HOT WATER USAGE FOR DAIRY FARM PURPOSES

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Warren Robert Church

1954

This is to certify that the

thesis entitled

"Hot Water Usage for Dairy Farm Purposes"

presented by

Warren R. Church

has been accepted towards fulfillment
of the requirements for

M. S. degree in Agricultural Engineering

Carl W. Hall
Major professor

Date May 20, 1954

HOT WATER USAGE FOR DAIRY FARM PURPOSES

By

Warren Robert Church

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agricultural Engineering

1954

Approved Carl W. Hall

5/27/54

7-9-54
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The study was conducted on 30 central Michigan dairy farms using stall type barns during the summer months of 1953. The size of herd varied from 10 to 90 cows. The primary objective of the study was to determine the amount and temperature of water being used in the milk house and to determine the proper criterion to be used for selecting the proper size heater for any given dairy enterprise. Bacteriological tests were conducted to determine the quality of the washing operation, a time and motion study to determine the time required for each operation in the milk house, and a study of the rates of hot water withdrawal in relation to the time of day.

Data at the farms were collected at the time of the evening and morning milkings and only one day was spent at each farm. The amount and temperature of water used for washing was recorded along with the rates of withdrawal and times required for washing the utensils. Swab tests were taken after the washing operation as a means for determining the quality of the washing operation.

In the laboratory, selected water heaters of various sizes were tested to determine the amount of water withdrawal, at a given rate, without temperature drop and the heat loss through the walls of the heaters. Heaters of the 6, 12, 20, 30, 50, and 80-gallon size were tested. A hot water meter was used to determine the quantity of water withdrawn and kilowatt-hour meters were used to determine

the heat loss through the walls of the heaters. The electrical meters were attached to the various heaters for a period of two weeks and the size of element required to maintain the temperature was determined.

The data were analyzed statistically to determine the relationship of the variables involved in the usage of hot water. The analysis showed that there was a significant relationship between the amount of water used for washing the utensils and the size of herd but it was found that there was a highly significant relationship between the amount of water used for washing the utensils and the number of pieces of equipment washed. When selecting a heater for a given dairy operation the tank capacity as well as the heating element size must be considered. A method is presented to determine the proper capacity of heater and size of element.

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ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks to Dr. Carl W. Hall, under whose inspirational guidance and constant interest in the project the investigation was conducted.

He is also greatly indebted to Professor Jewell M. Jensen for his kind guidance and valuable aid in checking the preliminary work of the project.

Acknowledgement is also due to Dr. Clyde K. Smith for his guidance in setting up the procedure to be followed for obtaining the bacteriological data and arranging for the bacteriology laboratory for conducting the tests. Thanks is also extended to Dr. Smith for the giving of his time in checking the preliminary work of the project.

He also extends his appreciation to Mr. James Cawood and his assistants for aiding in the procurement of equipment.

Thanks are extended to Ronan and Kunzl, Inc., Marshall, Michigan and Mr. George McKelvey for providing the research assistantship for the past year which has made the investigation possible.

The writer wishes to thank Mr. Herman Walt, Mr. Dennis McGuire and Mr. T. R. Potts for their efforts in securing the aid of the individual farmer cooperators who worked on the project.

The investigator also wishes to thank other individual cooperators for their aid in the investigation and all others who have been connected with the project.

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INTRODUCTION

For many years the lack of sufficient hot water in the farm dairy has been of much concern to the dairy farmer, water heater manufacturer and dairy sanitarian. It is recognized that a sufficient amount of hot water in the dairy is a prime prerequisite for the production of quality milk. With the proper washing techniques and good housekeeping practices, it is not difficult to produce a quality product. The proper amount and temperature of hot water on the dairy farm plays a very important part in the washing operation. Hot water should be available when required and should be close at hand.

Today, there appears to be little information which the farmer or dairy sanitarian can use to intelligently select the proper size heater for any given dairy enterprise. There have been several articles written on the subject but there appears to be little or no scientific data available and no concrete method has been established for the proper selection of a heater.

An increasing number of farms in the United States are becoming electrified and as of June 30, 1951, 4,529,620 or 84.2 percent of all the farms in the United States were supplied with electrical power.[1] The farmer is becoming

1. United States Department of Agriculture, Agricultural Statistics, 1952, p. 830.

more conscious of the fact that quality production is of utmost importance in the dairy farm operation. With the enactment of new legislation regulating the production of milk the operator is faced with new problems of producing the quality produce desired. Plenty of hot water available in the dairy is an aid which the farmer can use to produce a quality product. By using the proper size electric water heater in the dairy, hot water is made available at all times and at a location where it may be used.

The hot water requirements for dairy farm uses are not only of interest to the farmer but to the dairy sanitarian and water heater manufacturer. The dairy sanitarian is interested from the public health standpoint and one of his main duties is to see that the farmer is equipped to produce quality milk. When an unsatisfactory product is being produced oftentimes the dairy sanitarian is consulted with reference to the proper procedure to be followed to correct the condition. When the proper amount and temperature of water required to wash dairy equipment is known the sanitarian can pass on this information to the farmer. The water heater manufacturer is interested in the proper size heater to manufacture for the agricultural field. When the proper size heater is known for a given dairy farm operation, this information may be used as a guide for future water heater manufacture.

REVIEW OF LITERATURE

There have been several articles written on the subject of hot water usage for dairy farm purposes but there appears to be disagreement as to the proper criteria to use in selecting the proper size water heater. It was suggested by Marsden[2] in 1929 that the size of water heater depends more upon how the milk is handled than upon the number of cows in a given herd. It was also estimated by Marsden[3] that a five-gallon heater would suffice for a 20-25 cow herd. For this estimate the amount and kind of equipment used on the farm was not mentioned.

Roberts[4], in his study of residential water heaters indicated that the trend is toward larger two-element "off-peak" heaters for dwellings. The amount of insulation used and its method of installation would have a decided effect upon the power consumption of water heaters. Hienton[5] suggested that the efficiency of an electric water heater could be increased by as much as 13.9 percent by proper insulation. It was noted by Roberts[6] that the chemical

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2. Marsden, M. E. Electric water heaters in the dairy. Hoards' Dairyman 74:769, 1929.

3. Ibid, p. 767.

4. Roberts, E. H. A study of electric water heaters. Agr. Eng. 17:244, 1936.

5. Hienton, T. E. Electric water heaters for farm dairies. Successful Farming 39:16, 1941.

6. Roberts, op. cit., p. 244.

properties of certain waters should be kept in mind when heating water. It is known that certain mineral compounds are precipitated when water is heated and these minerals will collect on the heating elements as scale deposits and reduce the efficiency of the heating element. The calcium and magnesium salts, namely, calcium carbonate and magnesium chloride, will be precipitated at 180° F depending on the hardness of the water. It was found by Roberts[7] that the most economical temperature for heating water was between 150-160° F. The temperature to which water may be safely heated without mineral deposition depends upon the amount and kind of water hardness present. Roberts[8] stated that in general it was more economical to use heaters with two thermostatically controlled elements than with one thermostatically controlled element. The average thermostat setting for water heaters taken from 20 sources including gas and electric heater manufacturers, engineers, and utility companies was 152° F $\pm$ 9° F.

Hienton and Fore[9] in 1939 tested 15 pour-in type water heaters to determine the energy consumption per gallon per degree rise in temperature and the efficiency of the various heaters. It was suggested that water should be heated to 165° F during the warmer months and the temperature should

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7. Ibid, p. 244.
8. Ibid, p. 246.
9. Hienton, T. E. and Fore, J. M. Experiments with electric water heaters for dairy farms. Ind. Agr. Exp. Sta. Bull. 447:2, 1939.

be increased to 170° F during the colder months to properly wash dairy utensils. It was suggested by Schaenzer[10] that 180° F was the best temperature for washing dairy equipment but that boiling water was preferred. It was found that the time required to heat water depended upon the amount of water heated, wattage of the elements, insulation of the heater, and the final temperature. Where the heaters were uninsulated the high wattage elements were more efficient than the lower wattage elements. The three to fifteen gallon sizes were found to be practical for use on Indiana farms selling bulk milk. A more definite figure was recommended, namely, seven to ten gallons of hot water per ten cows when the herd was 20 cows or larger.

Fore[11] in 1940 stated that there were three general types of heaters for the small dairy farm, namely, the portable immersion type, open tank with built-in heater, and the "in" and "out" heater. The latter type is more commonly called the pour-in type heater. The portable immersion type heater may be used at any location desired where a 115-volt source is available. The element size ranged from 500 to 1300 watts. Excessive rusting resulted where the immersion type heaters were used. The immersion heater consists of a resistance element enclosed by a protective shield and attached to a power source. The resistance element assembly

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10. Schaenzer, J. P. Rural Electrification, 4th ed. Milwaukee: Bruce Publishing Co., 1948, p. 255.

11. Fore, J. M. Water heaters for the small dairy. Electricity on the Farm 13(5):14, 1940.

is placed directly into the water.

It was found by Scott[12] that a 40-gallon size water heater was large enough for a 50-cow milking herd if the milk was sold wholesale but this same size heater would only care for a 15-cow herd when the milk was sold retail. The findings by Scott substantiate the reference by Marsden that the heater size should be selected according to the method of handling the milk as indicated earlier in the review of literature. It was reported that a high percentage of the tank capacity may be withdrawn at the thermostat setting. Scott[13] indicated that 35 gallons of near-boiling water could be withdrawn from a 40-gallon heater.

An experiment was conducted by J. B. Stere[14] on 50 Western Pennsylvania wholesale dairy farms. The farmers participating in the experiment had herds ranging in size from eight to 45 cows and water heaters ranging in size from 10 to 80 gallons. The data were collected during the spring and summer months. Stere reported that the hot water needs for the farm could be grouped into three main groups; namely, regular, periodic, and miscellaneous uses. Of the 50 farms tested, only four farmers admitted having heaters of sufficient size. Many of the farmers found that it was possible to get along during the spring and summer months

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12. Scott, J. C. Premiums from hot water. Electricity on the Farm 10(5):10, 1937.
13. Ibid, p. 10.
14. Stere, J. B. How big a dairy water heater? Electricity on the Farm 21(2):8, 1948.

with their present heaters but the amount of water was insufficient during the winter months.

The daily hot water needs consisted of watering the calves, washing udders, and washing the milking machines and utensils. Each calf required one-half gallon of 150° F water per watering. Hand washing required one gallon of 150° F water per person per washing. The milking units required two gallons of 150° F water in conjunction with a germicidal agent to sanitize the milkers prior to milking. The water used for watering the calves, hand washing and utensil washing was tempered with cooler water to the desired temperature. The machine sanitizing solution was later used to wash the udders. Two gallons of water was recommended for every five cows. It was found that the average temperature of the wash solution was 135° F, during the washing interval. Five gallons of 150° F water was used to wash the milking units and other utensils after the milking operation.

The periodic water needs included the veterinarian, inseminator technician, and the milk tester. The veterinarian, technician, and milk tester each required a minimum of 2½ gallons of 150° F water per visit. When the water heater size was being determined allowance was made for only 2½ gallons of 150° F water as in the majority of cases all three specialists would not be at the farm at any one time. In general, it was found that the miscellaneous needs did not change the size of water heater required.

There were two types of heaters employed by the farmers; namely, the pressure and non-pressure types. The non-pressure type was the most common and ranged in size from 10 to 20 gallons. The advantages of the non-pressure heaters were: easy installation, use with a 115-volt circuit, no pressure, and freedom from freezing. The disadvantages of the non-pressure system were slow flow of water, temperature quickly reduced when the draw-off was intermittent, and slow in reheating. Additional disadvantages cited were that the thermostat was sensitive, hot water available at only one location, power supply may be easily interrupted, and the heater may become contaminated by using dirty utensils to fill the heater.

The pressure type heaters were usually connected for off-peak operation when 15 gallons or more of hot water were used per day. The "off-peak" heater control is a mechanism employed to control the operation of the lower element. The lower element is allowed to operate only when the power demand is below a limit as established by the local power supplier. The advantages noted for the pressure type system were the rapid flow of water, minimum drop in water temperature, hot water can be delivered to many locations, and the energy consumption is lower if 15 gallons or more of hot water are used per day. The disadvantages of the pressure type system were that extra plumbing was required and the water lines must be protected from the freezing weather.

Stere[15] suggested that the amount and temperature of hot water used for each operation and the time of day it was needed should be determined to intelligently select the proper size dairy water heater for any given dairy farm enterprise. To take care of peak demands it was suggested that the heater should hold one-fourth more water than the maximum water needed in any given single hour and that the size of elements be governed by the frequency of use. A heater of the "off-peak" type should be large enough to hold the total daily needs for hot water.

Forty-one wholesale dairies were studied, in Pennsylvania, to determine the proper size of water heaters for dairy farm purposes.[16] Farms with 50-gallon or larger "off-peak" water heaters were studied. It was stated that a 50-gallon heater was required for a herd up to 25 cows, a 66-gallon heater for a herd of from 26-35 cows, and an 80-gallon heater for a herd of 36-50 cows.

Heaters are principally of the pressure and non-pressure types and generally only pressure heaters of a certain size, as determined by the power supplier, may be operated by an "off-peak" control and thus receive a reduced electrical rate for the energy used. When the heaters are connected for "off-peak" operation the lower element is on the clock and the upper element is connected to the power at all times. It has been proposed by the National Electrical Manufacturers

15. Ibid, p. 12.
16. A revised report on special studies and research. Edison Electric Institute, Jan. 1947 - December, 1950, p. 10.

Association[17] that the upper element size be limited to 30 watts per gallon of tank capacity and the lower element size be limited to 20 watts per gallon of tank capacity. It is recommended[18] that the lower element be set eight degrees higher than the upper element to enable the lower element to do most of the heating. The late model water heaters of the pressure type are well insulated and are usually equipped with a "goose neck" heat trap located near the top of the heater. The heat trap is designed to prevent circulation of the hot water through the pipes and thus reduce heat loss due to radiation. It is common practice to make the heating element sheath of an alloy that has a larger coefficient of thermal expansion than the lime that may become deposited on the elements due to hardness of the water. The expansion and contraction of the heater element sheath aids in the removal of lime deposits by cracking the lime deposits and causing them to peel from the element. It has been found that the heaters with the elements on the outside of the tank have less trouble with liming.

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17. Pfingsten, A. H. Off peak water heaters and radiators in milk houses. Farm Electrification 3(1):38, 1949.
18. Ibid, p. 38.

OBJECTIVES

One of the main objectives of this study was to determine the amount and temperature of water being used on dairy farms to wash the dairy utensils and care for other needs. Another objective was to determine the criterion to be used for determining the amount of water and size of heater to be used for any given dairy enterprise. Bacteriological studies were to be conducted on the equipment after the washing operation to determine the quality of the washing operation. A time and motion study was conducted in conjunction with the study to determine standard times for various operations in the milk house. A method was to be designed for the proper selection of a water heater size and heater element size according to the data collected in the study. Suggestions were also presented for the efficient use of hot water on the farm.

PROCEDURE

Field Equipment

The equipment used in the field included the bacteriological equipment, hot water meter, Fahrenheit thermometers, stop watch, and a clip board. The hot water meter used for the study was a Badger model SC-X, 5/8 x 3/4" bronze meter. The meter had a maximum operating capacity of 26 gallons per minute. The meter was not operated at near capacity as the maximum flow recorded during the tests was 6.67 gallons per minute. The entrance pipe to the meter was 5/8" but connections were employed for use with 3/4" pipe. The meter was mounted on a frame so that it could be attached to the wash vats while in use. Flexible rubber hoses were used for meter connections at the farm. A -4° to 230° F thermometer was connected in series with the meter to record the temperature of the water withdrawn. The thermometer was placed in the line between the faucet and the meter. The thermometer bulb was in direct contact with the water during withdrawal for quick, accurate readings. The clip board and stop watch were mounted on a 1/4" plywood panel for taking and recording the data. The clip board and stop watch panel was designed for ease in taking data. Refer to Fig. 1 for clip board and meter panel assembly. Five-ounce capped bottles were used to secure the water samples.

Field Procedure

A study was conducted on 30 stall type Michigan dairy farms during the summer months to determine the amount and temperature of water used for a given dairy enterprise. The tests were conducted by observing the milking procedure and recording the amount and temperature of the water used for the herds ranging in size from 10 to 90 cows. The farms to be visited were selected at random within about a 20-mile radius of the campus. The cooperators were contacted personally prior to conducting the tests so that the objectives of the study could be outlined and to enable the operators to feel at ease about the study. The cooperators were selected by the aid of the local farm service advisors for the various power suppliers in the area studied. The data were obtained over a period of one day on each farm at the time of the evening and morning milkings.

With the aid of a time and motion study the times required for each washing operation in the dairy were recorded to the nearest 0.05 minute. The data collected in the time and motion study included the number and pieces of equipment washed and other miscellaneous uses of water. The time and motion study covered the period from the time the farmer first entered the milk houe until the time he left. Only the operations conducted in the milk house were broken down into individual operations. The time study also served to determine the rate of withdrawal and time of withdrawal relative to the start of the milking operation. Standard times were established for the various milkroom operations from the time and motion data.

The hot water meter was connected to the water heaters as shown in Fig. 2. As the water was withdrawn through the meter the temperature, quantity and rate of withdrawal were determined. The meter read to the nearest one gallon and readings were interpolated to the nearest one-fourth gallon.

At each farm prepared data sheets were compiled. Sample data forms used appear in Appendix I. Two data forms were filled out at the farm at the time of the visit and the remaining forms were filled out when the data was analyzed. The amount and temperature of the water used for the washing operation were determined along with the amount and kind of washing compound. Care was taken to determine if a sanitizer-detergent combination was used or if just a synthetic detergent was used. The duration for washing and rinsing each utensil was observed at each farm visited. After the utensils were washed and placed upon the racks to dry swabs were taken on each individual piece of equipment until about 15 swabs had been taken. Fifteen swabs of various pieces of equipment gave a good indication of the washing operation.

The swabs were taken according to standard procedure[19]

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19. American Public Health Association. Standard Methods for the Examination of Dairy Products, 9th ed., 1948, p. 216.

Fig. 1 Equipment used for collecting data in the field including the hot water meter and data board.

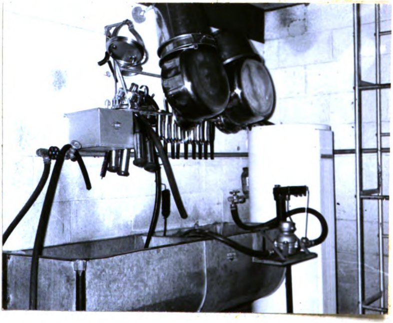

Fig. 2 Using field equipment for collecting data on the farm.

as outlined by the American Public Health Association. The swabs consisted of non-absorbent cotton, firmly twisted to about 3/16" in diameter by 3/4" long on wooden applicators. A buffered distilled water solution was provided for the swabs after the sample had been taken. The buffered distilled water solution was prepared by the college Bacteriology Department and was used as ordered. The buffer solution was placed in test tubes in 10-ml portions and stoppered with tightly wound cotton plugs. The swabs were kept prior to the test in separate vials which were stoppered with tightly packed cotton. When the tests were conducted the sterile swabs were removed from the individual vials and dipped into a vial of the buffer solution. The excess solution was removed from the swab by squeezing it out against the side of the vial. A four-square-inch area was covered by the swab (Fig. 3). The swabs were taken in locations that were suspected to be the least sanitary such as the neck of strainers and the side-wall junctions of pails. The areas were covered four times and the swabs were rotated during the operation to enable uniform sampling. After the swabbing operation the swab was placed in the vial of buffer solution from which it was moistened and the applicator was broken in half to keep the vial from becoming contaminated by the technician's hands (See Fig. 4). The swabs were than placed in a refrigerated chest to cool the specimens until they were tested. Fig. 5 shows the refrigerated chest

Fig. 3 Taking swabs of the dairy equipment.

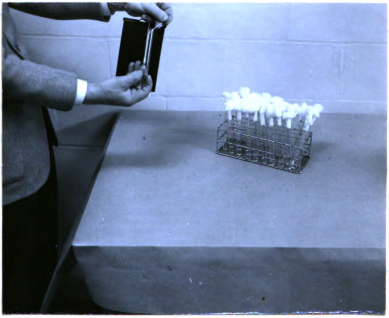

Fig. 4 Technique used for placing the swabs in the vials.

including the swabs and the ice which was used for refrigeration.

A sample of the water supply was secured at the farm and taken to the laboratory for testing. The sample was secured from the cold water supply. It was felt that the hardness of the water would have a definite influence upon the quality of the washing operation.

Laboratory Equipment

The equipment used in the agricultural engineering laboratory included five selected water heaters of varying size, watt-hour meters, hot water meters and thermometers. The electric water heaters were selected at random and included 6, 12, 20, 30, 50 and 80-gallon size heaters. Fifteen ampere, 220-volt, three wire, watt-hour meters were used in conjunction with the heaters to determine heat loss. The same hot water meter was used in the laboratory as was used in the field.

The bacteriological equipment was used in the bacteriology laboratory and consisted of equipment and reagents required for conducting the swab tests and the equipment and reagents for conducting the water hardness test. A shaking machine was used to obtain a uniform bacteriological sample for plating. Fig. 6 shows the mechanical shaking machine in operation. Petri dishes, 2.2 ml transfer pipettes, TGE

Fig. 5 Ice chest employed for maintaining low temperatures of the bacteriological samples between the farm and the laboratory.

Fig. 6 The mechanical shaking machine used in the bacteriological tests for obtaining representative samples.

(Tryptone Glucose Beef Extract) agar, and sterile skim milk were furnished by the Bacteriology Department. A 37° C incubator and colony counter were also provided by the Bacteriology Department. Equipment for the water hardness test was furnished by the school and the reagents used were prepared from stock chemicals. The TGE agar was made according to specifications as outlined by the American Public Health Association.[20]

Laboratory Procedure

The selected water heaters were designed for use on a 220-volt system and were equipped with varying size elements depending upon the size of the heater. The 6, 12, and 20-gallon heaters were "Hi-Put" heaters furnished by the sponsor of the project and the 50 and 80-gallon heaters were "Co-op" heaters furnished by the college. The 30-gallon heater was secured from one of the cooperators of the project. The various units were attached to a 220-volt system and the thermostats were adjusted to deliver water at approximately 155° F. When the heaters were up to temperature, the hot water was withdrawn at varying rates ranging from two to six gallons per minute to determine the amounts that could be withdrawn at various rates without temperature drop. Only one rate of withdrawal was used on the 30, 50, and 80-gallon heaters as these units were located some distance from the

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20. Ibid, p. 93.

laboratory. The rate selected for the 30, 50, and 80-gallon heaters was the average rate used by the farmers with pressure type heaters. A dictaphone was used to record the temperature of the water as it was being withdrawn at the various rates from the heaters tested in the laboratory. Temperature readings were recorded verbally on the dictaphone at intervals as determined by a stop watch. It was felt that readings should be taken at 0.05 minute intervals to get satisfactory curves showing water withdrawal relative to temperature drop. The dictaphone was used only on the 6, 12, and 20-gallon size heaters as they were conveniently located in the laboratory and in many cases a greater temperature change resulted per unit time with the smaller heaters than with the larger heaters. The temperature was recorded at 0.10 minute intervals with the 30, 50, and 80-gallon heaters. Graphs were made of the temperature drop versus the quantity of withdrawal for the various heaters and for the various rates of withdrawal to demonstrate the performance of the various heaters.

The 15-ampere, 220-volt, three wire watt-hour meters were attached to the various size heaters and allowed to remain for a two-week period. The heater thermostats were set at 155° F. The meters measured the heat loss through the walls of the heaters for the two-week period. No water was withdrawn from the units during this time. After the two-week period the heat loss was determined in kilowatt-hours and recorded as watts of heat loss per 100° F differential. The heat loss was also computed for the various sized heaters by observing the kind and thickness of insulation, surface area, and temperature differential. The actual values were later compared with calculated values. A 30-gallon heater was not available in the laboratory and the heat loss for this heater was interpolated.

The laboratory work for the bacteriological study was conducted in the Bacteriology laboratory. All of the equipment was furnished by the Bacteriology Department. When the refrigerated samples were brought in from the field they were placed on a mechanical shaking machine and shaken for 30 minutes prior to sampling. The object of this shaking procedure was to remove the bacteria from the cotton swab out into the solution. A more representative sample could be obtained once the bacteria were in solution. Three plates were made of each sample by taking varying amounts of the sample and placing them in sterile Petri dishes. Two milliliter, one milliliter, and one-tenth milliliter portions were plated from each sample as shown in Fig. 7. The standard TGE agar was melted, cooled to body temperature and placed in each Petri dish. (Refer to Fig. 8). Three milliliters of sterile skim milk were added to each 250 milliliters of agar prior to plating. The TGE agar served as a culture medium

Fig. 7 Technique followed for placing the samples in Petri dishes.

Fig. 8 Placing the melted T.G.E. (Tryptone Glucose Beef Extract) agar in Petri dishes. The T.G.E. agar is the culture medium.

for the bacteria. The individual plates were incubated at 37° C for 48 hours prior to counting. The individual colonies were counted on a "Quebec Colony Counter" and each colony was counted as one bacterium. Fig. 9 shows a Quebec Colony Counter being used. The bacteria, as determined from the plates, were recorded as the number of bacteria per square inch of utensil surface area. Only the plates containing between 30 and 300 colonies were used for recording the contamination. All plates with colonies that were too numerous to count were considered as 500 colonies per plate and were recorded from the highest dilution having plates too numerous to count. The two-milliliter plate counts were multiplied by 1.25 to determine the bacteria count per square inch of

Fig. 9 A Quebec Colony Counter being used to count the colonies on the standard agar.

utensil surface area. The one-milliliter plate counts were multiplied by 2.5 to determine the bacteria count per square inch and the one-tenth milliliter plate counts were multiplied by 25 to determine the bacteria counts per square inch of surface area. Fig. 10 shows typical plates with varying numbers of colonies present.

The water hardness was determined by the standard Versenate method.[21] The Versenate Method for the determination

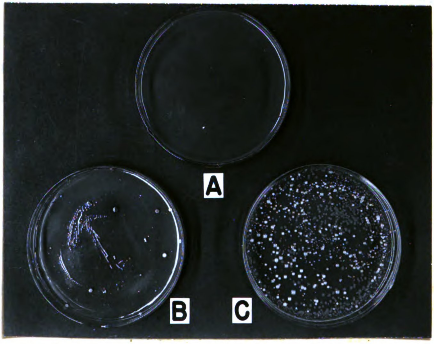

Fig. 10 Typical bacteriological plates showing varying degrees of contamination. Plate "A" is a sterile plate. Plate "B" is a plate that would be considered satisfactory for this study. Plate "C" is a plate too numerous to count and would be considered unsatisfactory. Plates with more than 300 colonies were considered too numerous to count.

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21. Anonymous. The Versenes. Tech. Bull. No. 2. Framingham, Mass: Bersworth Chemical Company, Sec. III, p. 5.

to the total hardness of water is superior to the soap titration method in accuracy and speed. Versene was used as the titrating agent as it reacts with calcium and magnesium to form complex ions. The calcium and magnesium are rendered inactive and the solution is kept perfectly clear. The endpoint of the titration was detected by the use of an indicator which changed in color from a wine red to a blue when the last of the calcium and magnesium was tied up. A buffer solution was added at the beginning of each titration to maintain the proper pH. The Versenate Method is accurate to 2 ppm and can be used over a wide range of water hardness. The Versene solution was standardized by using analytical standard calcium carbonate made up into a calcium chloride solution.

The reagents were obtained from stock materials and prepared according to standard procedure. The buffer solution was prepared by dissolving 13.5 grams of pure ammonium chloride in 114 milliliters of concentrated pure ammonium hydroxide. The mixture was then diluted to 200 milliliters. The indicator solution was prepared previously. The standard calcium chloride solution was prepared by dissolving 1.0 gram of pure calcium carbonate in a little dilute hydrochloric acid. The solution was diluted to exactly one liter and stored in a stoppered bottle. One milliliter was equivalent to 1.0 milligram of calcium carbonate. The standard Versenate solution was prepared by dissolving 4.0 grams of disodium-

dihydrogen versenate dihydrate in about 750 milliliters of distilled water. One-tenth of a gram of magnesium chloride ($MgCl_2 \cdot 6H_2O$) was added to the versenate solution. To standardize the versenate solution 25.0 milliliters of the standard calcium chloride solution was added to 10.0 milliliters of buffer solution plus three drops of indicator for endpoint detection and titrated against the prepared versenate solution. The above solution was titrated with the standard versenate solution to the color change. The versenate solution was later diluted so that one milliliter of versenate was equivalent to one milligram of calcium carbonate.

The procedure followed in testing a given sample was to pipette 50.0 milliliters of the water sample into a 250-milliliter flask and add 10.0 milliliters of the buffer solution and three drops of the indicator prior to titration. The sample was then titrated with the standard Versenate solution to the color change from wine red to blue. The total hardness (calcium and magnesium) was determined as ppm of calcium carbonate by multiplying the volume of versenate required in milliliters, by 20. Parts per million of hardness was divided by 17.1 to obtain grams of hardness per U.S. gallon.

PRESENTATION AND INTERPRETATION OF DATA

Field Data and Interpretations

Time and Motion Study

The data collected in the time and motion study included the time required for conducting various operations in the milk house as well as the number of pieces of equipment washed and other miscellaneous uses of water. The time and motion study was conducted only on the operations in the milk house and was not concerned with the actual milking operation. After the study was completed standard times were determined as shown in Table I. The time required for the milking operation varied directly with the number of cows being milked and inversely with the number of milking units used. The milking operation on the farms observed required an average of 8.8 minutes per cow per milking. Times required for milking varying size herds with varying numbers of milking units are shown in Table II.

The study was conducted only in stall-type barns and since loose-housing type barns are becoming increasingly popular it is well to include data for loose-housing barns relative to milking times. Cargill[22] found that it required

22. Cargill, B. F. Method engineering analysis of loose housing dairy barns. Unpublished manuscript for M.S., Michigan State College, p. 43.

TABLE I

AVERAGE TIMES AND RANGES OBSERVED FOR VARIOUS WASHING OPERATIONS

Operation	Average time (minutes)	Time range (minutes)
Disassemble milker	0.50	0.15 - 1.25
Assemble milker	0.50	0.10 - 0.95
Wash machine gaskets (two)	0.25	0.10 - 0.50
Wash inflation cups (four)	0.50	0.20 - 1.05
Wash three feet milker hose	0.20	0.10 - 0.60
Wash milker pail	0.80	0.20 - 2.45
Rinse milker pail	0.20	0.05 - 0.50
Wash milker head	0.60	0.10 - 2.50
Rinse milker head	0.20	0.05 - 0.45
Wash milker inflations (four)	0.90	0.20 - 2.50
Rinse milker inflations (four)	0.25	0.05 - 0.65
Disassemble strainer	0.40	0.20 - 0.90
Assemble strainer	0.40	0.20 - 0.60
Wash strainer	0.60	0.15 - 1.45
Rinse strainer	0.20	0.10 - 0.60
Wash 12-quart pail	0.30	0.20 - 1.05
Rinse 12-quart pail	0.20	0.10 - 0.30
Wash 14-quart pail	0.50	0.25 - 1.20
Rinse 14-quart pail	0.20	0.05 - 0.55
Wash 16-quart pail	0.60	0.30 - 1.20
Rinse 16-quart pail	0.20	0.10 - 0.30
Wash and rinse strip cup	0.40	0.30 - 0.60

TABLE II

TIME REQUIRED FOR MILKING VARYING SIZE HERDS WITH A VARYING NUMBER OF MILKING UNITS (STALL BARN)

Size of herd (cows)	Time in minutes per number of single units			
	One	Two	Three	Four
5	44.0			
10	88.0	44.0		
15	132.0	66.0	44.0	
20		88.0	58.6	44.0
25		110.0	73.4	55.0
30		132.0	88.0	66.0
35			102.8	77.0
40			117.2	88.0
45			132.0	99.0
50				110.0
55				121.0
60				132.0

6.7 minutes for milking per cow per milking when a loose-housing type of barn was employed and these results are shown in Table III.

The rates of water withdrawal and the times of withdrawal relative to the time of day were determined from the time and motion study. The average rate of withdrawal from the pressure type heaters was 3.92 gallons per minute and the average rate of withdrawal from the pour-in type heaters was 2.69 gallons per minute. The rate of withdrawal and the relative time of withdrawal is important from the standpoint of water heater selection. When a heater is operated on a time-clock mechanism the size of heater required may vary somewhat depending upon "off-peak" hours as established by the local power supplier.

Water Usage Study

The amount of water used for washing the dairy utensils varied widely. In some cases, as much as two to two and one-half times as much water was used for a given herd as compared with another herd of comparable size. The wash water temperatures did not vary widely and the mean temperature was approximately 120° F. It was observed that a water temperature much above 120° F was harmful to body tissue and that water at a temperature of 120° F, which was the common practice, was more comfortable for washing. When the temperature increased much above 120° F the hand became

TABLE III

TIME REQUIRED FOR MILKING VARYING SIZE HERDS WITH A VARYING NUMBER OF MILKING UNITS (LOOSE HOUSING BARN)

Size of herd (cows)	Time in minutes per number of single units			
	One	Two	Three	Four
5	33.5			
10	67.0	33.5		
15	100.5	50.5	33.5	
20	134.0	67.0	44.7	33.5
25		83.8	55.9	41.9
30		100.5	67.0	50.3
35		117.2	78.2	58.6
40		134.0	89.4	67.0
45			100.5	75.4
50			111.6	83.7
55			122.9	92.1
60			134.0	100.5
65				108.9
70				117.2
75				125.7
80				134.0

irritated. This finding closely agrees with the recommendation of Mallmann[23] who recommends a wash temperature of 115° to 120° F. Soil is more easily removed and cleaners act much better in warm water than in cold water. Cold water will not remove fats and oils and in no instance should cold water washing be tolerated.

The data collected on the 30 farms were analyzed statistically to determine the correlation between the amount of water used and the several factors involved. These data show that there was a significant relationship between the amount of water used and the size of herd, but also that there was a closer relationship between the amount of water used and the pieces of equipment washed. The amount of water used was determined on the basis of the number of units washed. The units were determined by relative surface area of the utensil according to the following schedule:

1 single milker unit	1.00 unit
1 strainer	0.25 unit
1 pail (16-14 qt.)	0.25 unit
1 pail (12-10 qt.)	0.20 unit
1 strip cup	0.05 unit

The amount of wash solution used is related to the number of units washed, as shown in Fig. 11. The statistical analysis

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23. Mallmann, W. L. Notes on dairy cleaners and cleaning dairy equipment. Mich. Agr. Exp. Sta. Quart. Bull. 27(1): 110, 1944.

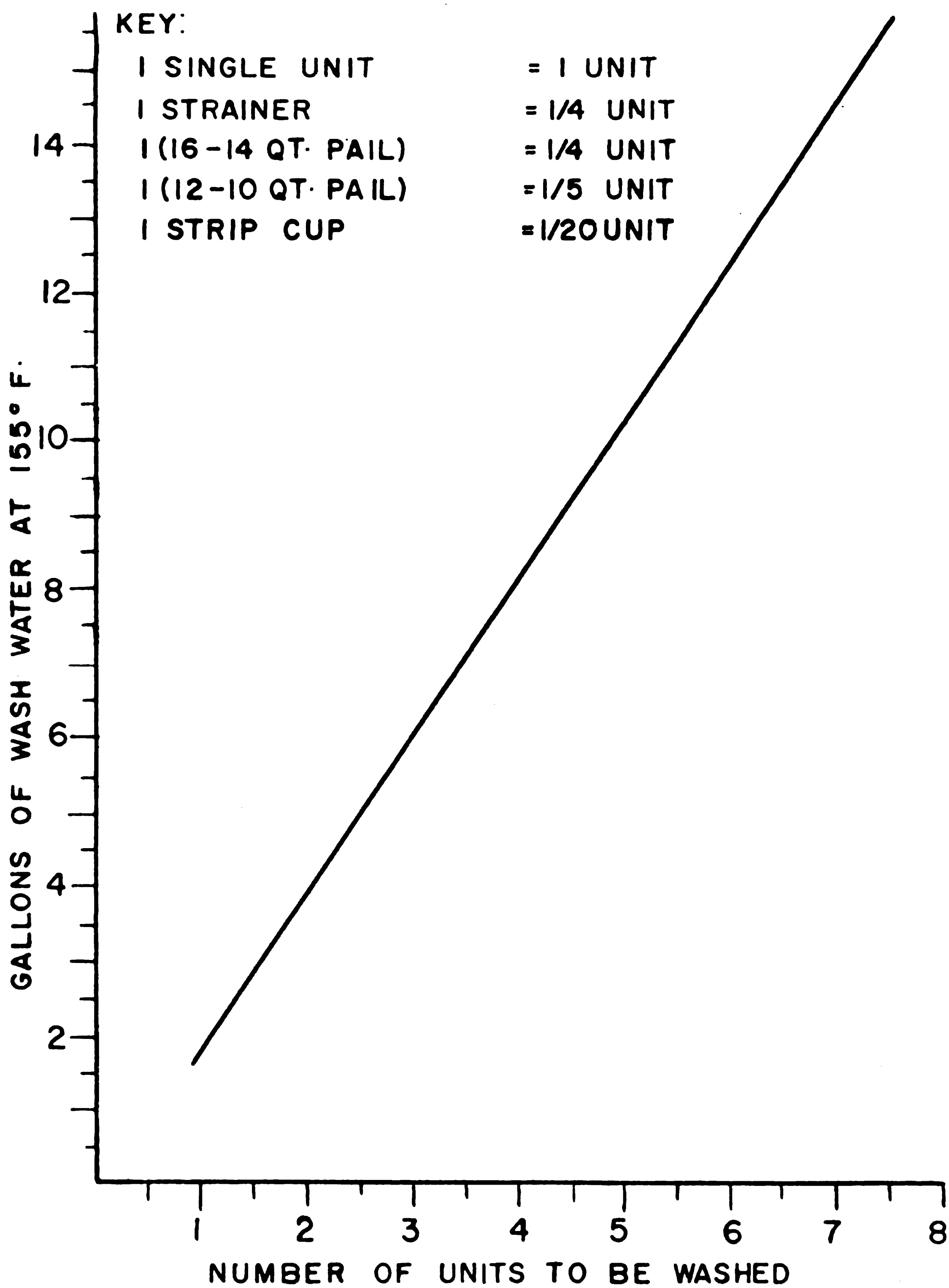

FIG. 11 AMOUNT OF WASH SOLUTION USED IN RELATION TO THE NUMBER OF UNITS WASHED.

was not concerned only with the amount of water used for washing relative to the amount of equipment washed but included other dependent and independent variables involved in the study as shown in Table IV.

Washing the udders prior to milking was practiced on 87 percent of the farms. For the purpose an average of 0.17 gal. of 110° F wash solution was used per cow per milking. It is recommended that a germicidal chemical machine rinse be used between cows during the milking operation to aid in the control of disease.[24] A germicidal rinse for teat cups was used on 40 percent of the farms. It was found on the average that 0.19 gal. of 110° F water per cow per milking was used for the machine teat cup rinse. The smallest size herd studied that used a machine rinse was 11 cows. It should be noted that the quantities mentioned above are average figures and the minimum quantity of udder wash and machine rinse used was one pail of each solution per milking. Of the 30 farms visited, 30 percent of the farms used short-tube milkers. It was found that the farms with short-tube milkers used an average of 3.8 gal. of 120° F water per unit of equipment washed, whereas the remaining farms averaged 2.8 gal. of 120° F water per unit washed. However, statistically no significant relationship was found between the amount of water used for the short-tube and the

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24. Jensen, J. M. Practical sanitation in caring for milking machines. <u>Mich</u>. <u>Agr</u>. <u>Exp</u>. <u>Sta</u>. <u>Cir</u>. <u>Bull</u>. 218:24, 1950.

TABLE IV

CORRELATION BETWEEN THE VARIABLES STUDIED SHOWING THE DEGREE OF SIGNIFICANCE

Variable		Significant (5% level)
Independent	Dependent	
Number of cows	Water consumption (gallons)	Yes
Units of equipment washed	Water consumption (gallons)	Yes (1% level)
Type of milker (long or short tube)	Water consumption/unit (gallons)	No
Heater temperature	Water consumption per 30 cow herd	No
Number of cows	Percent equipment sanitary (sanitizer)	No
Number of cows	Percent equipment sanitary (no sanitizer)	No
Temperature of wash water	Percent equipment sanitary (sanitizer)	No
Temperature of wash water	Percent equipment sanitary (no sanitizer)	No
Average time to wash milker pail	Percent milker pails sanitary (sanitizer)	No
Average time to wash milker pail	Percent milker pails sanitary (no sanitizer)	No
Average time to wash milker head	Percent milker heads sanitary (sanitizer)	No
Average time to wash milker head	Percent milker heads sanitary (no sanitizer)	No
Average time to wash milker strainer	Percent milker strainers sanitary (sanitizer)	No
Average time to wash milker strainer	Percent milker strainers sanitary (no sanitizer)	No
Amount wash water at 120° F/20 cows	Percent equipment sanitary (sanitizer)	No
Amount wash water at 120° F/20 cows	Percent equipment sanitary (no sanitizer)	No

long-tube milking machines.

Miscellaneous Observations

Pressure-type heaters were used on 80 percent of the farms with the water being piped under pressure to a double sink wash vat. Pour-in type heaters were used on the remaining 20 percent of the farms visited. The majority of the heaters were located near the wash vats -- 83 percent within 5 feet, 10 percent from 5 to 10 feet, and 7 percent at least 10 feet from the vats. About 95 percent of the farms with pressure type heaters had a mixer faucet located at the wash vat. The usual procedure was to wash the utensils in one side of the vat to remove the soil particles and to sanitize them in the other side of the vat. The average water heater temperature was 155° F. The average size of herd was 32 cows and 63.4 percent of the farmers visited were using 30-gallon heaters or larger.

Laboratory Data and Interpretations

Bacteriological Study

The bacteriological studied indicated that there was a definite advantage in using a germicidal agent in conjunction with the washing operation. This finding was in agreement with other studies.[25] At the farm, swabs were taken of the

25. Mallmann, W. L. Notes on the sanitization of dairy equipment. Mich. Agr. Exp. Sta. Quart. Bull. 27(1):112, 1944.

metal parts of the milking equipment. In every case a synthetic detergent was employed, but only 40 percent of the farms studied used a germicidal agent in the wash solution.

No bacteriological standard for sanitary equipment was found in the literature therefore the standard of 100 colonies per square inch of utensil surface, as used in the tests, was determined from other bacteriological standards as established for other conditions. The American Public Health Association[26] recommends that 100 colonies per eight square inches of utensil surface be the maximum allowable tolerance in dairy manufacturing plants. The U.S. Public Health Service,[27] however, recommends that counts less than 100 colonies per four square inches be considered sanitary for eating and drinking establishments. It was found by computation that the counts per milliliter were not significantly large when a standard of 100 colonies per square inch of surface area was used to determine the quality of the washing operation. The standard of 100 colonies per square inch was considered to be satisfactory when the conditions under which the swabs were taken, the accuracy of the swab contact method itself, and other existing standards were taken into consideration. The swabs were taken after the equipment had drained and partially dried. Swabs taken later

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26. American Public Health Association, op cit., p. 52.

27. U.S. Public Health Service. Ordinance and code regulating eating and drinking establishments. Public Health Service Publ. 37, p. 34, 1943.

would produce lower counts due to the drying effect of the bacterial cells, as many of the bacteria would be killed due to this dehydrating effect. The swabs were taken at a time when the counts were most likely to be the highest. For example, the contamination on a 14-quart pail was computed as two colonies per milliliter using the standard of 100 colonies per four square inches and four colonies per milliliter using the standard of 100 colonies per square inch of utensil surface. Other utensils would be in proportion to the 14-quart pail depending upon the surface area. Four colonies per milliliter were not considered significantly large for this study; therefore, bacteria counts of 100 colonies per square inch of utensil surface were considered sanitary. Without exception, a greater percent of the utensils washed in conjunction with a germicidal agent were sanitary as compared with the same type of utensil washed without a germicidal agent. In many cases there were 2/3 to 3/4 as many colonies present when a germicidal agent was used as compared with results when no germicidal agent was used for a given utensil. The effect of the use of a germicidal agent is shown in Table V.

These observations substantiate the belief that a germicidal agent is beneficial for the dairy farm from a bacteriological standpoint. The values shown in Table V were expressed as colonies per square inch of utensil surface and were taken from plates with 30 to 300 colonies per plate.

TABLE V

BACTERIOLOGICAL DATA SHOWING THE RELATIVE EFFECT OF THE USE OF A GERMICIDAL AGENT ON THE CLEANLINESS OF THE EQUIPMENT*

Utensil	No germicidal agent				Germicidal agent			
	Colonies			Percent sanitary	Colonies			Percent sanitary
	0-100	100-500	500+		0-100	100-500	500+	
Milker pail A (side)	6	4	6	37.5	16	1	0	94.2
Milker pail A (bottom)	6	7	2	40.0	12	1	0	92.5
Milker pail B (side)	7	7	26	17.2	18	4	4	69.2
Milker pail B (bottom)	17	5	18	42.5	16	2	7	64.0
Neck of strainer	6	1	20	27.2	11	1	6	61.0
Side of strainer	9	3	15	33.3	11	3	3	64.7
Milker head	21	12	8	51.3	20	2	4	72.9

*Plates with 100 colonies per dquare inch or less were considered to be sanitary

If all three plates for any one swab were too numerous to count (T.N.C.) the count was considered to be 500 colonies and the plate with the greatest dilution was considered. The counts computed by this method were recorded to two significant figures. Tables VI and VII show the relative position of the insanitary equipment with regard to the degree of insanitation.

It can be seen from Tables VI and VII that, almost without exception, the farmers using a germicidal agent in conjunction with their washing operation had less contamination per square inch of utensil surface than did the farmers who used no germicidal agent. The strainer was found to be the least sanitary piece of equipment studied. The neck of the strainer was less sanitary than the sides which was probably due to the inaccessibility of that part of the utensil. The study indicated that there was some variation in the quality of the washing relative to the type of milker used on the farm. Variations between types of milkers may not be justified because only a small number of units were observed in each case and erroneous results could easily result.

It was observed that the farmers who had low count equipment in general practiced "good housekeeping" methods in the milk house. The cooperators who washed their equipment thoroughly with an adequate amount of hot water, in conjunction with a synthetic detergent and germicidal agent, and

TABLE VI

BACTERIOLOGICAL DATA SHOWING THE RELATIVE DEGREE OF CLEANLINESS OF THE INSANITARY EQUIPMENT WHEN NO GERMICIDAL AGENT WAS USED

Utensil	Percent sanitary	Percent plates		Percent insanitary	
		(colonies/in^2) 100-500	(colonies/in^2) 500+	(colonies/in^2) 100-500	(colonies/in^2) 500+
Milker pail A (side)	37.5	25.0	37.5	40.0	60.0
Milker pail A (bottom)	40.0	46.7	13.3	78.8	22.2
Milker pail B (side)	17.5	17.8	65.0	21.2	78.8
Milker pail B (bottom)	42.5	12.5	45.0	27.1	78.3
Neck of strainer	22.2	3.7	74.1	4.8	95.3
Side of strainer	33.3	11.1	55.6	16.7	83.3
Milker head	51.3	29.3	19.5	60.0	40.0

TABLE VII

BACTERIOLOGICAL DATA SHOWING THE RELATIVE DEGREE OF CLEANLINESS OF THE INSANITARY EQUIPMENT WHEN A GERMICIDAL AGENT WAS USED

Utensil	Percent sanitary	Percent plates		Percent insanitary	
		(colonies/in^2) 100-500	(colonies/in^2) 500+	(colonies/in^2) 100-500	(colonies/in^2) 500+
Milker pail A (side)	94.2	5.9	0	100	0
Milker pail A (bottom)	92.5	7.5	0	100	0
Milker pail B (side)	69.2	15.4	15.4	50.0	50.0
Milker pail B (bottom)	64.0	8.0	28.0	22.2	77.8
Neck of strainer	61.0	5.5	33.5	14.3	85.7
Side of strainer	64.7	17.7	17.6	50.0	50.0
Milker head	77.9	7.7	15.4	33.3	66.7

had a well-designed milk house, with proper ventilation and lighting, did a good job of washing the equipment.

There was little correlation between the hardness of the water and the cleanliness of the equipment after washing because a synthetic detergent[28] was used in each case. The water hardness, expressed in parts per million, ranged from less than 5 ppm to 565 ppm. There was a wide variation in the hardness values obtained on farms within short distances of each other. With the exception of one farm, all of the cooperators had a hard water supply. None of the farms visited used water softeners in series with the water supply. As mentioned, reliance was placed upon the synthetic detergent to condition the water.

Selected Water Heater Study

The water heater studies were conducted on six selected water heaters of various sizes. Heaters studied included 6, 12, 20, 30, 50, and 80-gallon sizes. The studies were conducted to determine the amount of water that could be withdrawn from various size heaters at various rates of withdrawal without temperature drop. The thermostats of the heaters were set at 155° F which was the average temperature used by the cooperators visited in the study.

Data obtained from the various size heaters are presented in graphical form as seen in Figs. 12 through 19. Water was

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28. McCutchen, J. W. Synthetic detergents up to date. II. Soap and Sanitary Chemicals 28(7):49, 1952.

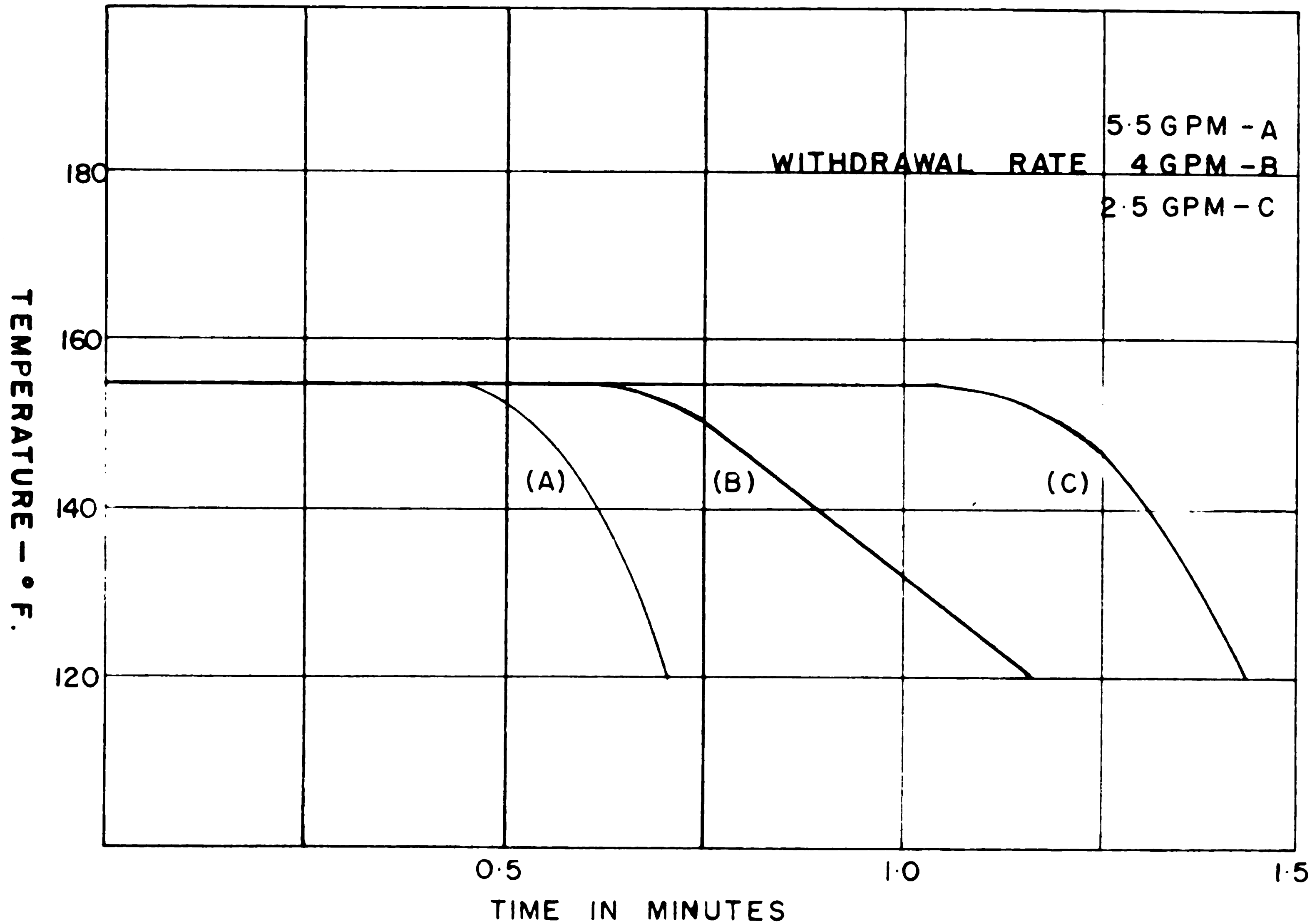
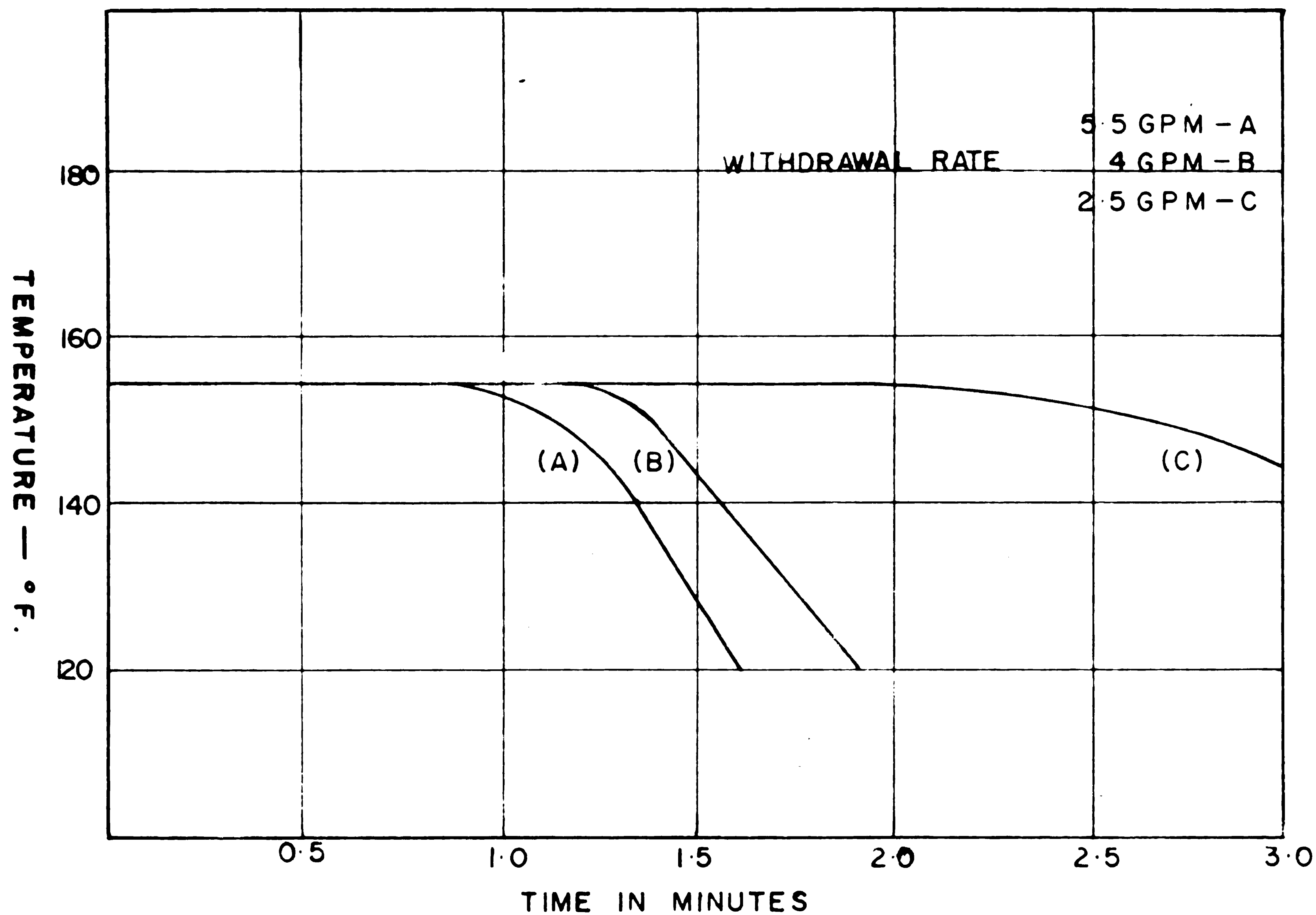
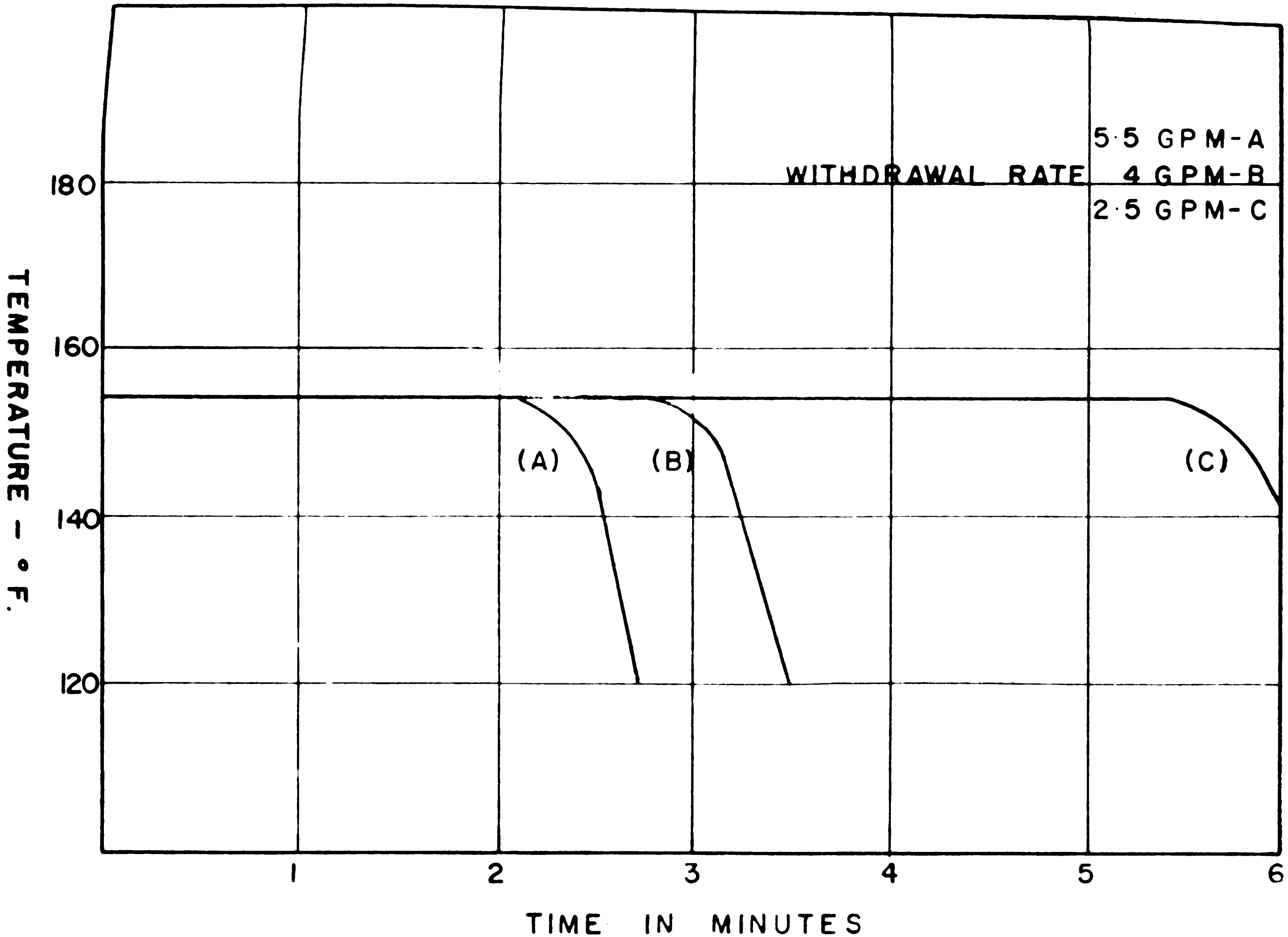


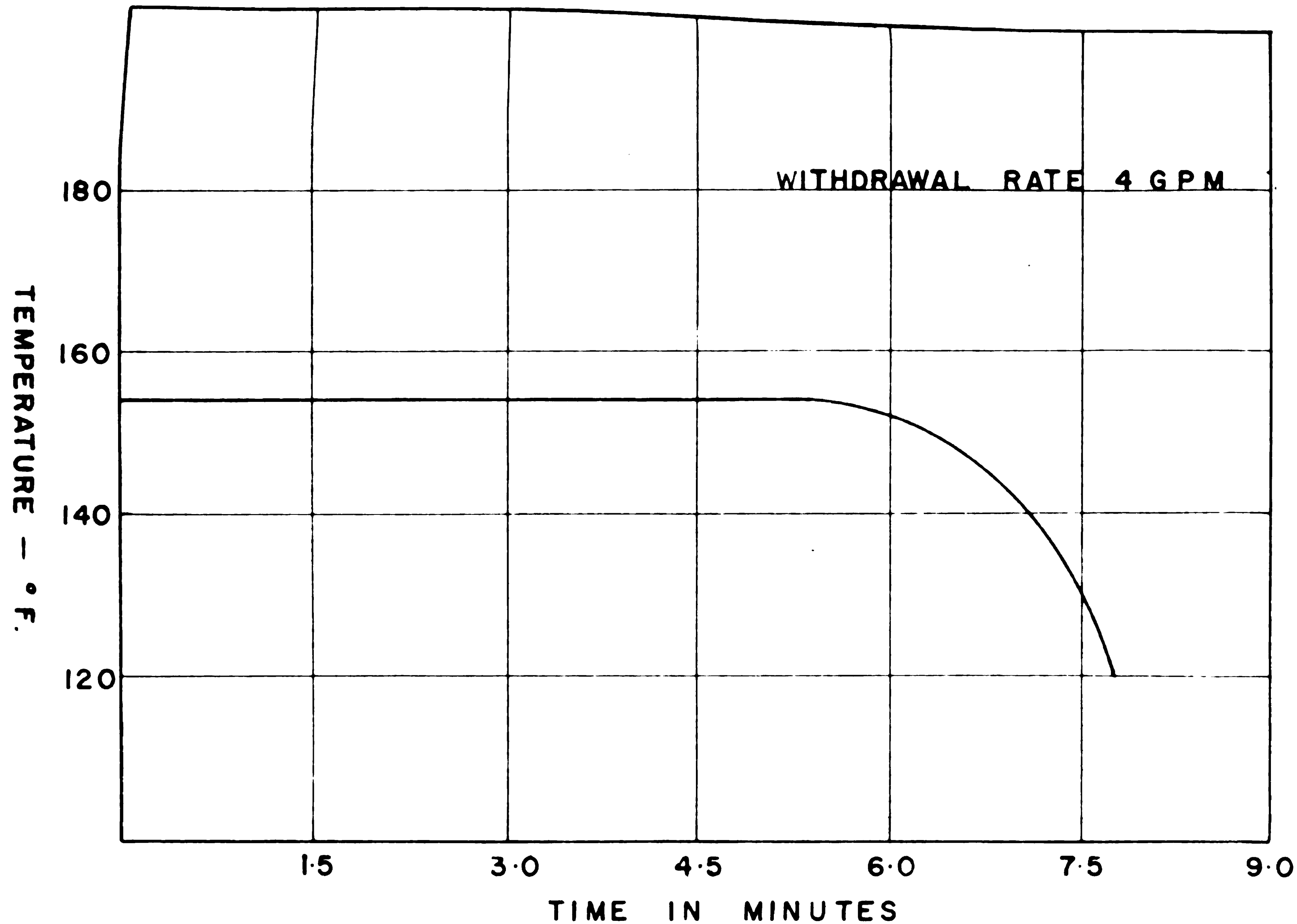
FIG. 12 WITHDRAWAL CURVE FOR A SIX GALLON HEATER



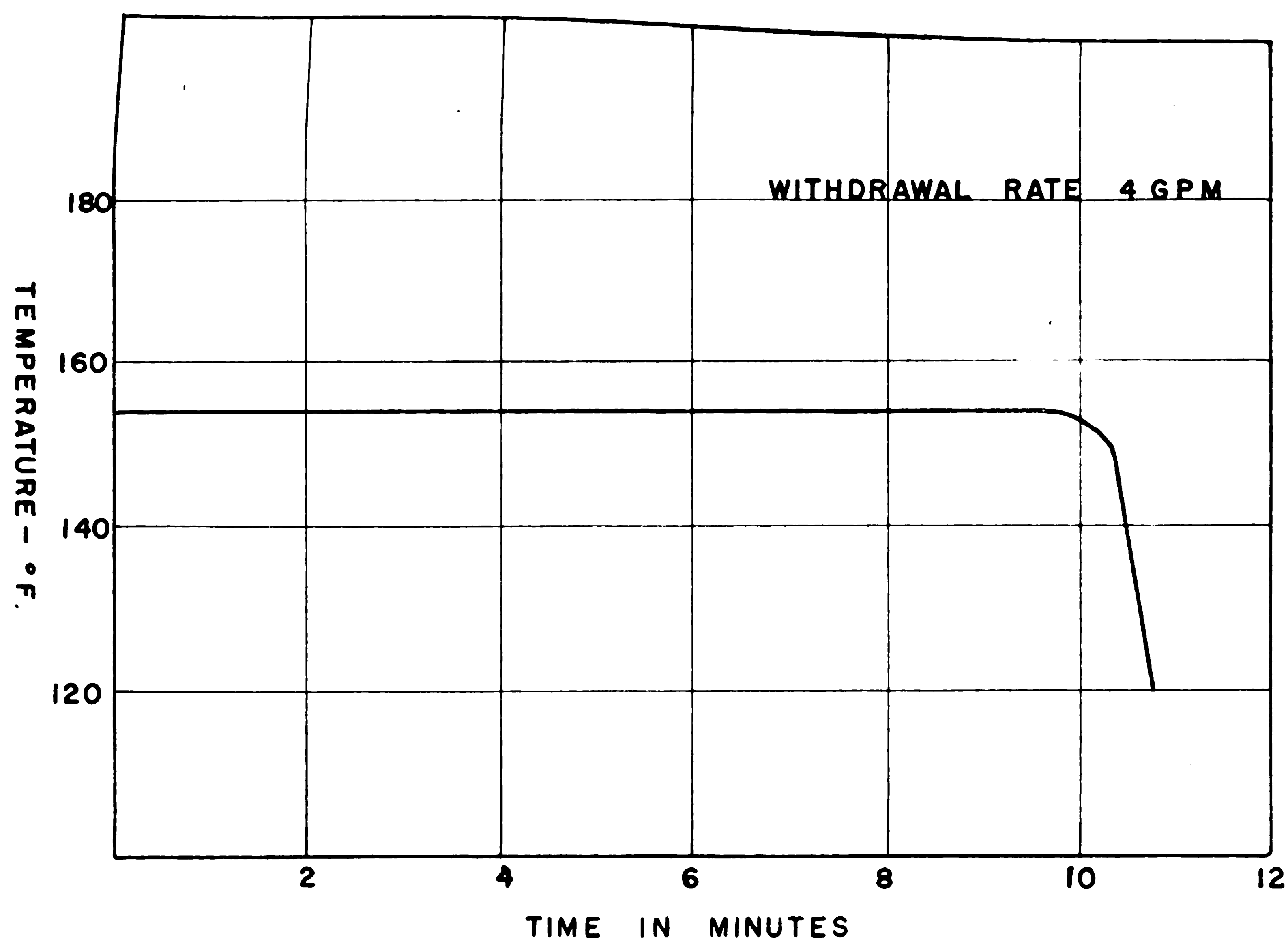
FIG·13 WITHDRAWAL CURVE FOR A TWELVE GALLON HEATER



FIG·14 WITHDRAWAL CURVE FOR A TWENTY GALLON HEATER



FIG· 15 WITHDRAWAL CURVE FOR A THIRTY GALLON HEATER



FIG·16 WITHDRAWAL CURVE FOR A FIFTY GALLON HEATER

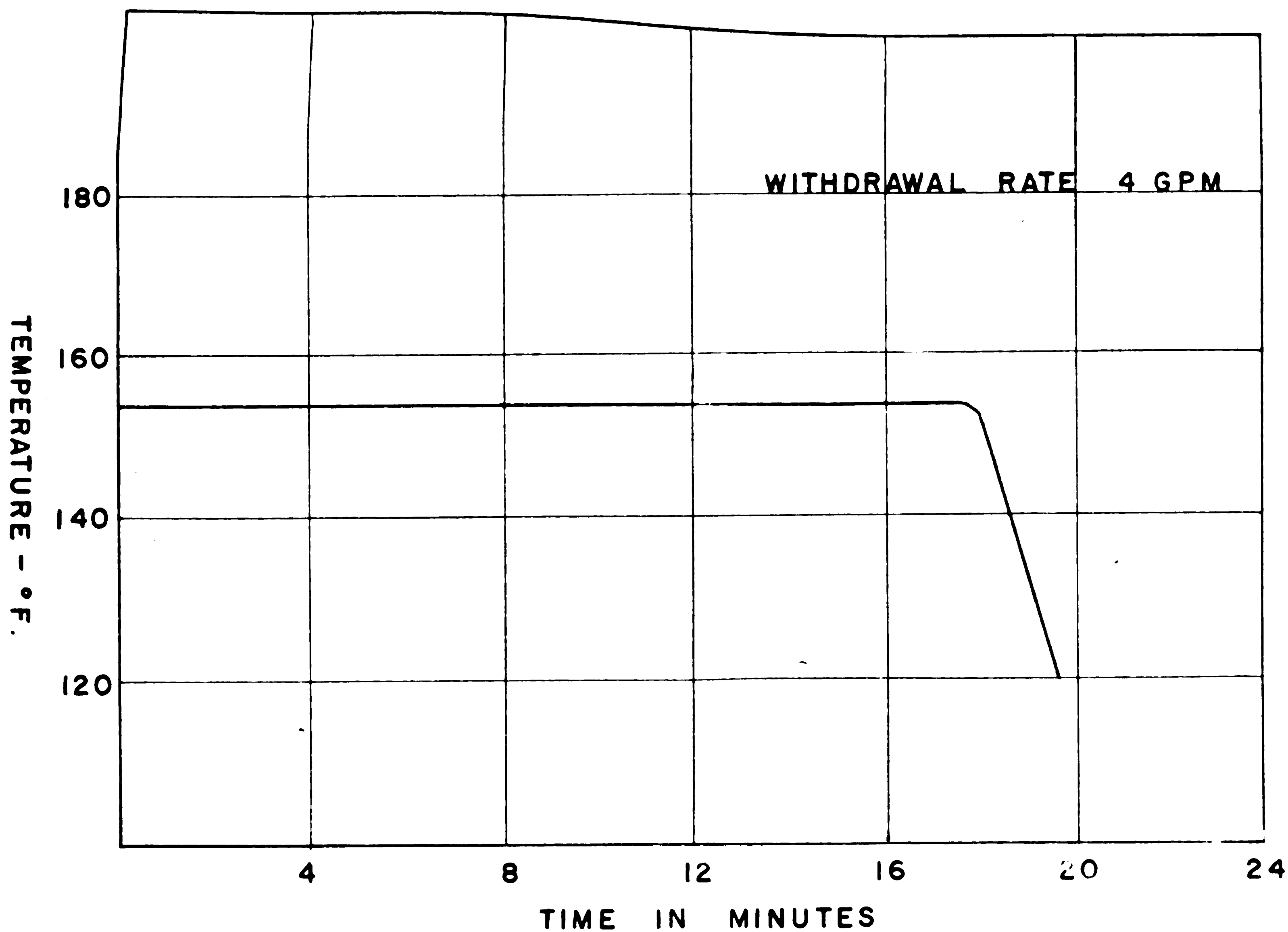


FIG. 17 WITHDRAWAL CURVE FOR AN EIGHTY GALLON HEATER

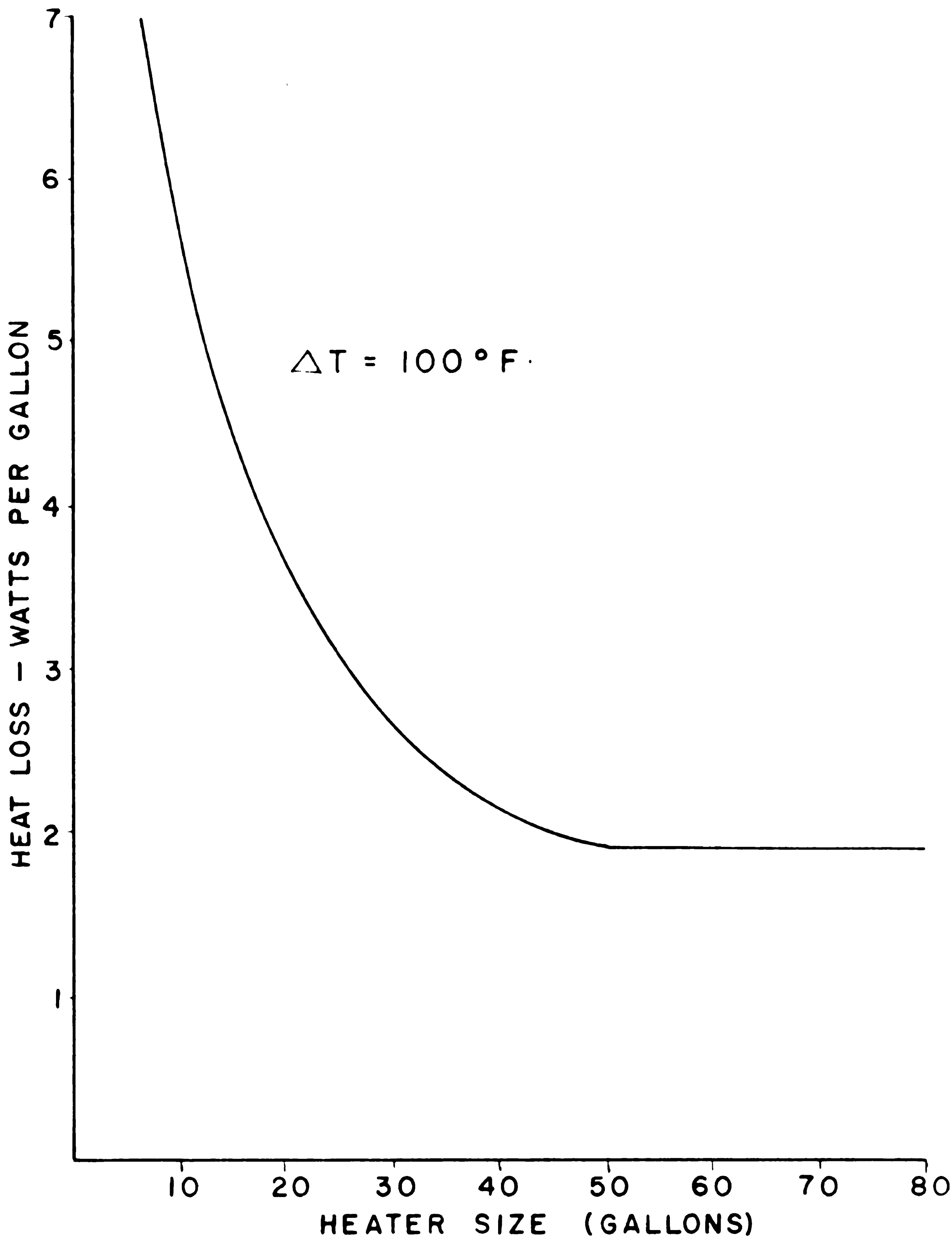
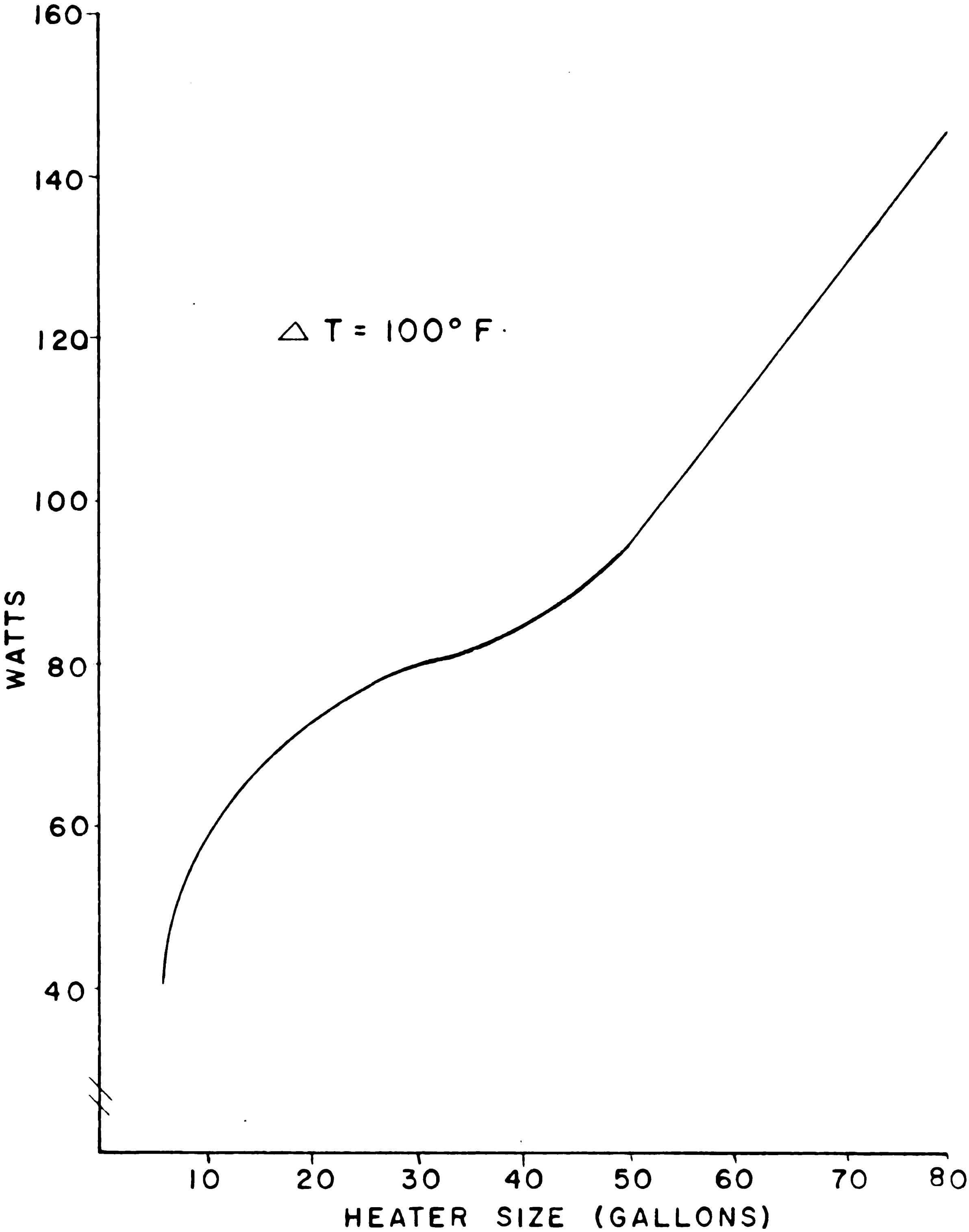


FIG. 18 HEAT LOSS IN WATTS PER GALLON FROM VARIOUS SIZE HEATERS



FIG·19 ELEMENT SIZE TO MAINTAIN TEMPERATURE FOR VARIOUS SIZE HEATERS withdrawn from the heaters at four gallons per minute because this rate of withdrawal was common practice among the farmers visited with pressure type heaters. It is noted from the graphs that as the size of the heater increased a greater proportion of the heater tank capacity could be withdrawn without temperature drop. The relationship of quantity of water withdrawn at temperature and heater tank size is presented in Table VIII. The values presented in Table VIII are average values obtained and varied somewhat depending on the temperature of the water in the tank. Several tests were conducted on the 6, 12 and 20-gallon size heaters but only one test was conducted on the 30, 50 and 80-gallon heaters because of their inaccessibility. Temperature differentials were noted for a given thermostat setting due to the temperature lag in the thermostats. A greater quantity of water could be obtained when the heating element had just stopped heating than when the element was about to begin to heat. The rate of temperature drop was greater for the 6, 12, and 20-gallon heaters tested than for the 30, 50, and 80-gallon sizes. The quantities of water withdrawn from the various heaters depended upon the rate of withdrawal. More water could be withdrawn from a given heater without temperature drop at a low rate of withdrawal (below 4 gallons per minute) than at a higher rate of withdrawal as can be seen from Figs. 12 through 17.

The heat loss through the walls of the various heaters

TABLE VIII

QUANTITIES OF WATER WITHDRAWN AT THE RATE OF FOUR GALLONS PER MINUTE FROM VARIOUS SIZES OF HEATERS WITHOUT TEMPERATURE DROP

Size of heater	Gallons withdrawn (155° F)	Percent of tank capacity withdrawn
6-gallon	2.5	41.8
12-gallon (squat type)	4.8	40.0
20-gallon	11.0	55.0
30-gallon	21.5	71.6
50-gallon	39.0	78.0
80-gallon	71.5	89.5

depended upon the size and shape of the heater, amount and kind of insulation and the difference in temperature between the heater and the surrounding air. The heat loss through the walls was calculated and actually tested with watt-hour meters as described in the procedure. Table IX shows the relationship between the size of heaters and the wattage required to maintain temperature. The heaters selected varied in type (upright or squat) and construction. The figures presented may not be valid for all heaters of that size but give an indication relative to the heat loss. It was noted that as the size of the heater increased the heat loss per gallon of tank capacity decreased. The calculated values were found to be much lower than the actual values. Lack of uniform insulation around outlets from the units, such as the thermostats and pipe outlets, would account for much of the difference in values obtained. The density of the insulation about the tank would also affect the values obtained. A comparison of the actual and calculated values is shown in Table IX. The effect of heater size on heat loss is shown graphically in Figs. 18 and 19.

Water Heater Selection

A method for determining the water heater and element size for a given dairy farm enterprise, based upon the data collected in this study is as follows:

A. Determine the required heater size.

TABLE IX

ACTUAL AND CALCULATED VALUES OF POWER LOSS THROUGH THE WALLS OF VARIOUS SIZE HEATERS

Heater size (gallons)	Measured heat loss (Watts/100° F)		Calculated heat loss (Watts for ΔT = 100°F)
6	41		15.5
12	71	(squat type)	31.5
20	73		45.5
30	80	(interpolated)	51.0
50	90		55.0
80	145		81.0

1. Determine the hot water usage for the washing operation depending on the quantity of equipment to be washed, based on the number of units (Fig. 11).
2. Determine the maximum number of calves raised. Allow 1/2 gallon of 155° F water per calf per watering. (This water is later blended with 55° F well water).[29]
3. Allow 2½ gallons of 155° F water for miscellaneous needs.[30]
4. Determine the total amount of water at 155° F used after the milking operation by adding items 1, 2, and 3.
5. Determine the proper size heater from Table VIII.

B. Determine the required heater element size.

1. Determine the water for washing the udders and rinsing the machines, allowing 1/5 gallon of 155° F water per cow per milking, with a minimum of 2 1/5 gallons of 155° F water per herd.
2. Determine the time intervals for milking depending on the size of herd, number of machines used, and the type of milking barn (Table II or III).
3. Determine the proper element size to return the water from item B(1) to temperature. With a 1000-watt element 4.12 gallons of water can be heated from 55° F to 155° F in one hour.
4. Determine the heat loss through the walls of the heater (Table IX).

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29. Stere, op cit., p. 8.
30. Ibid, p. 9.

5. Calculate the total minimum wattage required by adding the values from step 3 and step 4 if the heater is to return to temperature during the milking operation.

The wattage determined in step B(3) is the wattage required to heat only the water back to temperature during the milking period. To determine the proper heater element size, as outlined in Part B for water heater selection, the water required for washing the udders and rinsing the milking machines during the milking operation must be determined regardless of whether an udder wash or machine rinse is actually used on the farm. An additional wattage should be allowed to take care of heat loss through the walls. Table IX shows the relationship between heater tank size and heat loss through the walls for selected heaters.

Two examples are presented using this method. The first example is for a small sized herd and the second example is for a medium sized herd.

Example 1

Conditions:

15-cow herd, 2 single unit machines, 1 strainer, 2 14-quart pails, 2 10-quart pails, 1 strip cup, and 3 calves (Stall barn).

A. Determine the required heater size.

1. Determine the amount of 155° F water for blending to be used for washing the milking equipment (Fig. 11).

2 single unit milkers	2.00 units
1 strainer	0.25 units
2 14-quart pails	0.50 units
2 10-quart pails	0.40 units
1 strip cup	0.05 units
Total units to be washed	3.20 units

For 3.20 units, 6.50 gallons of 155° F water is used. (Fig. 11).

2. Determine the number of calves raised.

   Three calves are raised -- allow 1/2 gallon of 155°F water per calf or 1½ gallons of 155° F water.

3. Determine the requirements for miscellaneous needs.

   Allow 2½ gallons of 155° F water for these needs.

4. Determine the total water usage after milking.

Washing solution	6.50 gallons 155° F water
Calves	1.50 gallons 155° F water
Miscellaneous	2.50 gallons 155° F water
Total usage	10.50 gallons 155° F water

5. From Table VIII it can be seen that a heater of the 20-gallon size is required so that 10.5 gallons of hot water are available for washing.

B. Determine the required heater element size.

1. Determine the usage for udder wash and machine rinse.

   1/5 x 15   3 gallons 155° F water

2. Determine the time interval for milking.

   Table II -- 65.6 minutes or 1.1 hours

3. Determine the element size required to heat water from 55° F at the well to 155° F at the heater.

1 kw-hr.	4.12 gallons heated through 100° F interval
Usage	3.00 gallons 155° F water

$$\text{Wattage required} = \frac{(\text{gal. } 155^\circ \text{ F}) \times 1000}{4.12 \times (\text{time for milking in hours})}$$

$$= \frac{3.0 \times 1000}{4.12 \times 1.1} = 663 \text{ watts}$$

4. Determine the wattage required to overcome heat loss during the milking interval.

   From Table IX the power required to maintain temperature for a 20-gallons heater is 73 watts.

5. Determine the total minimum wattage required to return heater to temperature.

Heat loss	73 watts
Water heating	663 watts
Total minimum wattage required	736 watts

In the Michigan area when a heater selected for any given herd is 30 gallons or larger it may be attached to an "off-peak" mechanism to control the operation of the lower element. When this is the case, the wattage determined from step B(5) may not be used at the time of the evening and morning milkings as the power may be interrupted by the clock and possibly not enough water will have been withdrawn to activate the upper element. If the lower element is unable to operate at milking time, it will be necessary to

select a heater with capacity large enough for water usage before and after milking (See Example 2). For an "off-peak" heater the element size should be sufficient to return the water to 155° F within the shortest time available for heating between milkings. Thus, if heating is permitted between 10 P.M. and 7 A.M. and between 12 noon and 7 P.M., as is the common practice on Michigan farms, the unit should recover within these times and this criterion should be used as a basis of element size. There is a safety factor inherent in the construction of "off-peak" heaters, as used in Michigan, namely there is an upper element that is usually one-half again as large as the lower element[31] that is not controlled by the "off-peak" mechanism and will operate as the thermostat directs. This upper element can operate during "peak" hours if necessary. It should also be noted that with such heaters only one element can operate at any one time. In any event, it would be well to consult the local power supplier regarding "off-peak" water heater operation.

<u>Example 2</u>

Conditions:

30-cow herd, 3 single unit machines, 2 strainers, 2 16-quart pails, 4 10-quart pails, 1 strip cup, and 5 calves (Stall barn).

A. Determine the required heater size.

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31. Pfingsten, op. cit., p. 38.

1. Determine the amount of 155° F water for blending to be used for washing the milking equipment (Fig. 11).

3 single unit milkers	3.00 units
2 strainers	0.50 units
2 16-quart pails	0.50 units
4 10-quart pails	0.80 units
1 strip cup	0.05 units
Total units to be washed	4.85 units

For 4.85 units, 10 gallons of 155° F water is needed (Fig. 11).

2. Determine the number of calves raised.

Five calves are raised -- allow 1/2 gallon of 155° F water per calf or 2½ gallons of 155° F water.

3. Determine the requirements for miscellaneous needs.

Allow 2½ gallons of 155° F water for such needs.

4. Determine the total water usage after milking.

Washing solution	10.00 gallons 155° F water
Calves	2.50 gallons 155° F water
Miscellaneous	2.50 gallons 155° F water
Total usage	15.00 gallons 155° F water

5. From Table VIII it can be seen that a heater of the 30-gallon size is required.

B. Determine the required heater element size.

1. Determine usage for udder wash and machine rinse.

$1/5 \times 30 = 6.00$ gallons 155° F water

2. Determine the time interval for milking.

Table II -- 87.15 minutes or 1.46 hours.

3. Determine the element size required to heat water from 55° F at the well to 155° F at the heater.

1 kw-hr.	4.12 gallons heated through 100° F interval
Usage	6.00 gallons 155° F water

$$\text{Wattage required} = \frac{(\text{gal. } 155^\circ \text{ F}) \times 1000}{4.12 \times (\text{time for milking in hours})}$$

$$= \frac{(6.0) \times 1000}{4.12 \times 1.46} = 1000 \text{ watts}$$

4. Determine heat loss during milking interval.

From Table IX the power required to maintain temperature for a 30-gallon heater is 80 watts.

5. Determine the total minimum wattage required to return the heater to temperature.

Heat loss	80 watts
Water heating	1000 watts
Total minimum wattage required	1080 watts

When the heater in Example 2 is controlled by an "off-peak" mechanism the lower element may be inactive during the milking operation and a larger heater element should be selected. The heater should be of sufficient size to handle the water usage before and after milking. In Example 2 a 30-gallon heater would be sufficient for such a condition

as determined by adding A(4) and B(1) and referring to Table VIII. The element size for this heater as determined previously would be sufficient because the heater could recover before the next milking.

Practices for Efficient Use of Water

1. Hot water should be piped under pressure to the wash vats and a mixer faucet should be provided to enable the operator to have blended water quickly of the proper temperature.
2. Heaters should be provided with heat traps to prevent the circulation of the hot water within the pipes.
3. The heater should be located as close to the wash vats as possible to reduce the heat loss through the pipes during and after withdrawal.
4. Do not use a larger size pipe than is necessary to convey the water to the wash vats because the heat loss through the pipes increases rapidly as the size of pipe increases. The volume of water retained in the pipes is proportional to the square of the diameter and the heat transfer surface is proportional to the diameter.
5. If pour-in type heaters are used they should be located adjacent to the wash vats so that the water may be placed directly into the vats.
6. A water softener in conjunction with the heater would

prevent much of the lime deposit on heating elements and add greatly to the efficiency of the heater. An economical analysis is not available. In this study, there was no relationship between the hardness of the water and the quality of the washing operation as all of the farmers visited were using a synthetic detergent.

7. Faucets should be checked constantly to reduce the loss of water due to dripping.
8. In cold climates, the water pipes to and from the heater should be protected from freezing.

SUMMARY

The amount of hot water used for a given dairy farm enterprise depends upon several factors. The data showed that there was a significant relationship between the amount of water used and the size of herd, but also that there was a closer relationship between the amount of water used and the pieces of equipment washed. This study has demonstrated that the amount of water used for washing the dairy utensils depends upon the number of pieces of equipment to be washed and the need for udder wash and machine rinse depends upon the size of the milking herd. A time and motion analysis was conducted in conjunction with the water study to determine the time required for doing various jobs in the milk house. Swabs were taken of the equipment after they had been washed to determine the quality of the washing operation. A better job of washing resulted when a germicidal agent was used in conjunction with the wash solution than when only a detergent was used alone. The hardness of the water supply and the time employed for washing the various utensils had no noticeable effect upon the quality of the washing operation, as every farmer visited was using some form of synthetic detergent. The temperature of the water used for washing the utensils had no noticeable effect upon the quality of the washing operation because the temperatures used did not

vary widely and such temperatures were designed principally to remove the soil from the utensil and not to act principally as a germicidal agent. The bacteriological study substantiated the common belief that a germicidal agent is a valuable aid for cleaning milking utensils.

The water heater studies showed that as the tank capacity increased the quantity of water that could be withdrawn without temperature drop also increased. A greater quantity of water at temperature could be withdrawn from a given size heater at a slower rate of withdrawal than at a faster rate of withdrawal. When selecting a heater for any given dairy herd operation it is well to consider both the tank size and the heating element size. The heater element size will depend upon the length of time required for milking, time during the day available for reheating particularly with units with "off-peak" heater controls, and the heat loss through the walls of the heater. The heat loss increased as the size of the heater increased but the heat loss per gallon of tank capacity decreased as the size of the heater increased for a given temperature differential.

The study indicated that the proper method to follow for washing milking equipment was to wash the equipment in the amount of 155° F water as indicated from Fig. 11. The 155° F water as it comes from the heater must be tempered with cooler water to 120° F from a practical standpoint.

A synthetic detergent and a germicidal agent should be used in conjunction with the wash solution during the washing operation.

CONCLUSIONS

1. The amount of hot water used for washing dairy utensils depends upon the number of pieces of equipment washed.
2. Each "unit" washed required 2.1 gallons of 155° F water per washing. This water was later blended with 55° F well water to 120° F for the actual washing operation.
3. The main uses of hot water in the milking operation consisted of utensil wash, udder wash, machine rinse, calf water and miscellaneous uses.
4. The times required for washing various milking equipment varied widely from farm to farm.
5. Average times required for washing various pieces of equipment were nearly proportional to the surface area washed and the accessibility of the surface area.
6. A better job of washing resulted when a germicidal agent was used in conjunction with the wash solution than when only a detergent was used alone.
7. The hardness of the water supply had no noticeable effect upon the quality of the washing operation as every farmer visited was using some form of a synthetic detergent.
8. The time required for washing the various utensils had no noticeable effect upon the quality of the washing.
9. The temperature of the water, as used by the farmers,

for washing the utensils had no noticeable effect upon the quality of the washing operation.

10. The wash water temperature used was mainly for the purpose of removing the soil and not to act as a germicidal agent.

11. Water much above 120° F was found to be harmful to body tissue and hotter water was not practical when the utensils were washed by hand.

12. The water heater studies showed that as the tank capacity increased the quantity of water that could be withdrawn without temperature drop also increased.

13. A greater quantity of water at temperature can be withdrawn from a given size heater at a slower rate of withdrawal than at a faster rate of withdrawal.

14. The heater element size depends upon the time required for milking, time available between milkings for reheating, and the heat loss through the walls of the heater.

15. The heat loss increases as the size of the heater increases but the heat loss per gallon of tank capacity decreases as the capacity increases.

16. The average size herd surveyed was 32 cows and 63.4 percent of the farmers visited were using 30-gallon heaters or larger.

17. A 20-gallon size heater will be sufficient for a 15-cow herd or smaller.

SUGGESTIONS FOR FUTURE STUDY

1. Pen barn hot water requirements.
2. The use of large tank sizes with small heating elements relative to small tank sizes with large heating elements.
3. Mechanical washing with hotter water relative to hand washing at 120° F.
4. Merits of heating water from the "high" side of refrigerating units.
5. Merits of putting two elements in small heaters and controlling by "off-peak" mechanisms.
6. The equity of flat rate discount for heaters relative to metered water heating.
7. Hot water requirements for flush or circulatory cleaning of pipe lines and bulk tanks.

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APPENDIX I

DATA FORMS USED FOR COLLECTING AND COMPILING DATA

[illegible]

[illegible] ______ [illegible] ______

Type of heater ______ [illegible] ______

Voltage ______ [illegible] ______ [illegible] ______

Size: Gallons ______ [illegible] ______

Time now attached ______ [illegible] removed ______

Type of cooler ______ [illegible] Make ______

Type of milker ______ Water hardness ______ P.P.M. ______

Make of milker ______ Number of units ______

NOTE:

Method of [illegible]

Number of cows

Weight of milk shipped per day

Type of [illegible] and [illegible]

Amount of cold water used ________ Night ________ Morning ________

Water hardness ________ PPM

Water use at night - amount ________ Temperature ________

Water use in morning - amount ________ Temperature ________

Temperature cold water ________

K.W.H. used for heating per day ________

Time of first drawing ________ Amount ________ GPM ________ Temp. ________

Time of drawing ________ Interval ________ Amount ________ GPM ________ Temp. ________

APPENDIX II

LIST OF INDIVIDUAL PROJECT COOPERATORS

LIST OF COOPERATORS

Name	Address	
Allen, Harry	Route 4	Mason, Michigan
Bibbons, Kenneth	Route 4	Mason, Michigan
Bowlby, Jay		Ovid, Michigan
Cheney, Ludell	R.F.D.	Mason, Michigan
Carruthers Farm		Bancroft, Michigan
Dansby, William	R.F.D.	Williamston, Michigan
Dickinson, Derwood	Route 4	Mason, Michigan
Eifert, Robert	Route 4	Mason, Michigan
Emens, Coe	R.F.D.	Mason, Michigan
Glenn, Harold	Route 1	Dansville, Michigan
Gorgenson, Gerald	Route 3	Webberville, Michigan
Graf, Fred	Route 2	Stockbridge, Michigan
Graf, John	Route 2	Dansville, Michigan
Graves, William	Route 2	Webberville, Michigan
Hall, Chellis	R.F.D.	Mason, Michigan
Hazle, Wesley	Route 1	Ovid, Michigan
Kalczymski, Theodore	Route 2	Webberville, Michigan
Klocksiem, Harold	Route 2	Laingsburg, Michigan
Kurka, Joseph	Route 2	Ovid, Michigan
Kurtz, Kenneth	4320 E. Cavanaugh Rd.,	Mason, Michigan
Lantis, Earl	Route 2	Stockbridge, Michigan
Loomis, Ralph	Route 1	Perry, Michigan
Lott, Raymond	Route 1	Dansville, Michigan

LIST OF COOPERATORS Continued

Name		Address
McAvoy, Thomas	Route 3	Owosso, Michigan
Montaven, Otis	Route 4	Mason, Michigan
Phiester, Kenneth	R.F.D.	Webberville, Michigan
Smith, Owen	R.F.D.	Mason, Michigan
Waltz, Carlyle	R.F.D.	Mason, Michigan
Wilcox, Raymond	R.F.D.	Mason, Michigan
Williams, Leon	Route 3	Elsie, Michigan

APPENDIX III

METHOD USED FOR THE STATISTICAL ANALYSIS

The method used to determine the dependence of the amount of water at 120° F used for washing the dairy utensils upon the number of cows in the milking herd.

Number of cows in herd X	Gallons of water used at 120° F Y	Number of cows in herd X	Gallons of water used at 120° F Y
32	12.35	30	21.90
35	11.23	30	8.80
25	4.36	25	22.88
30	5.92	30	22.55
23	5.77	40	39.90
17	14.04	21	13.85
45	18.55	30	25.67
15	12.20	43	11.54
15	9.75	30	9.42
90	25.22	20	16.00
37	4.00	53	27.05
30	5.87	20	8.35
27	18.18	18	6.02
29	2.77	25	9.72

$n = 28$ $X^2 = 31,939$

$X = 855$ $Y^2 = 7,598.21$

$Y = 393.86$ $XY = 13,442.61$

$$r_{YX} = \frac{\Sigma XY - \frac{\Sigma X \Sigma Y}{n}}{\sqrt{\left[\Sigma X^2 - \frac{(\Sigma X)^2}{n}\right]\left[\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}\right]}}$$

$$= \frac{13{,}442.61 - \frac{(855)\ (393.86)}{28}}{\sqrt{\left[31{,}939 - \frac{(855)^2}{28}\right]\left[7{,}598.21 - \frac{(393.86)^2}{28}\right]}}$$

$$r_{YX} = 0.4092$$

A correlation coefficient of 0.4092 with 26 degrees of freedom is significant at the 5 percent level.[32]

32. Snedecor, G. W. Statistical Methods. Ames: Iowa State College Press, 1948, p. 149.

A second example is presented to show the dependence of the amount of water at 120° F used for washing the utensils upon the number of "units" washed.

Number of "units" washed X	Gallons of water used at 120° F Y	Number of "units" washed X	Gallons of water used at 120° F Y
4.25	12.35	3.75	8.80
4.00	11.23	4.05	22.88
4.75	4.36	4.75	22.55
3.60	5.92	6.90	39.90
2.45	5.77	4.40	13.85
3.25	14.04	4.05	25.67
4.65	18.55	5.85	11.54
2.95	12.20	6.75	9.42
3.25	9.75	3.00	16.00
6.95	25.22	5.75	27.05
4.75	4.00	2.80	8.35
4.55	5.87	4.75	18.18
3.25	6.02	5.10	.2.77
4.75	9.75	7.00	21.90

$n = 28$ $\quad$ $X^2 = 615.39$

$X = 126.3$ $\quad$ $Y^2 = 7,598.21$

$Y = 393.86$ $\quad$ $XY = 1924.64$

$$r_{YX} = \frac{\Sigma XY - \dfrac{\Sigma X \quad \Sigma Y}{n}}{\sqrt{\left[\Sigma X^2 - \dfrac{(\Sigma X)^2}{n}\right]\left[\Sigma Y^2 - \dfrac{(\Sigma Y)^2}{n}\right]}}$$

$$= \frac{1924.64 - \dfrac{(126.3)\ (393.86)}{28}}{\sqrt{\left[615.39 - \dfrac{(126.3)^2}{28}\right]\left[7{,}598.21 - \dfrac{(393.86)^2}{28}\right]}}$$

$$r_{YX} = 0.4837$$

According to Snedecor[33] a correlation coefficient of 0.4837 with 26 degrees of freedom is significant at the 1 percent level.

33. Ibid, p. 149.

APPENDIX IV

METHOD FOR CALCULATING HEAT LOSS

The method used to calculate heat loss through the walls of the various heaters tested is presented in the following two examples.

<u>Example 1</u> - Six-gallon heater

Conditions:

1. Surface area - 5.03 ft^2
2. Insulation - 2.5 inches = 0.208 feet

   Rock wool - K = 0.022
3. Temperature difference - 100° F

$$Q = \frac{A\ K\ (\Delta t)}{X}$$

where: A = Surface area in ft^2
K = Insulation constant
t = Temperature differential
X = Insulation thickness in feet

$$Q = \frac{A\ K\ (\Delta t)}{X} = \frac{5.03\ ().022)\ 100}{0.208}$$

Q = 51.3 BTU/hr or 15.5 watts

<u>Example 2</u> - Thirty-gallon heater

Conditions:

1. Surface area - 15.6 ft^2
2. Insulation - 2.35 inches = 0.196 feet

   Rock wool - K = 0.022
3. Temperature difference - 100° F

$$Q = \frac{A\ K\ (\Delta t)}{X} = \frac{15.6\ (0.022)\ 100}{0.196}$$

Q = 175 BTU/hr or 51 watts