# STUDIES ON THERMAL METHODS OF MEASURING THE HOLDING TIME IN HIGH-TEMPERATURE SHORT-TIME PASTEURIZERS

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**Data are presented on the properties of thermal waves produced by several means of suddenly increasing or decreasing the temperature of the fluid moving through the holding tube of a high-temperature short-time pasteurizer. Thermal holding-time measurements made with eight instruments or methods are compared with the holding time measured by the 3-A standard salt test. The reasons for variation in the correction factor, the difference beween the holding times measured by the salt test and a thermal test, are discussed.**

The measurement of holding time by thermal methods involves rapidly changing the temperature of the fluid being pasteurized and then, with sensitive temperature-measuring devices, noting the first appearance of fluid with other than the normal pasteurizing temperature at the inlet end of the holding tube and again at the outlet end of the tube. The time interval involved is taken as a measure of the holding time. These methods offer an advantage over the salt test since they can be used while the pasteurizer is being oprated on milk.

There are many methods and instruments available for the thermal type of holding-time measurement. Unfortunately, the results obtained with the various methods do not always agree, nor do they agree with the results obtained with the salt test. In many respects this is similar to the situation which existed before the method of using the salt conductivity test was standardized. The work reported here was undertaken to study as many as possible of the factors having an influence on the results of a thermal holding-time measurement.

## Experimental

Most of the recording instruments used as thermal timers have electrically-operated chart drives and some use an electronic circuit for temperature measurement. The functioning of such an electronic instrument when powered by a supply subject to voltage variations was one of the suggested topics for investigation. The chart-drive mechanism on a typical electronic timer with a four-minute chart drive was checked by using a stop-watch to time the period for the chart to revolve through 60 seconds at various applied voltages. The timer was plugged into a "Variac" and the applied voltage was checked with a voltmeter. The results of the tests are given in table 1.

The consistency with which this instrument responded to a sudden change in temperature was also checked at various applied voltages. A simple measure of the consistency of the response was to measure the time for the recording pen to go from 155° to 165°F when the bulb at room temperature, was plunged into a well agitated water bath at 170°F. This instrument used resistance-type sensing elements and the temperature range covered was 155° to 170°F. The average results of five trials at each voltage are given in Table 2.

These results indicate that the chart speed of this instrument is not affected by line voltage variations down to about 50 volts and that the speed of response of the recording thermometer is nearly constant down to about 80 volts. A study of the individual values

Table 1 — Variation of Chart Speed with Applied Voltage

| Applied voltage, volts | 60-second chart interval as timed by stopwatch, seconds |
|---|---|
| 110 | 59.9 |
| 100 | 59.9 |
| 90 | 59.9 |
| 80 | 59.8 |
| 70 | 59.9 |
| 60 | 59.8 |
| 50 | 59.3 |
| 40 | Motor failed to move chart |

TABLE 2 — VARIATION OF RESPONSE TIME WITH APPLIED VOLTAGE

| Applied voltage, volts | Time for recorded temperature to go from 155° to 165°F, seconds |
|---|---|
| 110 | 4.7 |
| 100 | 4.4 |
| 90 | 4.3 |
| 80 | 4.1 |
| 70 | 6.1 |
| 60 | 26.1 |
| 50 | Pen failed to indicate any change |

averaged to obtain the data for Table 2 indicates that there is no significance to the slight decrease in response time between 110 and 80 volts. The significant change does occur between 70 and 80 volts.

*Properties of thermal waves*

The electronic timer was next used to study the properties of thermal waves generated by various manipulations of the steam supply to a Cherry-Burrell high-temperature short-time pasteurizer with a rated capacity of about 3,500 pounds of milk per hour. During these tests the pasteurizer was operated on water at about 3,000 pounds per hour.

The holding tube on this unit consisted of 26 feet of 1½ inch Pyrex brand glass pipe. The necessary steam for heating purposes was supplied to the unit at about 75 psig through a 3/4-inch line. The flow of steam was controlled by a diaphragm valve.

The first method of producing a thermal wave was to by-pass the controls on the diaphragm valve in the steam line and to open the valve wide for five seconds. This permitted an extra charge of steam to enter the heating-water tank. The resulting changes in the temperature of the water being pasteurized were measured by the timer bulbs mounted on either end of the holding tube. This method gave a rate of rise in temperature of about 0.1°F per second at the bulb at the inlet end of the holding tube and a rate of rise of about 0.05°F per second at the bulb at the outlet end. The total rise in temperature at the first bulb was only about 0.3°F. The rise at the second bulb was often indistinguishable from slight temperature fluctuations naturally present in the system. It was not possible to make more than a very rough estimate of the holding time from charts made with this method of steam injection.

The timer used in these tests was equipped with a selector switch enabling one to record the temperature at either the inlet bulb or the outlet bulb. The procedure in making a holding-time measurement consisted of setting the switch to record for the first bulb, adding extra steam to the heating system and then, after the temperature at the first bulb showed a definite rise, switching to the second bulb. The time interval between the first appearance of the thermal wave at either bulb was the measured holding time.

An auxiliary 3/4-inch steam line was then installed to obtain a sharper thermal wave. The line ran from the main steam supply line, contained a manually operated quick-acting gate valve, and terminated in the heating-water tank just above the port from which water was drawn and pumped to the plate heater. Steam supplied through this line did not mix with the bulk of the water in the heating-water tank, as was the case in the previous tests. By opening the valve in this line for a few seconds, thermal waves causing relatively abrupt changes in temperature at both bulbs were obtained. The properties, as measured at both ends of the holding tube, of the thermal waves produced by opening this valve for different lengths of time are given in Table 3.

The figures given in the last two columns of table 3 are the time intervals between the first appearance of the thermal wave and the time when the temperature indicated by the bulb in question returned to normal. The rate of rise in temperature was calculated from the temperatures recorded during the interval immediately after the initial appearance of the thermal wave. For a short time after the wave appeared, the temperature increased at a uniform rate. The rates given in the table are for this period of uniform increase.

TABLE 3 — PROPERTIES OF THERMAL WAVES WHEN STEAM WAS INJECTED INTO HEATING-WATER TANK

| Duration of extra steam injection, | Total rise in temp., °F. | | Rate of rise in temp., °F./sec. | | Time for wave to pass, sec. | |
|---|---|---|---|---|---|---|
| sec. | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| 1 | 0.7 | 0.5 | 0.2 | 0.1 | 14 | 17 |
| 3 | 2.1 | 1.6 | 0.3 | 0.2 | 19 | 25 |
| 5 | 3.5 | 2.4 | 0.4 | 0.3 | 27 | 32 |
| 7 | 4.5 | 3.2 | 0.4 | 0.3 | 32 | 37 |
| 9 | 5.5 | 3.9 | 0.4 | 0.3 | 40 | 41 |

TABLE 4 — PROPERTIES OF THERMAL WAVES WHEN STEAM WAS INJECTED DIRECTLY INTO HEATING-WATER LINE

| Duration of extra steam injection, sec. | Total rise in temp., °F. | | Rate of rise in temp., °F./sec. | | Time for wave to pass, sec. | |
|---|---|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| 1 | 1.7 | 1.1 | 0.5 | 0.2 | 36 | 39 |
| 3 | 3.6 | 2.5 | 0.8 | 0.4 | 36 | 42 |
| 5 | 5.6 | 3.8 | 1.0 | 0.5 | 42 | 48 |
| 7 | 7.4 | 5.0 | 1.0 | 0.6 | 48 | 54 |

The time at which the thermal wave reached either bulb could be estimated fairly accurately to within ± 0.5 second. Holding-time measurements were made by applying the extra steam for 1, 3, 5, 7, and 9 seconds. There was practically no difference in the readability of the charts and in each case the holding time indicated was between 22.5 and 23.0 seconds.

Next an additional steam line was installed which allowed injection of the extra steam directly into the hot water line at a point about six inches before the water line entered the final heating section of the pasteurizer. The line was of 3/4-inch pipe and the flow of steam was controlled by the same valve used in the previous tests. Properties of the thermal waves obtained with this setup are given in Table 4.

If, with this setup, the extra steam was applied for more than seven seconds, the resulting thermal wave caused an excessive amount of throttling on the part of the automatic steam controls. This sudden throttling of the steam supply often resulted in the temperature falling to the point where the system would go into diverted flow. Although the charts showed sharper rises in temperature than those of the previous set, there was no appreciable increase in the ease of estimating the time at which the thermal wave reached either bulb. The holding time was estimated at 22.5 seconds in each case when extra steam injections of 1, 3, 5, and 7 seconds duration were used.

These results indicate the desirability of introducing the extra steam into the heating-water circuit as close to the plate heater as possible. Allowing this steam to mix with all of the water in the hot-water tank should be avoided if a sharp thermal wave is to be obtained.

Two methods were used to produce waves in which the changes in temperature were downward rather than upward. The first consisted of stopping the heating-water pump for a few seconds. The results of these tests are given in Table 5.

The holding times estimated from charts made by this method were between 23.5 and 24.0 seconds. The method, however, was quite unsatisfactory because the small and slow changes in temperature produced were difficult to read on the charts.

Cold waves were also produced by injecting various volumes of ice water into the holding tube. The injections were made through a 3-A standard salt-test electrode using a veterinary-type syringe. The salt-test electrode used for the injection port was mounted in one arm of a number 9 cross and a thermal bulb in an adjacent arm. The cross was used to replace the tee ordinarily located at the inlet to the holding tube. Temperature changes were measured and recorded with the electronic timer used in the previous tests. The results of the tests are given in Table 6.

In these trials, the holding times read from the charts varied inversely with the volume of ice water injected. The holding times were 21.5, 20.5, and 20.3 seconds for injections of 10, 25, and 50 cubic centimeters of ice water respectively.

Because the injection of the ice water was made so close to the first bulb, the properties of the wave recorded at this point are somewhat questionable. The drop in temperature was extremely rapid. However, it is probable that much of the ice water was able to pass the bulb so rapidly that the true drop in temperature was not recorded. The time at which this abrupt drop in temperature started

TABLE 5 — PROPERTIES OF THERMAL WAVES PRODUCED BY MOMENTARY STOPPAGE OF THE HEATING-WATER PUMP

| Time pump off, sec. | Total decrease in temp., °F. | | Rate of decrease in temp., °F./sec. | | Time for wave to pass, sec. | |
|---|---|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| 3 | 0.2 | 0.2 | 0.05 | 0.05 | 14 | 23 |
| 5 | 0.4 | 0.3 | 0.1 | 0.05 | 42 | 49 |
| 7 | 0.8 | 0.5 | 0.15 | 0.1 | 44 | 47 |
| 9 | 1.2 | 0.8 | 0.15 | 0.1 | 47 | 54 |

TABLE 6 — PROPERTIES OF THERMAL WAVES PRODUCED BY INJECTING ICE WATER INTO THE HOLDING TUBE

| Volume of ice water injected, | Total decrease in temp., °F. | | Rate of decrease in temp., °F./sec. | | Time for wave to pass, sec. | |
|---|---|---|---|---|---|---|
| c. c. | Inlet | Outlet | Inlet | Outlet | Inlet | Outlet |
| 10 | 0.15 | 0.1 | 0.4 | 0.05 | 7 | 12 |
| 25 | 0.6 | 0.5 | 1.4 | 0.2 | 11 | 21 |
| 50 | 1.0 | 1.2 | 1.5 | 0.5 | 21 | 40 |

could be estimated to about 0.1 second. The time at which the wave reached the second bulb could be estimated to about 0.5 second.

### *Direct Comparison of Salt and Thermal Test*

Both a salt-test electrode and a resistance thermometer bulb were mounted at each end of the holding tube. An injection of 50 cubic centimeters of iced, saturated salt solution was used to activate the thermal timer and also an automatic Solubridge flow timer connected to the salt-test electrodes. The holding times indicated by the two instruments agreed within about 0.3 to 0.5 second. The holding time indicated by the salt test was always the shorter of the two.

### *Alternate Method of Reading the Holding Time from the Recorder Charts*

The holding time was ordinarily taken as the time interval between the first appearance of the thermal wave at the inlet and outlet bulbs. An alternate method of estimating the holding time was also tried. The method consisted of reading the time between the mid-point of the temperature rise recorded by the first bulb and the mid-point of the rise recorded by the second bulb.

The steady temperature at either bulb before the appearance of the thermal wave and the maximum temperature reached as the wave passed could both be read from the charts with accuracy. One-half the difference between these two temperatures recorded at the inlet bulb was added to the steady temperature before the appearance of the wave. A line at this new temperature was drawn through the recorded increase in temperature due to the thermal wave. These two lines intersected at nearly a right angle and the time corresponding to the point of intersection could be estimated closely. The same procedure was used for the temperatures recorded at the outlet bulb. The time interval between the two points of intersection obtained in this manner was taken as a measure of the holding time. This time was always slightly longer than the time interval between the points of initial changes in temperature at the two bulbs.

Charts were obtained by injecting steam, for five seconds, into the hot water line just before the plate heater of the Cherry-Burrell pasteurizer. The holding times estimated by both methods from each of nine charts are given in Table 7.

Although this alternate method did eliminate much of the guesswork in reading the charts, the ordinary method still seems the more desirable of the two. In addition to being the more logical way of interpreting the charts, the ordinary method gave holding time values closer to the true holding time.

### *Comparison of Various Instruments and Methods for Measuring Holding Time*

These tests consisted of comparing the performance of various instruments designed for or adaptable to the measurement of holding time by thermal methods. Results obtained with the 3-A salt conductivity method were used as the basis for comparing the holding times indicated by the various instruments.

One set of tests was made using the instruments on the Cherry-Burrell pasteurizer in the University bottling plant. All thermal waves were generated by injecting steam, for 5 seconds at about 75 psig, into the hot-water line just before the plate heater. The pasteurizer was operated on water during the tests.

TABLE 7 — COMPARISON OF HOLDING TIMES OBTAINED BY REGULAR AND ALTERNATE METHOD OF READING RECORDER CHARTS

| | Interval between initial temp. changes, sec. | | Interval between mid-point of temp. rises, sec. |
|---|---|---|---|
| | 22.5 | | 23.9 |
| | 22.0 | | 23.5 |
| | 22.5 | | 23.8 |
| | 22.5 | | 24.1 |
| | 22.0 | | 23.7 |
| | 22.0 | | 23.9 |
| | 22.0 | | 23.5 |
| | 22.5 | | 23.8 |
| | 22.5 | | 24.1 |
| Mean | 22.3 | Mean | 23.8 |

Another set of tests was made on an experimental pasteurizer. This unit consisted of a positive pump, a counter-current, tubular heat exchanger, and a 2-inch, box-type holding tube 24.4 feet long. In operation, about 6,200 pounds of water per hour were supplied to the heat exchanger at about 140°F and was heated to 160°F. The water then went through the holding tube and was discharged either to a tared receiver or to waste. Thermal waves were generated by injecting steam into the hot-water line going to the heat exchanger. A two-second steam injection was used since it gave a rise in temperature comparable to that obtained when the steam line to the Cherry-Burrell pasteurizer was opened wide for 5 seconds.

During each set of runs, conditions were kept as nearly constant as possible for each of the available instruments. The 3-A standard salt test was run on each of the setups using an automatic Solubridge timer.

The instruments or methods used to measure holding time by the thermal method were:

1. An electronic timer with resistance-type sensing elements, a single recording pen with selector switch, and a circular chart covering the range 155° to 170°F and making one revolution in 4 minutes.

2. Mercury in glass stem thermometers (-10° to 110°C) mounted at each end of the holding tube. The appearance of the thermal wave was noted by a sudden rise in temperature. The time was measured with a manually operated stopwatch.

3. Bi-metallic thermoregulators of 10-ampere capacity at 115 volts, connected in series with an electric light bulb and a selector switch. The regulators were set to make contact at the following temperatures:

For the experimental pasteurizer

| | |
|---|---|
| Bulb 1 | 160.8°F |
| Bulb 2 | 162.0°F |

Pasteurization temperature 159.5°F

For the commercial pasteurizer

| | |
|---|---|
| Bulb 1 | 163.0°F |
| Bulb 2 | 163.2°F |

Pasteurization temperature 162.2°F

Bulb 1 and bulb 2 refer to the sensing elements mounted at the inlet end and the outlet end of the holding tube respectively. The time was measured with a manually operated stopwatch.

4. A single-pen timer using vapor-pressure type sensing elements and a circular chart making one revolution in 30 seconds. The pen recorded at one level for bulb 1, and at another level for bulb 2. The pen jumped from level 1 to level 2 when the temperature at bulb 1 reached a preset level and returned to level 1 when the temperature at bulb 2 reached another preset level. The holding time was read between the two abrupt movements of the pen. The preset response points used were:

For the experimental pasturizer

| | |
|---|---|
| Bulb 1 | 161.1°F |
| Bulb 2 | 160.9°F |

Pasteurization temperature 159.5°F

For the commercial pasteurizer

| | |
|---|---|
| Bulb 1 | 163.1°F |
| Bulb 2 | 163.1°F |

Pasteurization temperature 162.1°F

5. A double-pen timer using vapor-pressure bulbs and a circular chart making one revolution per minute. Both pens recorded at the same level for normal operating conditions. The appearance of a thermal wave at bulb 1 caused the pen recording for bulb 1 to move upscale. The pen recording for bulb 2 moved downscale when the thermal wave reached bulb 2. Pen movement was in response to a sudden change in temperature rather than to the temperature having reached a selected response point. The holding time was the interval between the points where the up- and downscale movement of the pens started.

6. Vapor-pressure thermometer controllers used in a setup similar to that for the bimetallic regulators. The controllers were set to make electrical contact at 1°F above the normal temperature at the bulb in question in all tests.

7. Small resistance-type sensing elements connected to an automatic salt-test timer which responded to changes in resistance to the elements caused by the passage of a thermal wave.

8. Copper-constantan thermocouples connected to a recording strip-chart potentiometer with a chart speed of 8 inches per minute. A selector switch was used to permit recording the potential of either thermocouple, which changed abruptly on the appearance of the thermal wave.

The first five instruments or methods were used on both the commercial and the experimental pasteurizers. The rest were used on either one or the other. Method 8 was used on the commercial pasteurizer after the installation of a new, fixed speed pump. It was necessary, therefore, to work with this method at flow rates higher than those used with the other methods. All other conditions were the same as those prevailing when the other methods were tested. The results of these comparative tests are given in Table 8.

With the experimental pasteurizer, it was not possible to control the pasteurization temperature as closely as with the commercial pasteurizer. With those instruments having a preset response point, the holding time was influenced by the temperature existing in the holding tube during the run. A correction has been made for that part of the range in the measured holding times due to the slight variations in pasteurization temperatures when working with the experimental setup. This correction was calculated from the known rate of rise in temperature at each of the bulbs and the range in pasteurization temperatures measured during the series of twenty runs. This cor-

TABLE 8 — COMPARISON OF HOLDING TIMES MEASURED BY EIGHT DIFFERENT METHODS

| Instrument or method* | Number of trials | Mean flow rate, lb. /hr. | Difference between highest and lowest meas. flow rate, % of mean | Range limits of measured holding times, sec. | Range, sec. | Part of range due to temp. variations, sec. | Mean holding time, sec. | Mean holding time corrected to flow rate for salt test, sec. | Difference between salt-test time and thermal-test time, sec. |
|---|---|---|---|---|---|---|---|---|---|
| *Commercial Pasteurizer* | | | | | | | | | |
| Salt test | 20 | 2749 | 2.1 | 22.13 – 22.58 | 0.45 | – | 22.34 | 22.34 | 0.0 |
| 1 | 20 | 2768 | 3.5 | 25.5 – 26.25 | 0.75 | – | 26.04 | 26.22 | 3.88 |
| 2 | 20 | 2814 | 3.5 | 24.7 – 27.0 | 2.3 | – | 26.07 | ~~26.69~~ | 4.35 |
| 3 | 20 | 2771 | 2.3 | 25.2 – 28.9 | 3.7 | – | 26.71 | 26.92 | 4.58 |
| 4 | 20 | 2672 | 1.8 | 30.8 – 31.9 | 1.1 | – | 31.25 | 30.35 | 8.01 |
| 5 | 20 | 2647 | 2.4 | 27.1 – 28.1 | 1.0 | – | 27.67 | 26.64 | 4.30 |
| 8 | 20 | 3329 | 1.0 | 20.6 – 22.6 | 2.0 | – | 21.6 | 26.15 | 3.81 |
| *Experimental Pasteurizer* | | | | | | | | | |
| Salt test | 20 | 6207 | 1.4 | 13.73 – 14.06 | 0.33 | – | 13.91 | 13.91 | 0.0 |
| 1 | 20 | 6211 | 1.6 | 15.0 – 16.0 | 1.0 | – | 15.54 | 15.55 | 1.64 |
| 2 | 20 | 6217 | 1.0 | 14.9 – 16.3 | 1.4 | – | 15.56 | 15.58 | 1.67 |
| 3 | 20 | 6217 | 1.4 | 15.7 – 17.8 | 2.1 | 0.7 | 16.72 | 16.75 | 2.84 |
| 4 | 20 | 6247 | 1.4 | 16.7 – 17.1 | 0.4 | 0.1 | 16.93 | 17.04 | 3.13 |
| 5 | 20 | 6233 | 1.0 | 15.6 – 15.9 | 0.3 | – | 15.73 | 15.80 | 1.89 |
| 6 | 20 | 6199 | 0.1 | 16.1 – 17.9 | 1.8 | 0.4 | 16.94 | 16.92 | 3.01 |
| 7 | 20 | 6188 | 0.1 | 13.94 – 14.86 | 0.92 | – | 14.31 | 14.27 | 0.36 |

*A description of the instruments and methods is given in the text.

rection is indicated in column 7 of Table 8. The corrections are small since the greatest difference between the highest and lowest steady-state, or pasteurization, temperatures recorded during any set of runs was always less than 1°F.

With instruments having a preset response point, it is possible to vary the apparent holding time over relatively wide limits by appropriate choice of the response point. In some of the tests presented in Table 8, the instruments of this type were not set at response points which gave maximum sensitivity. When this was the case, the difference between the holding times measured by the salt test and by the particular thermal method in question was large. Quanitative data on this effect are given in a later section.

The data presented in Table 8 indicate that the difference between the holding times measured by the salt and thermal methods, or the correction factor as it is sometimes called, varies with the instrument used and with the pasteurizer being checked when considering one particular instrument. It appears that, without comparing the salt and the thermal tests under the particular conditions under which the thermal test was to be used, it would be extremely difficult to accurately predict what the correction factor should be.

Some of the instruments used in this work were extremely sensitive and quick to respond to a temperature change. The fact that all instruments showed a correction factor is of interest. It seems to confirm the logical assumption that there must always be some slight correction factor since part of the thermal wave is dissipated through the transfer of heat to the holding tbue itself. This dissipated part of the thermal wave cannot be detected regardless of the sensitivity of the thermal timer. When using a tracer method, such as the salt test, to measure holding time it is true that the salt becomes extremely dilute at the front of the charge but, it is still theoretically possible to detect the first trace of it appearing at the outlet end of a holding tube.

### *Effect of Flow Rate on Correction Factor*

Tests were performed to determine how the correction factor would vary for a particular pasteurizer when the flow rate through it changed over fairly wide limits. The experimental high-temperature short-time pasteurizer was used for these tests. The holding time was measured by the salt test, with the thermal timers listed as numbers 1 and 5. The holding-time measurement is independent of the

TABLE 9 — EFFECT OF FLOW RATE ON CORRECTION FACTOR

| Flow rate, lb./hr. | Holding time by salt test, sec. | Holding time by timer No. 1, sec. | Correction factor, sec. | Holding time by timer No. 5, sec. | Correction factor, sec. |
|---|---|---|---|---|---|
| 4378 | 19.45 | 21.97 | 2.52 | 22.38 | 2.93 |
| 6207 | 13.91 | 15.55 | 1.64 | 15.80 | 1.89 |
| 7504 | 11.42 | 13.06 | 1.64 | 13.19 | 1.77 |

pasteurization temperature with both of these timers. The result of the tests are given in Table 9.

The results indicate a marked increase in the correction factor for flow rates lower than normal, whereas the correction factor remains nearly constant as the flow rate is increased above normal.

*Effect of Pasteurization Temperature on the Correction Factor*

When using an instrument with a preset response point, the apparent holding time will vary as the pasteurization temperature is raised or lowered. The following tests were run to determine the magnitude of such changes when using a typical instrument of the preset response-point type. Instrument No. 4 was used with both bulbs set to respond at 162.4°F. All tests were run with water in the experimental pasteurizer.

The pasteurization temperature was kept constant to within ± 0.1° F at four different levels between 159 and 162°F. The holding time was measured ten times at each temperature. The flow rate was measured for each run and holding times were corrected to a flow rate of 6207 pounds per hour, for which the salt test showed 13.91 seconds. The results are given in Table 10.

TABLE 10 — EFFECT OF PASTEURIZATION TEMPERATURE ON THE CORRECTION FACTOR

| Temperature, °F | Holding time by thermal test, sec. | Correction factor, sec. |
|---|---|---|
| 159 | 19.69 | 5.78 |
| 160 | 18.42 | 4.51 |
| 161 | 17.43 | 3.52 |
| 162 | 16.53 | 2.62 |

SUMMARY AND CONCLUSIONS

It was found that the operation of an electronic type of thermal timing instrument was dependable in spite of variations in its voltage supply between 110 and 80 volts. Below 80 volts the response to temperature changes became sluggish and at about 40 volts the chart-drive motor failed to operate.

The thermal waves used commonly consisted of slugs of overheated product moving through the holding tube. The time interval between the first appearance of this overheated slug at the inlet end again at the outlet end was taken as the holding time. An application of extra steam to the system was used to produce the wave and the properties of the wave varied with the method of applying this steam.

The injection of extra steam into the heating water tank resulted in an ill-defined thermal wave if this steam was allowed to mix with the bulk of the water in the tank. Injecting the steam into the heating water tank at a point directly above the suction port of the water circulating pump gave better results. The most abrupt changes in temperature were obtained when the extra steam was introduced into the hot water line at a point just before the plate heater. In a commercial pasteurizer operating on water at about 3,000 pounds per hour, the introduction of extra steam at 75 psig for 5 seconds by either of the last two methods gave abrupt and easily measureable changes in temperature.

Thermal waves in which the changes in temperature were downward were also used. When these waves were produced by momentarily stopping the heating water pump, the changes in temperature were too small and too gradual to be detected with accuracy. Cold waves were also produced by injecting ice water into the holding tube. Relatively abrupt changes in temperature were produced by this method. However, the measured holding time varied inversely with the volume of ice water injected.

When 50 cubic centimeters of ice saturated salt solution was used to activate both a thermal timer and a Solubridge with sensing elements mounted adjacent to each other at either end of a 26-foot, 1 1/2-inch holding tube, the time indicated by the salt test was always about 0.3 to 0.5 second less than that indicated by the thermal test.

When reading the holding time from charts made by a timer which recorded temperature, the most convenient interval to take as a measure of the holding time was that between the first indication of change in temperature at each bulb.

Holding times obtained with eight different instruments designed

(continued on page 25)

cedure. This has been demonstrated repeatedly. Results indicate that a worn and cracked inflation may even approach the condition of a reservoir of mastitis bacteria along with other types.

The marked reduction in every case in numbers of mastitis streptococci on teat cups due to the germicide rinse, and the simplicity of the added step certainly justify teat cup disinfection in the milking procedure. This step together with the udder wash before milking both fit into the fast milking system and occasion hardly any delay in the milking routine. Changing the germicide solution frequently enough to maintain solution strength obviously is desirable. Results indicate about equivalent destruction of mastitis streptococci by quaternaries and hypochlorites. One advantage of quaternaries over hypochlorites for teat cup disinfection in the mastitis sanitation procedure is that a warm solution of hypochlorite may cause faster deterioration of rubber inflations due to the oxidizing effect of the hypochlorite. Quaternaries also may avoid chapping of teat surfaces coming in contact with the germicide on the disinfected teat cups.

Species of bacteria such as *M. pyogenes aureus* may show greater resistance to action of some germicides than does *S. agalactiae*[16] but the sanitation principles developed in the studies on mastitis streptococci in general should apply as well to other causative bacteria.

The question of quaternary contamination of milk from teat cup disinfection procedures is frequently brought up. Studies indicate that this step with reasonable care introduces an insignificant quantity of quaternary into the milk. Equipment such as pails, strainers, surface coolers and cans, sanitized with quaternary instead of hypochlorite may contribute detectable quantities of quaternary to the milk. Quantities of quaternary contributed by proper mastitis sanitation procedures have been below detectable levels.

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## THERMAL METHODS

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for or adaptable to the measurement of holding time by thermal methods were compared with those obtained with the 3-A standard salt test. These comparative tests were run on two pasteurizers with capacities of about 3,000 and 6,000 pounds per hour, respectively. The correction factor, or difference between the holding times as measured by the salt test and a particular thermal test, varied with the different instruments when they were used on the same pasteurizer. The correction factors also varied when the same instrument was used on different pasteurizers. Correction factors found in these tests ranged from about 0.4 second to 8.0 seconds.

When the experimental, 6,000-pound-per-hour pasteurizer was operated at 75 percent of its rated capacity, there was a marked increase in the correction factor over that found for the normal capacity. Increasing the capacity of the pasteurizer 25 percent above normal caused little change in the correction factor.

The holding time, and hence the correction factor, varied with the pasteurization temperature when using a thermal timer with a preset response point. With a pasteurizer operated at 6,200 pounds of water per hour, the correction factor went from 5.78 seconds at 159° F to 2.62 seconds at 162°F when the response point for both bulbs was set at 162.4°F.