reassembled and sanitized, raw milk was dumped into the raw tank. With the agitator on, samples were taken for bacteriological, physical and chemical analysis. The recording and pump switches were placed in the "ON" position. After a few minutes of milk circulation in the surge tank, the heater switch was turned on which energized the heater. The milk was allowed to circulate through the diverted flow until the surge tank temperature was such that the heater was able to heat the milk to 161° F. which put the milk into forward flow. This was accomplished by moving the paddle handle to the number 10 position and observing the ammeter so that not more than 50 amperes would be used at any one time. Meanwhile, the 212° F. indicating thermometer (which replaced the metering valve) was observed so that at no time did the temperature go above 167° F. and then only occasionally did it go above 163° F. When the recording thermometer was recording a temperature that was close to the cut-in point, the paddle position was reduced so that the temperature of the milk leaving the heater was very close to 163° F. The need for this extra 3 degrees was due

to the fact that the holding section was of stainless steel and had no insulation around it. Therefore, in order to prevent the milk passing through the holding section, from being cooled to below 161° F. it was necessary to increase the heater exit temperature of the milk.

The heater exit thermometer was observed continually throughout the entire operation to make sure the temperature of the milk did not get out of range. A record of the temperatures that occurred throughout a run using this new temperature control is presented in Figure 4.

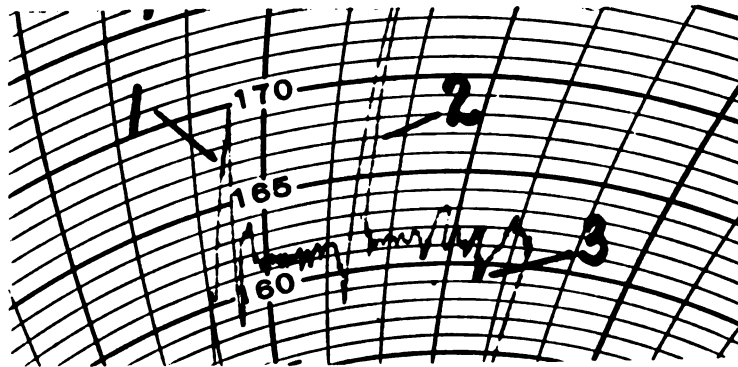


Figure 4. A record of a run made with an insulating paddle as the electrical control.

1. Adjusting the temperature controls.
2. Adding cold raw milk.
3. Went into diversion.

Data of a typical run using the paddle control for maintaining the desired temperature are given in Table 13.

Table 13. A typical run using the paddle control for maintaining the desired temperature

Minutes	Surge tank	:	:	:	Heater exit	:	Control
operating:	temperature (°F):	Voltage:	Amperes:	temperature (°F):	position		
0	48	: 200	: 50	: 153	: 9.0		
12	62	: 200	: 50	: 157	: 8.0		
14	62	: 200	: 38	: 163	: 3.5		
24	62	: 200	: 35*	: 165	: 3.5		

*Minimum limit

As can be seen in Figure 4, the temperature remained rather constant throughout the entire run. The milk diverted only when colder milk was dumped into the surge tank. The data of Table 13 illustrate the rather low temperature required in the surge tank before the heater was able to place the milk in forward flow. The 200 volts was not intentional but was the result of other machinery being hooked up to the same 205-volts line.

Since milk offers less resistance when warm than when cold, the ampere consumption was not able to go below 35; thus the temperature would rise somewhat. The paddle had to be manually moved to a trifle lower position after the amperage consumption was a little above 35 amperes.

After two hours of operation the machine was disassembled and the parts observed. The paddle had a caseous deposit on its edge. The deposit seemed to be the greatest near the upper portion of the paddle and on up to the inside of the heater outlet hole.

2. Creaming ability

Since the temperature in the heater at the upper section was high enough to cause the casein to be deposited, it was thought that the creaming ability of the milk was also injured. The extent of cream line destruction when the paddle was used as the temperature control is shown in Table 14.

Table 14. The creaming ability of the processed milk testing 3.6 percent butterfat

Sample number:	Treatment : temperature (° F.)	Operating : time (minutes)	Cream volume			
			Milliliters	Percent	Percent	reduction
1	48.0	0	18	100.0		0.0
2	62.0	12	16	88.9		11.1
3	163.5	14	15	83.4		16.6
4	162.0	24	15	83.4		16.6
5	163.0	30	15	83.4		16.6

The data show a 16.6 percent reduction in cream line. This loss is much less than the previous runs using other equipment but still it seemed that if the "hot spot" in the heater could be eliminated the creaming ability of the milk would not be injured in the least and maximum creaming would result.

3. Flavor

The flavor of the treated milk was excellent throughout the 50-gallon run. The cooked flavor of previous runs was not noticed unless the temperature went out of range, that is, above 163° F.

4. Acidity of milk

Acidity was determined as a means of choosing normal milk since milk containing an acidity which is higher than normal would heat quicker due to greater conductivity. Erroneous heating times would result since the average milk has a normal acidity.

5. Phosphatase

Never in any of the previous runs or in the present runs, was there a positive phosphatase test in the pasteurized samples. Only the raw and diverted samples tested positive phosphatase.

6. Bacteriological tests

- a. Total count The bacteria plate count is recorded in Table 15.

Table 15. The total bacteria population in samples plated and incubated according to Standard Methods

Sample Source	Organisms per ml. of milk sample	Percent	Percent reduction
Raw	8,300,000	100.0	0.0
Diverted	50,000	1.66	98.34
Pasteurized	22,000	0.66	99.34
Pasteurized	20,000	0.06	99.94
Pasteurized	51,000	1.40	98.60
Pasteurized	38,000	0.22	99.78

The percentage reduction of bacteria as a result of pasteurization averaged at least 99 percent (Table 15).

- b. Thermophilic and thermophilic organisms The determination of thermophilic and thermophilic organisms was not made since the cream line reductions and the casein deposit on the paddle were still to be corrected.

- c. Coliform organisms The coliform organisms in the samples treated were as follows:

Sample	Desoxycholate plate count
Raw	111,000
Diverted	10
Pasteurized	0
Pasteurized	1
Pasteurized	0
Pasteurized	0

F. PASTEURIZATION OF MILK SUBSTITUTING A SLIDING BOX
FOR THE PADDLE IN ELECTRICAL CONTROL

In an effort to prevent the formation of casein in the heater, a sliding box was devised in such a manner that it would fit snugly into the heating chamber. The box cut off the electricity by masking but did not affect the flow of the milk. The mechanical motion of the box was up and down, the up position providing complete masking of electrical input. The masking could be so complete that the current flow was barely perceptible, which was noticed by the ammeter needle slightly moving from the zero position.

At first the sliding box was a block which was solid on the bottom except for four holes drilled through it. Later four flat pieces of insulating material were mounted in the form of a hollow box.

1. Operation

The operation of the pasteurizing equipment using the sliding box was identical as in the paddle control runs. The box was moved up and down rather than in a pivot fashion as was the paddle. The voltage was changed from 205 to 245 volts.

The run was shortened appreciably by the high voltage applied to the chamber, the same slight fluctuation of the ammeter needle which had preceded previous break downs was noticed. Approximately 15 minutes later this was followed by a dropping of the milk temperature at the outlet calling for movement of the power input control to a higher position. This was quickly followed by a sulfurous off flavor in the pasteurized milk. On disassembly it was found that a deposit of casein of about 1/8 inch maximum thickness had formed across the lower face of the shield block

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bridging the carbons and that this deposit, especially on contact with the carbons, had been blackened as by arcing.

The box had possibilities of being used in the method of electrical control but further experiments were not carried out since the cost of the equipment and the necessary modifications of recess forming would be far greater than the cost of the paddle previously used.

The experience from the use of the sliding box pointed out that higher than 205 voltage should be avoided to keep down the amount of casein formation in the heater section.

G. PASTEURIZATION OF MILK USING THE PADDLE TYPE CONTROL
AND A RESISTANCE STABILIZER

Warm milk had a tendency to get warmer since warmer milk offered less resistance to the current flow. This caused a creeping of temperatures while in forward flow to points beyond the normal range. The compensation for this creeping of temperature was overcome by a constant change in paddle position which could not be done right at the moment of temperature change. Therefore, a resistance stabilizer was designed to be activated by the thermostat setting to which it was attached. The electric wiring used in the pasteurizer with the resistance stabilizer is illustrated in Figure 5. A record of the run is shown in Figure 6.

1. Operation

After pasteurization was started, the manual control handle of the paddle was adjusted until the thermostat contacts were in action with nearly equal balance between the duration of opened and closed periods. This was done irrespective of the reading of the mercurial thermometer, the recording thermometer, or whether the milk was in forward or diverted flow.

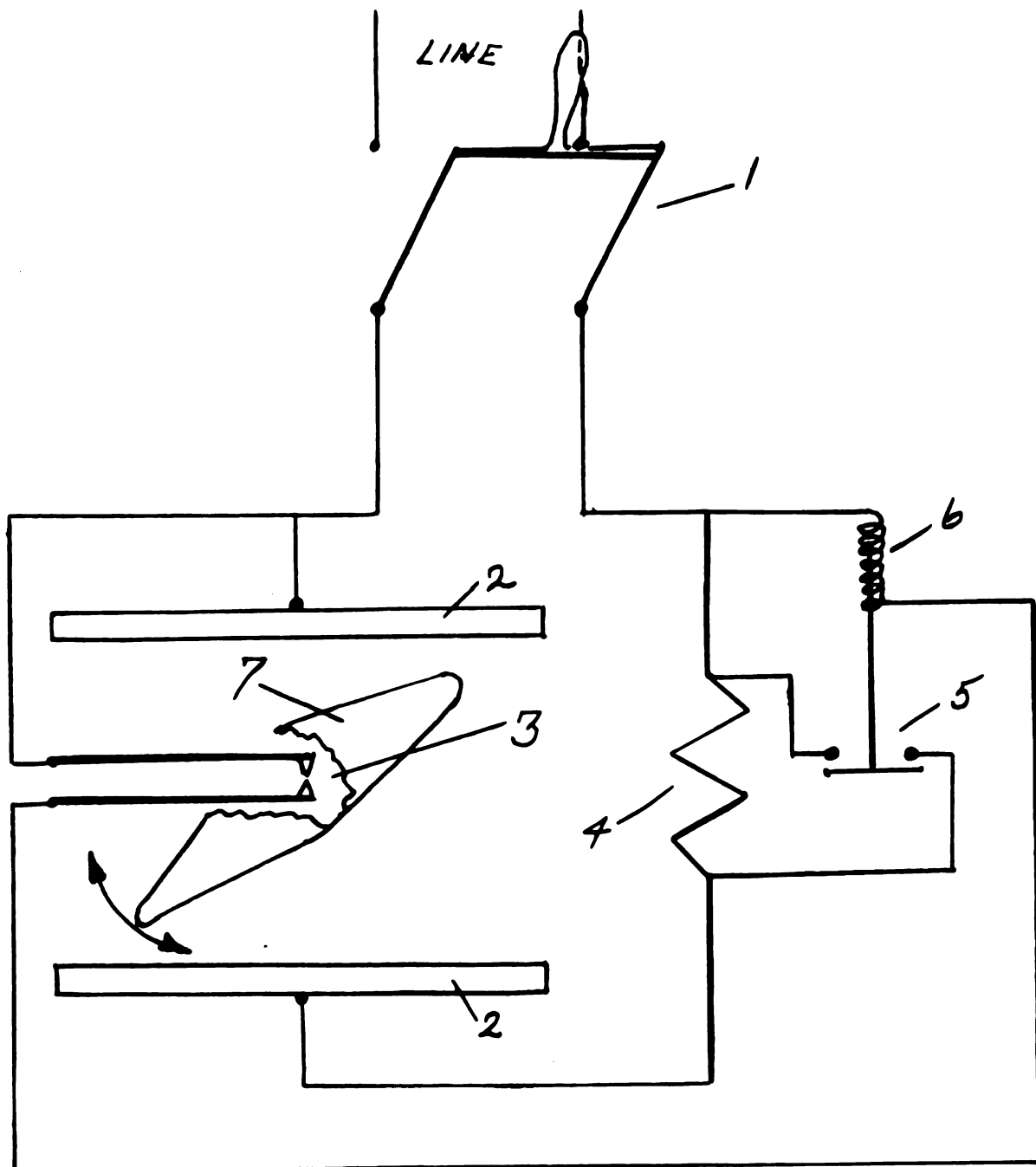


Fig. 5. The system of electrical wiring used in the perfected pasteurizer showing: 1. Main switch, 2. Electrodes, 3. Thermostat, 4. Stabilizing resistance, 5. Relay contacts, 6. Relay actuating solenoid, 7. Pivottally supported primary power input control paddle.

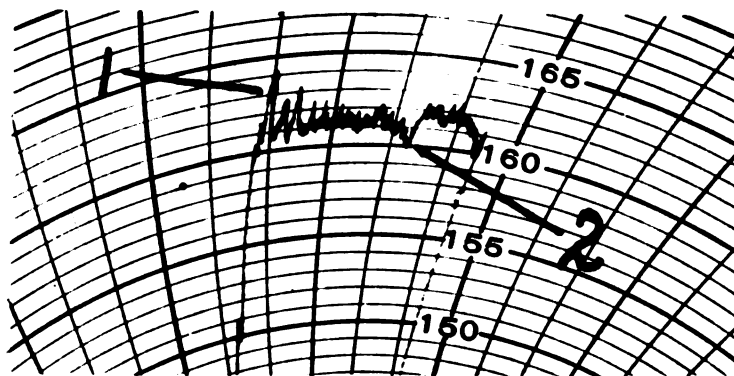


Figure 6. A record of a run made using the resistance stabilizer and the paddle for temperature control.

Since the raw tank temperature was too low for the heater to heat the milk so that it would go into forward flow in a single pass, it was necessary to warm up the raw milk in the surge tank by diversion. The operation consisted of manipulating the manual control to position 10 so that the maximum permissible current was drawn. This position was kept until the diversion valve was in forward flow. It was found that the power input control had to be well tended to prevent excessive current input during warm up. When the control paddle was correctly adjusted, the temperature at the recorder and the behavior of the flow diversion valve took care of themselves automatically.

After the thermostat signal clicked on and off intermittently for a few minutes, and the recording and mercurial thermometers did not come up to pasteurizing temperature, the adjustment of the thermostat was made so that a slightly higher temperature was required to open the contacts. This adjustment was quite sensitive and therefore, only a slight movement of the adjusting screw was made.

During the operation raw milk was added one can at a time. This prevented any radical changes in temperature which would cause the flow to go into diversion. When the change in temperature was anticipated the manual control handle was adjusted to consume more current so when the milk was added the temperature would drop to the normal pasteurization temperature. It was particularly desirable that no sudden drop in raw milk temperature beyond the range for which the stabilizer would readily make compensation to prevent temporary diversion from forward flow.

If it was known that the next milk to be added to the raw tank was colder than the milk in the tank, the manual power input control handle was adjusted to increase the power input until the ratio of open to closed time of the thermostat contacts was approximately 5:1. Upon addition of the colder milk the ratio of open to closed time automatically became less and the operator had an opportunity to stabilize the electrical input at the normal ratio of 1:1 if the temperature of the raw milk was not too drastically lowered.

Conversely, if the milk that was added was warmer than that already in the tank the manual control handle was first adjusted so that the ratio of closed to open duration was approximately 5:1. After the warmer milk was added the 5:1 ratio dropped, thus giving the opportunity to stabilize it at a 1:1 ratio by manipulating the power control if necessary.

Except when adding raw milk it was found best to operate with a ratio of closed to open duration of the thermostat contacts of 2:1 or 3:1. This caused a saving of slight, unnecessary loss of electrical energy in the resistance stabilizer since the excess electrical energy was used to heat the resistance in the stabilizer.

Data obtained from a run made by the operating instructions just given are presented in Table 16.

Table 16. A typical run using a paddle as the electrical control with a resistance stabilizer

Time (min.)	Tank temp. (° F.)	Amperage	Control position	Volts input	Mercurial thermometer (° F.)	Recording thermometer (° F.)	Flow direction
0	52	50.0	8.0	200	0.0	0.0	D.
5	63	48.5	6.5	200	159.0	150.0	D.
10	74	38.0	4.0	200	163.0	163.0	F.
15	58*	49.0	7.5	200	162.0	162.0	F.
20	58	49.0	8.0	200	162.0	162.0	F.
25	56	Adjusting	Adjusting	200	164.5	164.5	F.
30	70	44.0	6.5	200	163.0	163.5	F.
35	50*	Adjusting	Adjusting	200	157.0	157.0	D.
40	62	49.0	8.0	200	163.5	164.0	F.
45	70	49.0	4.75	198	162.0	162.0	F.
50	70	50.0	4.5	198	164.0	165.0	F.

*Raw milk was added.

As is illustrated in Table 16, the temperature remained much more constant throughout the entire run. The run was made to determine the effect of adding frequently small amounts of cold raw milk to lower the temperature of the milk in the surge tank. Compensation for the lowering in surge tank temperature was made according to directions outlined in the operation of the machine reported earlier.

DISCUSSION

The time needed to preheat the raw milk in the surge tank, using the original equipment, was studied and was found to be too long for practical operations. A higher voltage of 245 was substituted for the 208 volts previously used. This new voltage reduced the preheating time to as little as 5 minutes. This resulted in a great saving of time.

The metering valve was used to raise or lower the temperature of the milk. This was found to be inadequate for when the flow was increased, the holding time decreased, while the holding time increased when the flow was decreased. This caused an overholding of the milk since the maximum flow resulted in 16 seconds holding while the minimum flow resulted in 33 seconds holding. This was corrected by changing the method of temperature control and by substituting a positive pump to provide a constant flow of milk. Thus the holding time remained constant throughout the runs.

The head pressure of the pump caused a change in holding time even when the flow remained the same. When a check was made of the holding time while the valve position was set at 9, with the water level in the tank high and with it low, it was found that the holding time was 2 seconds greater at the lower level. This meant that the milk would remain in the holding tube two seconds longer than necessary. Thus, the lower water level might have been the cause of overholding.

A home-made sol-u-bridge was found to increase the holding times in the same valve positions when compared with a commercial sol-u-bridge. The home-made sol-u-bridge was found to be satisfactory but was slower in recording the closing of the circuits by the salt. The inaccuracy of the home-made sol-u-bridge could have been the cause of overholding.

The gallons processed per minute depends upon the speed of the milk pump. The speed of the original pump was found to be 1600 revolutions per minute. This speed is such that much churning and agitation result during pumping and if cold milk is pumped the cream portion of the milk might churn into butter granules. To correct this a variable speed pump was found satisfactory to some extent at 1520 revolutions per minute. Lower speeds than 1520 caused a rapid rise in temperature and, therefore, poor controlling of the milk temperature.

The agitator revolving at 60 revolutions per minute, caused no churning.

The quantity of milk that flowed while in diversion was from 580 to 4,260 milliliters more than when the milk was in forward flow. This was found to be the cause of the rapid temperature rise when the milk suddenly went from diversion to forward flow. A restriction on the stem of the diversion valve was removed to equalize the respective flows. Thus the temperature remained constant instead of rising rapidly when the milk went into forward flow.

1. Pasteurization of milk using original equipment

The temperature change was not responded to rapidly enough to make necessary adjustment in valve control. After 10 minutes of operation in forward flow the milk would suddenly go into diversion for no apparent reason. Therefore, equipment was necessary that would respond rapidly to a slight change in temperatures. This was found in the way of an ammeter, a paddle or sliding box, and a resistance stabilizer which will be discussed later.

The creaming ability of the milk treated with the original equipment was found to be reduced by as much as 50 percent. The reduction was found to be due to churning action of the centrifugal pump operating at 1600 rounds per minute. Installing a Waukesha positive pump overcame this difficulty and this will be discussed in a later paragraph.

The physical, chemical and bacteriological tests were found to be satisfactory except the creaming ability of the milk. Cooked flavor resulted if treatment temperatures exceeded 165° F.

The acidity of the milk dropped by as much as 0.01 percent as a result of pasteurization.

Bacterial reduction was as much as 99.9 percent. Since there were definite signs of overholding, this was not considered significant.

2. Pasteurization of milk substituting a variable speed pump for the original tri-clover centrifugal pump

The pump was found to be inadequate for it also churned out portions of the cream. The extent of cream line reduction caused by the variable speed pump was 46 percent. The pump was therefore discarded.

3. Pasteurization of milk using a Waukesha positive pump and an electrical control paddle

With the substitution of the positive pump it was necessary to remove the thermal thermometer, the variable speed pump and the metering valve. With their removal the Waukesha positive pump replaced the variable speed pump; a 212° F. indicating thermometer replaced the metering valve, and a petcock was placed in the thermal thermometer.

With the new equipment installed, the milk processed per hour was found to be 357 pounds. The amount of milk could be increased or decreased by increasing or decreasing the length or width of the holding and adjusting the speed of the pump to compensate the holding section increase. The adjustment should be made to such an extent that the holding time was 16 seconds.

4. Pasteurization of milk using redesigned equipment with the paddle as the electrical control

Since the metering valve was discarded, the method of operation was changed. An indicating (mercury-in-glass) thermometer was placed at right angles to the holding section in the place of the metering valve, thus providing the much needed indications of temperature changes taking place in the heater. The type of run was found to be favorable since the milk remained in forward flow for a much longer period of time, since adjustments in controls could be made just about as fast as the changes were taking place. Upon disassembling the heater section and removing the paddle it was found that a heavy caseous deposit formed on the edge of the paddle. The deposit shorted the electrical circuit and thus caused the ammeter to weave during the run. The conclusion was not reached, however, until the paddle section was disassembled.

The creaming ability of this milk was affected much less than was ever encountered before. Therefore, the paddle method of electrical control was considered to be the best tried. The extent of cream line reduction was only 16.6 percent. Sixteen and six tenths percent reduction was considered to be too high and an effort was made to reduce the loss. It was thought that there was arcing of electricity in the chamber and thus a "hot spot"

developed which precipitated casein and therefore, also injured the creaming ability of the milk.

The bacteriological tests conducted on this run were found to be satisfactory since a reduction of as much as 99.94 percent was encountered. No count was greater than 51,000 organisms per milliliter. The coliform counts made by using desoxycholate were found to be 0 in all pasteurized samples but one. The raw milk of this test contained 111,000 organisms per milliliter.

The phosphatase tests of all pasteurized samples in this and all prior runs were negative, while all raw and diverted samples were positive.

5. Pasteurization of milk substituting a sliding box for the paddle in electrical control

In an effort to prevent casein deposit formation, which was found to be the cause of a foul, sulfurous flavor in pasteurized milk, especially after a four or five hour run, a sliding box was substituted in the heating chamber. The effect the box had on the electricity passing through the milk was the same as if the length of the electrodes was shortened by cutting. As the box moved up it covered a greater area of electrode, thus reducing the electrical effect of the milk. Therefore, the temperature of the milk was reduced. The box also caused the off-flavor to develop in the pasteurized milk. However, it was found that voltages greater than 205 enhanced the development of the casein deposit. Plans are in the making to design a paddle which not only would pivot but would also slide up and down in the electric heater. This would give the features of both the sliding box and the paddle. It was also learned that cooling water on the electrodes reduced the tendency of casein deposit.

6. Pasteurization of milk using the paddle type control and a resistance stabilizer

The stabilizer was wired into the circuit as is shown in Figure 6. It acted to the setting of a thermostat which was substituted in the place of the indicating thermometer. The set screw of the thermostat was adjusted so that its range would be between 164 and 165° F. Therefore, any temperature above 165° F. could not be taken care of by the 1/2 ohm resistance in the resistance stabilizer box.

The milk leaving the heater was between 164 and 165° F. When these temperatures were approached, the signal (a small volt meter) responded intermittently, thereby taking care of the tendency of warm milk to rise in temperature due to its lesser conductivity at higher temperatures. With the thermostat setting at 164 to 165° F. the milk traveled through the holding tube where the temperature dropped as much as 5° F. The recording and mercurial thermometers registered temperatures of 161° F.

Several precautions must be observed when using the stabilizer as an automatic method of temperature control with the pivoting paddle. The problems of stabilization of the intermittent, on-and-off signal encountered when adding cold or excessively warm milk to the surge tank can be overcome if a large insulated storage tank is used. The operator would be required to stabilize the raw storage tank temperature with the control paddle in the heater and the intermittent signaling only once during the pasteurization of the entire storage tank of milk.

With the stabilizer added to the paddle manual control, it was found that a sensitive control could be had and that the milk would stay in forward flow for a long period of time.

The producer-size Electro-pure pasteurizer was found to be economical in operation since only a source of electricity is the added requirement; while if holding processing was practiced on the farm, soft water for the boilers and a source of fuel would be required.

7. Cost to pasteurize

The Electro-pure machine is designed to consume 10 kilowatts per hour. Therefore, 10 kilowatts would pasteurize 357 pounds of 35.7 pounds would require one kilowatt. The cost of a kilowatt in the rural areas is .02 cents. So $\frac{35.7}{2}$ equals 17.85 pounds pasteurized for one cent. $\frac{17.85}{2}$ equals approximately nine quarts of milk pasteurized for one cent. This equals 0.111 cents per quart of milk as the cost of pasteurization.

8. The efficiency of pasteurization was compared in the experimental high-temperature short-time pasteurizer with the holding pasteurizer

The milk for the comparison was obtained as described in the experimental procedure. The milk was then pasteurized in the experimental pasteurizer and samples were taken for chemical, physical and bacteriological analysis. The only advantage held by the holder method of pasteurization was the lower amount of creaming ability that was lost. Other than this there was no apparent difference in bacterial destruction except that coliform organisms were found more often in the (vat) holder pasteurized samples than in the high-temperature short-time pasteurized samples.

The milk was not checked for thermoduric or thermophilic organisms in the comparison of pasteurization processes since it is known that thermoduric organisms survive high-temperature short-time pasteurization much easier than in holder pasteurization. If the test were conducted with a special milk, such as high thermoduric milk, then it would be a particular

special milk which would not be the case commercially. If a high thermotolerant count in raw milk is tolerated, then regardless of the method of pasteurization, high total counts will result.

2. Comparison of experimental pasteurizer to a large, steam operated commercial model

Due to the fact that a local dairy recently installed a steam type high-temperature short-time pasteurizer, it was thought that a comparison of efficiencies of pasteurization might be carried out.

The results of the tests indicated that there were only a 7-percent loss of creaming ability in the case of the commercial unit, while the experimental model reduced the creaming ability by as much as 24 percent.

The phosphatase tests were all negative in the pasteurized samples.

The coliform tests were negative in all the commercial pasteurized samples while the experimental samples showed one positive coliform test and that being only one organism per milliliter. The desoxycholate agar was used for plating the coliform organisms which appeared as red colonies between the two layers of media. This media was found excellent and is used as routine testing in the Michigan State College Dairy Bacteriology Laboratory.

In all comparisons of the different methods of pasteurization, only one sample obtained from the experimental model had a total bacterial count of 50,000 organisms per milliliter. It was not considered serious since the count was 51,000 organisms per milliliter.

It must not be overlooked that at least 40 complete runs were made in the experimental pasteurizer, three runs with the holder pasteurizer and only one with the commercial unit. Therefore, the possibility of obtaining coliform organisms in the experimental pasteurizer was much greater.

SUMMARY

With respect to original equipment when 240 volts was used with a 6-inch heater the time required to heat the milk to pasteurization temperature was only 15 minutes; whereas 90 minutes were required when 205 volts was used.

The metering valve was ineffective as a means of temperature control. Any necessary changes to compensate for rise in temperature affected the holding time which fluctuated between 16-33 seconds.

Methods of time-temperature control included a metering valve, thermal thermometer and centrifugal pumps. All were found to be inadequate.

When milk went from diverted to forward flow the volume decreased as much as 29.5 to 125 percent, causing a marked, rapid rise and a lack of control in the temperature of the processed milk.

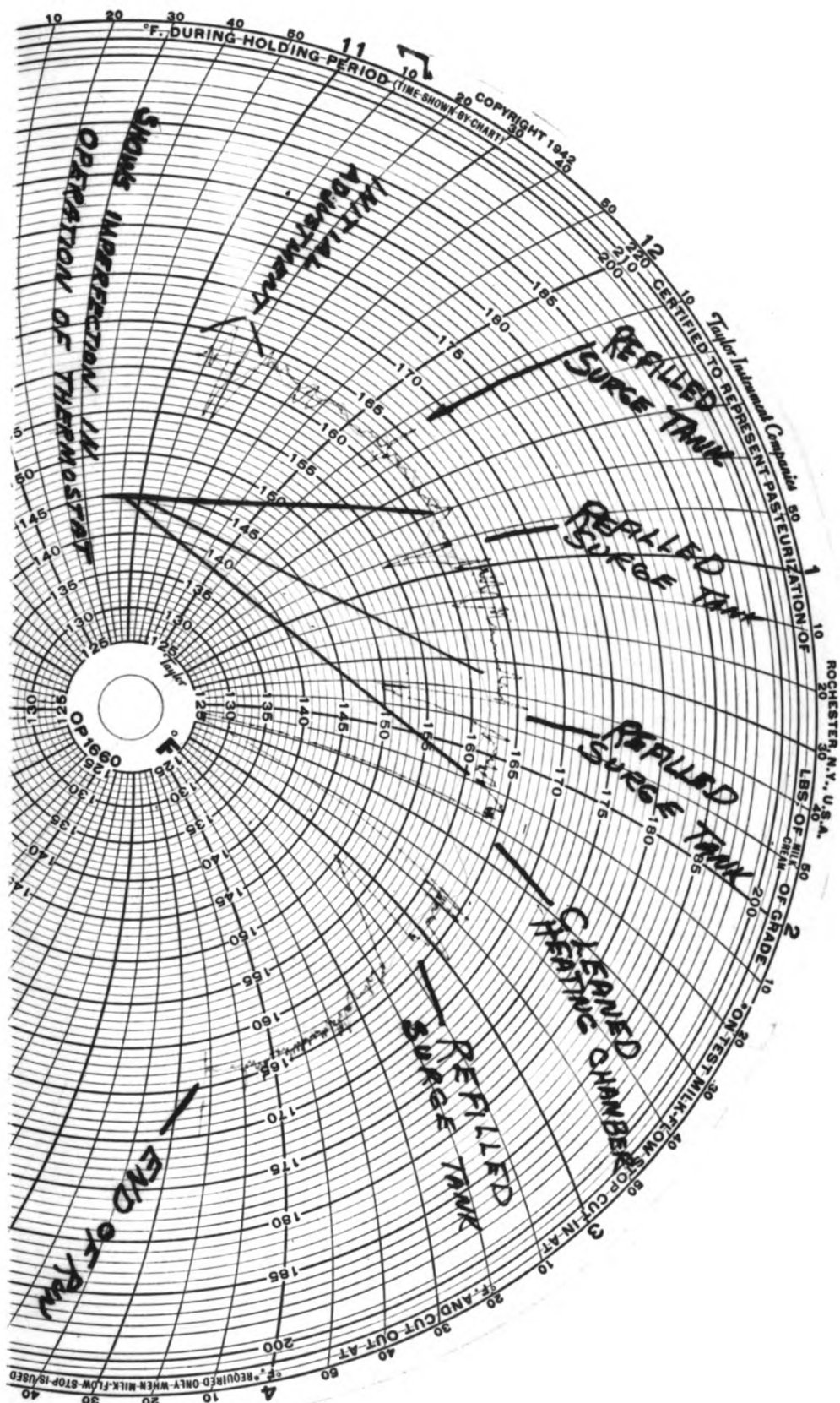
Although pasteurization so far as reduction of organisms and elimination of coliform bacteria were concerned was adequate, the creaming ability of the milk was reduced by as much as 50 percent, a cooked flavor was encountered and some churning resulted.

With respect to redesigned equipment, the original attempted time-temperature controls were replaced by a positive Waukesha pump and an indicating thermometer which provided satisfactory operation but required constant attention.

Later a manual control paddle (Figure 8), a sliding box (Figure 9) and a resistance stabilizer were added to affect a more sensitive control. These were found very effective. However, some minor adjustments were found necessary to prevent off-flavor development and deposition of casein on parts of the heating unit.

The redesigned equipment yielded adequately pasteurized milk with a high percentage of bacteria reduction, having excellent flavor and no cream plug, but impaired the creaming ability by as much as 21 percent.

Figure 7. Illustrating a pasteurization period run covering five hours, using a resistance stabilizer and the insulating paddle.



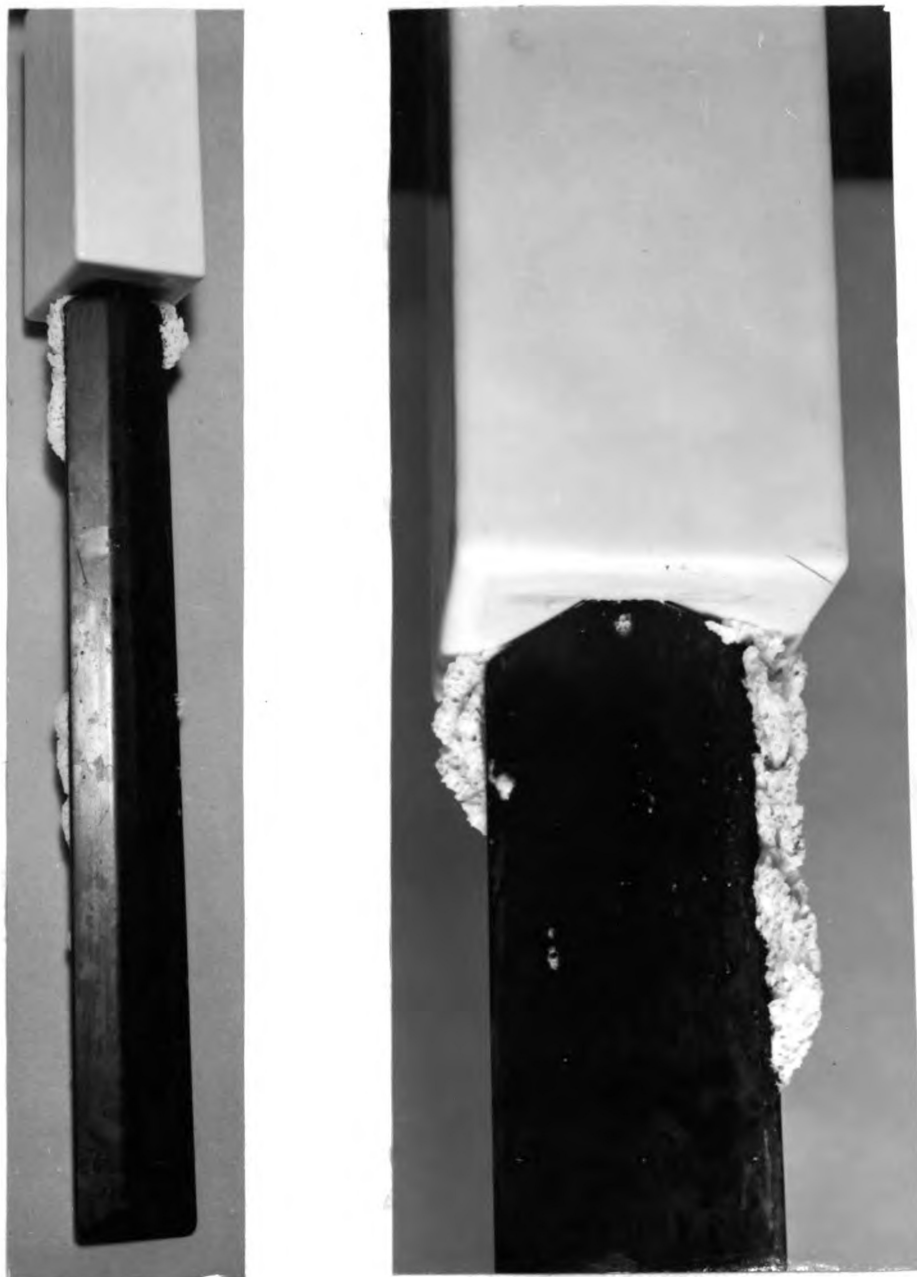


Figure 8. Showing two views of the hard rubber electrical control paddle just as it was removed from the upper end of the heater. The white spongy material is casein deposit.

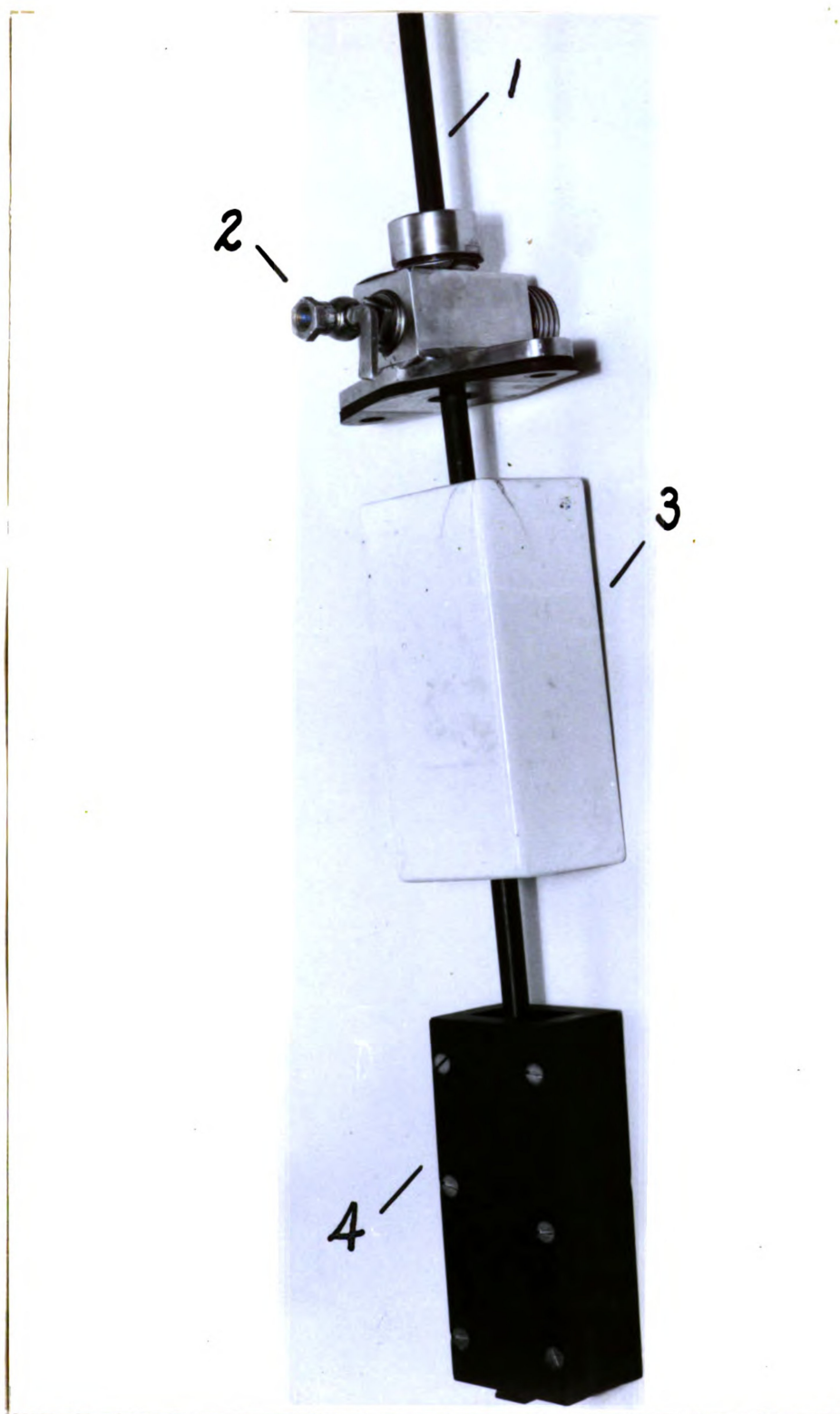


Figure 9. Sliding box, electrical control, showing:
1. Adjusting handle 2. Preheat sample
point 3. Porcelain insulation 4. Resinous
sliding box.

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