MILKING MACHINES:

VII. FURTHER STUDIES ON METHODS OF STERILIZATION

A. H. ROBERTSON, M. W. FINCH, AND ROBERT S. BREED

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A. H. ROBERTSON, M. W. FINCH,* AND ROBERT S. BREED

SUMMARY

Since bacterial counts from samples of machine-drawn milk, as taken from the milker pail, may and ordinarily do contain significant numbers of bacteria from other sources than that of the milker tubes and teat-cups, and since the object of the present work was to determine the amount of bacterial contamination derived from the teat-cups and tubes under various conditions, all bacterial counts given, except as noted, were obtained by analysing samples of sterile water which had been "milked" from an artificial udder thru the machines. Samples were caught before coming in contact with any part of the machine except the teat-cups, tubes, and such parts of the pulsator as could not be eliminated. Except as noted, tests were made from teat-cups and tubes from B-L-K machines in daily use in the Station stables.

In order that the counts might represent the maximum counts obtainable from agar plates, the plates were incubated for five days at 21° C.

Caring for the teat-cups and tubes by placing them in hot water (temperature from 150° to 180° F.) and allowing them to remain in the water long enough to secure practical sterilization was found to give excellent results. This heating was not unduly destructive of rubber tubing such as is furnished today with nearly all milkers; but it was found to be rapidly destructive of the rubber mouth-pieces and inflations of certain types of milkers. For this reason, this method of sterilization is not recommended for all makes of milkers.

Control of the growth of bacteria in the milker tubes by keeping the tubes in cold, running water between milkings has been further tested. It was found that the tubes eventually became coated with large numbers of water bacteria even where the temperature of the water was lower than 58° F. For this reason it is not regarded as an entirely satisfactory method of caring for tubes.

* Formerly Assistant Bacteriologist at this Station.
Chemical sterilization of the milker tubes by means of chloride of lime, commercial hypochlorite solutions, and commercial chloramine powders has been further tested. Hypochlorite solutions have been found to be remarkably effective sterilizing agents when used as rinsing solutions, while chloramine solutions used as rinses failed to sterilize the milker tubes at the strengths tested.

On the other hand, hypochlorite solutions were found to lose their effective strength so rapidly in the interior of the rubber tubing that they did not sterilize the tubes at the strengths recommended by manufacturers of the commonly used commercial solutions. These must be used in such strong solutions to sterilize the tubes, and must be renewed so frequently, that, used alone, they make very unsatisfactory solutions for sterilizing milker tubes. This weakness of the hypochlorites is overcome by combining them with strong brine solutions, the latter being themselves fairly satisfactory solutions in which to keep milker tubes.

Chloramine solutions used in 10 per cent brine in a crock were found to be effective and satisfactory agents for use in sterilizing milker tubes. However, the cost of chloramine powders and commercial hypochlorite solutions in comparison with that of home-made hypochlorite solutions prepared from chloride of lime is so great that these commercial preparations are not recommended for use.

The best of the chemical sterilizing solutions (chloride of lime in a saturated brine) corrodes some metals and alloys occasionally used in milker parts; but in the better types of mechanical milkers, these corroducible metals such as aluminum, aluminum alloys, and cheap solder are no longer used for parts exposed to the action of the sterilizing solutions.

The bacteriological condition of tubes taken apart completely and scrubbed daily was found to be very bad unless some means of sterilizing the parts was used. The moist inner surfaces of rubber tubing, no matter how thorough they are cleaned, offer ideal growing conditions for bacteria at ordinary temperatures.

In the conclusion of this bulletin, general directions are given for the cleaning and care of milking machines that have been prepared as a result of conferences between many workers familiar with the practical and scientific problems involved in keeping these machines in a thorough sanitary condition.
INTRODUCTION

For a number of years the Station has tested various methods suggested for sterilizing the rubber parts of milking machines, hoping that better and simpler means of accomplishing this result might be found.

The problem would be much simpler if all the milker parts could be made of readily cleanable metal. However, no one has devised really successful machines constructed solely of metals. Consequently, the use of rubber parts is a necessity and has added much to the difficulty of maintaining the sanitary condition of the machines. This in turn has led to the development of successful methods of sterilizing the rubber parts used in milking machines. The parts of the machines that present the greatest difficulty in sterilization are the teat-cups, rubber tubing, and pulsators. Practical difficulties arise in applying either heat or chemicals so as to sterilize the teat-cups and tubes. Furthermore, it has not proved an altogether simple mechanical problem to safeguard entirely the milk in the pail from direct contamination with the condensation moisture that accumulates in unsterilized vacuum lines.

The general use of milking machines by dairymen, who have naturally had little appreciation of the amount of contamination that was being added to milk thru poorly cleaned milkers, has caused much concern among those who are eager to maintain the quality of all dairy products at a high level. In spite of all of the investigational and extension work that has been done in this field the problem remains an acute one. For this reason it has seemed worth while to publish the results that have been secured at this Station by using various procedures recommended for sterilizing milkers. Generalizations on the efficiency of any of the methods tested should be made with care, as many things may influence this efficiency. In applying the methods reported as successful, care must be taken to follow directions exactly or good results may not be secured.

GENERAL PROBLEM

Dairy utensils are ordinarily kept in excellent condition by removing milk remnants and other foreign material by washing, followed by scalding and drying. This method of treatment is effective where ordinary metal utensils are concerned but fails completely with the
rubber parts of mechanical milkers. All investigators agree that, where the teat-cups and tubes are scrubbed and kept in a condition that appears clean to the eye, they may nevertheless harbor untold millions of bacteria. The presence of these bacteria is usually evident by the stale or foul odor of the tubes. Such odors are especially noticeable where the tubes are held at temperatures that favor the growth of bacteria.

Because ordinary methods of caring for milk utensils fail to keep milker tubes in good condition, various methods of sterilizing the tubes have been developed. Some of these depend upon killing the bacteria in the tubes by means of heat and others upon killing by means of various non-poisonous preserving or sterilizing solutions. In still other cases the rubber parts are kept in fair condition by keeping the tubes constantly cooled by a stream of cold water, the low temperatures retarding the growth but not killing the bacteria.

PRESENT SITUATION IN THE FIELD

A review of the literature issued previous to 1917 has been given in Bulletin No. 450 of this Station and need not be repeated. Since that time Hart and Stabler\(^1\) have reported upon their work in California from field observations supplemented by tests upon the rapidity with which hypochlorites lose their effective strength in contact with organic matter, and they conclude that chemical sterilization of milker parts is unsatisfactory. Their method of heat sterilization consisted of placing teat-cups and tubes in water which was then brought to a temperature of from 160° to 180° F. for 15 to 20 minutes. This method of sterilization was applied at two high class dairies using Sharples, Empire, and Perfection milkers, and at one ordinary dairy, using a Perfection milker, where conditions were not entirely satisfactory. Excellent results were secured at the two high class dairies. The bacterial counts were decidedly lowered after the changes introduced at the ordinary dairy, altho the counts from the milk persisted in remaining in the hundreds of thousands, a result which may have been due to other things than the milking machine.

From this limited data the authors make the generalization that "heat sterilization is the only way to successfully sterilize milking machine rubber parts under ordinary ranch conditions," and that "no chemical solution has been found to successfully accomplish these results under practical conditions."

Meanwhile this Station has also carried out an investigation of the reasons why dairymen were failing to secure results in the field with chemical sterilization of milker parts that were as good as those secured in the Station dairy. This work is reported upon by Bright in Bulletin No. 472. Two dairies where the milk had been under observation at the Station for several years were visited. The milk from these dairies had been giving high bacterial counts, altho claims were made in each case that the Sharples or Empire milkers were being sterilized by the use of brine and chloride of lime, and that the machines were cleaned in the same way as those at the Station. Yet results were not what they should be. In both cases, when Bright took over the operation and cleaning of the machines by methods really similar to those previously found successful in the Station dairy, the improvement obtained was immediate and excellent, and continued so as long as the machines were cared for by him. The record of a third dairyman using an Empire machine is also given in this bulletin. In this case the dairyman had himself applied chemical methods of sterilization successfully.

The conclusion reached from this work was that dairymen frequently failed to observe essential details necessary for the proper sterilization of their milker tubes by the chemical method. In view of this situation an educational campaign has since been carried on thruout the State with the cooperation of the Extension Service of the New York State College of Agriculture. As a result of this campaign and of educational work by other agencies, reports are now coming in from control laboratories, which inspect samples of milk from individual dairies, that numerous dairymen, who sterilize their milker tubes by immersion in brine and hypochlorite solutions or in strong and frequently renewed hypochlorite solutions and who send milk to Grade A receiving stations, receive continuously the premiums at these plants for the production of milk with a bacterial count less than 10,000 per cc. Both the heat-sterilization method

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2 Formerly Assistant Bacteriologist at this Station.
and the brine-chloride of lime chemical solution method of sterilizing milking machines have also been tried with entire success in New York State certified dairies sending milk into New York City.

While these results are sufficient to demonstrate without question that those who feel that chemical sterilization is not a successful method to use under farm conditions are incorrect in their conclusions, there remain many dairymen in the State who are not applying these methods of sterilization successfully. In many cases this is due to a lack of appreciation of what steps are essential to success and, in other cases, they are following, or attempting to follow, imperfect directions given them by companies selling commercial sterilizing solutions.

METHODS USED

The method used in judging the efficiency of any particular means of sterilizing the milker tubes in the present study was essentially the same as that previously used (Bulletin No. 450). This consists in "milking" sterile water from an artificial udder and catching a sample of this water for bacterial analysis as it enters the milker pail. Any contamination of this water under these conditions must be derived from the teat-cups and tubes, or from its passage thru the pulsator.

It is felt that such a method of securing samples is essential if the most valuable data are to be secured. Bacterial counts from milk as drawn into the milker pail, as ordinarily made, leave much to be desired in that the source of the bacteria found is always in question. In counts made under these conditions, important sources of contamination other than the teat-cups and tubes are the interior of the udder, the exterior of the teats, the milker pail, and leakage from the vacuum line (Bulletin No. 488). Any one or all of these sources of contamination may, and usually do, contribute significant numbers of organisms during milking.

While it is evident in those cases where low counts are obtained from the analysis of milk samples that none of the sources mentioned have contributed significant numbers of bacteria, yet the exact source of the organisms present is always in doubt.

The bacterial counts of the samples were determined by plating in duplicate from suitable dilutions and incubating for five days at
21° C. This prolonged incubation was chosen in order that all possible colonies might develop on the agar. The counts given are known to be higher than would have been obtained if the standard time and temperature of incubation (two days at 37° C.) had been followed. The nutrient agar used had the following composition:

- Distilled water......................... 1,000 cc.
- Liebig's beef extract................... 3 grams
- Difco peptone.......................... 5 grams
- Shredded agar......................... 15 grams

The reaction was adjusted so that the pH value was between 6.8 and 7.0.

All of the counts given in this bulletin show the condition of tubes from the B-L-K machines in regular use in the Station stables. The rubber tubing varied in condition from new tubing to old and cracked tubing, replacements of rubber parts being made only as needed. The four sets of teat-cups in use were commonly sterilized by different methods so that four tests were ordinarily run simultaneously. Except as noted, the sterilization methods under test were used for months at a time, the intention being to follow the effect of each method of treatment under both summer and winter conditions.

The work of caring for the tubes was left entirely in the hands of the regular dairy help. While these men have become accustomed to carrying out varied experimental directions and have learned to follow directions carefully thru long experience at the Station, the care they gave the teat-cups and tubes was only such as could be given by any practical dairyman. Mr. William Casey has been chiefly responsible for the use and care of the machines at the stable, and Mr. William Lydon has done the cleaning of the tubes and utensils at the dairy. Both men have been interested in the experiments and have carried out their part of the work in a way that has contributed greatly to the value of the results. The authors are also under obligation to Mr. George A. Smith, formerly of the Station staff, who had supervision of the herd and dairy during the time when the tests were made.
EXPERIMENTAL RESULTS

The results obtained will be discussed according to the general method used in destroying or retarding bacterial growth as follows: (1) Sterilization by heat, (2) retardation of bacterial growth by low temperatures, (3) chemical sterilization, and (4) removal of bacteria by scrubbing and polishing parts. The term "sterilization" as applied to the tubes is not intended to imply complete sterilization in the bacteriological sense unless it is so specified, but is intended to imply practical sterilization.

1. HEAT STERILIZATION

In the earliest work done at this Station on the sterilization of milker tubes as reported by Harding and Smith (Bulletin No. 317), tests were made to determine the results secured by scalding and scrubbing the tubes thoroly. Because of the high counts obtained from the milk drawn thru the machine, this method of caring for the tubes was soon replaced by one in which the tubes were kept in a salt brine.

In 1917, Ruehle\(^3\), who was at the time testing various methods of sterilizing milker tubes, also tried the hot water method of sterilization. At that time our attention was called to the matter by reports from the Sharples Milker Company that they were supplying so-called surgical rubber tubing to some of their customers who wished to sterilize their tubing by steam or by boiling. We also received in December, 1917, a statement from Mr. I. C. Weld, Inspector for the G. M. Oyster Milk Company, Washington, D. C., that he had recommended the hot water method of sterilization to one of the producers supplying milk to this milk company who was having trouble in producing milk with a low bacterial count. Sterilization by means of a hypochlorite solution was then in use at this dairy and the milker was of the Sharples type. The method of sterilizing recommended by Weld was to place the tubes, after cleaning in the usual way, in water in a 10-gallon milk can or other suitable container. The water was then brought to the boiling point for a few minutes either by placing the container on a stove or by forcing live steam thru it. The teat-cups and tubes were allowed to cool slowly in the water and to remain in the water until the next milkling, when they were taken out and used without further treatment.

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\(^3\) Formerly Assistant Bacteriologist at this Station.
At that time Weld reported that he had seen the rubber tubes and connections in use on one of these farms after eight months of this treatment and that they had not been damaged to any perceptible degree. Since that time he has urged the use of this treatment with satisfactory results in his district where nearly all of the milkers in use are of the Sharples type.

The first experiments with the hot water method were made on our B-L-K machines on November 17, 1917. The tubes, after being cleaned in the usual way by drawing cold water, hot alkali water, and clear hot water thru them, were placed in a 30-quart covered pail of water on a stove and the water brought to a temperature of 180° to 200° F. Bacteriological tests were to have been made as soon as the men became accustomed to this method of caring for the tubes; but at the end of two days the discs and mouth pieces of the teat-cups had so lost their elasticity that they could no longer be used, as the teat-cups continually dropped from the udders. The tubing, on the other hand, had retained its elasticity.

On November 19, the mouth pieces and discs were replaced by new parts, and the temperature used for sterilizing the tubes was reduced to between 160° and 170° F. Observation showed that, under these conditions, the temperature remained above 140° F. for about two hours. By December 6, in spite of the lower temperatures the rubber mouth pieces and discs had to be renewed again. Meanwhile, however, as shown in Table 1, several tests had been made of the bacterial condition of the tubes under this method of treatment. The bacterial count of the 5 liters of sterile water "milked" thru these tubes was found to vary between 6 and 750 per cc. These low figures show that the tubes were continuously in excellent bacteriological condition.

In view of the rapid destruction of the mouth pieces and discs of the B-L-K teat-cups, it was decided on December 6 to make a third trial using still lower temperatures (150° to 160° F.). However, even with these lower temperatures it was necessary to replace the mouth pieces and discs on January 1, 1918, and again on January 13. As shown in Table 1, the bacterial counts from the tubes varied from 18 to 2,700 per cc., indicating that the heat used was not quite as effective in sterilizing the tubes as in the previous tests. At the end of the experiment the long rubber tubes had so lost their elasticity that it was necessary to replace them.
Table 1.—Amount of Bacterial Contamination from B-L-K Tubes Sterilized with Heat. Agar Plate Counts per cc. from Sterile Water “Milked” thru the Tubes.

Data secured by Ruehle.

<table>
<thead>
<tr>
<th>Date</th>
<th>First milking</th>
<th>Second milking</th>
<th>Third milking</th>
<th>Fourth milking</th>
<th>Temperature of water†</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 18</td>
<td>10</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>162°F</td>
</tr>
<tr>
<td>Nov. 26</td>
<td>117</td>
<td>500</td>
<td>750</td>
<td>690</td>
<td>162°F</td>
</tr>
<tr>
<td>Nov. 27</td>
<td>158</td>
<td>171</td>
<td>78</td>
<td>62</td>
<td>170°F</td>
</tr>
<tr>
<td>Dec. 3</td>
<td>27</td>
<td>92</td>
<td>200</td>
<td>95</td>
<td>167°F</td>
</tr>
<tr>
<td>Jan. 7</td>
<td>84</td>
<td>46</td>
<td>18</td>
<td>31</td>
<td>152°F</td>
</tr>
<tr>
<td>Jan. 8</td>
<td>2,700</td>
<td>1,200</td>
<td>125</td>
<td>610</td>
<td>154°F</td>
</tr>
</tbody>
</table>

† Water and tubes were heated in a 30-quart pail on the stove to the temperature given. The pail was then removed from the stove and allowed to cool, the tubes remaining in the water until the next milking.

The conclusion reached was that the heat-sterilization method was entirely successful in keeping the tubes in good bacteriological condition; but that on B-L-K machines, at least, it could not be regarded as a success because of the rapid destruction of certain of the rubber parts.

Attempts were then made by getting in touch with the manufacturers making rubber parts for milking machines to determine whether it was feasible to supply rubber parts that would resist heat. Numerous attempts were made by Bright in 1918 and 1919 to secure rubber parts for B-L-K machines made of rubber that would resist heat; but no manufacturer could be found who could supply heat-resistant, molded rubber parts of the sort required for the conical teat-cups used in B-L-K machines.

On August 16, 1921, because claims were being made for the general applicability of heat sterilization to all milking machines, one of the authors of the present bulletin (Robertson) repeated the tests made by Ruehle in 1917. The teat-cups and tubes were placed in a 30-quart pail after cleaning, and the water was brought to a temperature between 160°F and 170°F as before. The mouth-piece rubbers and discs were found to be as rapidly destroyed as before. Two sets were destroyed in the course of the experiment which lasted 33 days. Four bacterial tests were made to determine the efficiency of heating as a means of sterilizing the tubes. The four
counts obtained were 98, 150, 150, and 480 per cc. These show
that the condition of the tubes was excellent and about the same
as it was during the tests made by Ruehle.

In order to test this matter more extensively rubber parts were
secured from seven commonly used milkers in 1918 and again in
1921. These rubber parts were subjected to heat daily for 20 days
as follows: (a) Under steam pressure in an autoclave, (b) in
flowing steam, (c) in boiling water, and (d) in hot water, temperature
160° to 170° F. Under these conditions, the rubber parts supplied
with the majority of milkers were found to be more resistant to
heat than was commonly believed. This was particularly true
of the best, cloth-wrapped, pole-lined, steam-vulcanized, rubber
tubing, while it did not hold so generally for parts vulcanized in
iron molds. Moreover, it was noted that in several cases where
a good quality rubber tubing was stretched over a metal ring, it
had become over vulcanized by the heat and was brittle and cracked.
With some metals, the rubber appeared to melt, causing it to stick
to the metal.

As these rubber parts were not attached to the usual metal parts
and as they were not exposed to the fats from the skin and from
the milk, definite conclusions regarding the life of the rubber under
field conditions ought not to be drawn from these experiments.
Certainly the rubber would have deteriorated more quickly under
field conditions than under the experimental conditions.

Consultations with expert rubber chemists and visits to factories
manufacturing rubber parts for milkers have also shown that the
problem of furnishing rubber parts resistant to heat sterilization
is not a simple one, and that it varies according to the type of the
machine. Moreover, experts seem to agree that the conditions of
manufacture and differences in raw materials are such that the heat-
resisting quality of these rubber parts can not be perfectly stand-
ardized.

Meanwhile, data have been secured from control laboratories
inspecting milk produced on certified farms which show that on at
least one New York State certified farm equipped with De Laval
milkers the heat sterilization method is being used successfully for
the production of high grade milk without undue destruction of
rubber parts. This machine is one in which all rubber parts consist
of cloth-wrapped, straight tubing.
From these data and observations reported by other investigators, the conclusion has been reached that the heat sterilization method can be recommended as an efficient method of sterilization for those machines which are, or which may be equipped, with rubber parts that will resist destruction by heating in water or in steam twice daily for a reasonable length of time. Dairymen using it, however, must be prepared to renew the rubber parts more frequently, and to have more trouble from the use of inelastic and broken inflations and poor tubing than is the case where chemical methods of sterilization are used.

2. RETARDATION OF BACTERIAL GROWTH BY LOW TEMPERATURES

In Bulletin No. 450 of this Station, Ruehle, Breed, and Smith reported that under experimental conditions in our stables, properly cleaned tubes remained in a satisfactory bacteriological condition for the production of Grade A milk where water at a temperature of less than 58° F. was allowed to flow continuously thru and over the tubes between milkings. In this work, the main milk tubes were attached directly to faucets so that a current of water from the city supply continuously passed thru the tubes. The teat-cups themselves were allowed to hang in a 15-gallon crock, which overflowed with water.

From March 11, 1919, until July 19, 1920, two sets of B-L-K teat-cups and tubes were again treated in a similar way. During 1919 and the winter of 1920, a number of samples of milk drawn thru these tubes were examined to determine the germ content, samples being taken directly from the milker pail after the first cow was milked. While these do not show the amount of contamination derived directly from the tubes, they do show the general condition of the milk. Twenty-one counts, made between March 11, 1919, and April 28, 1919, varied from 2,500 per cc. to 44,000 per cc., all but three of the counts being 10,000 or less. Between May 14 and August 20, 1919, when the temperature of the tap water was between 60° and 63° F., six similar tests were made. In this case, the counts were never less than 15,000 and never more than 50,000 per cc.

A single test of milk drawn thru these tubes made during the cold winter weather of February, 1920, when the temperature of the tap water had fallen to 37° F., showed a count of 95,000 per cc. While
this one test is not enough to tell the real condition of the tubes, it is significant in explaining the results secured during June and July, 1920. At that time a series of tests were made to determine the condition of the tubes by "milking" sterile water thru them. The results are given in the first part of Table 2. It will be seen that the counts showed the tubes to be in very bad condition and much worse than they had been during the previous season. The figures as given do not tell the whole story, however, for the high counts were due largely to a rusty-brown, chromogenic, rod-shaped, non-sporo-forming organism that appeared in almost pure culture and which was derived from the water. Evidently this organism had found favorable living conditions both in the crock and in and on the teat-cups and tubes. It had previously been noted on almost all plates made either directly from these tubes or from milk drawn thru them. Rusty brown spots also occasionally appeared in the cream of milk containing this organism.

When it was discovered that these tubes were in bad condition, an attempt was made to sterilize one set of tubes more effectively by sucking a chloride of lime solution thru them four times daily, once just before and once just after each milking. The results secured are given in the second part of Table 2. By comparing the counts given in the two parts of this table it will be seen that the hypochlorite disinfecting solution had some effect in reducing the contamination from the tubes, but this effect was not sufficient to bring the tubes back into satisfactory condition.

Another observation of interest in this connection is the fact that six samples of milk drawn thru these tubes during May, 1920, analysed by incubating the plates by the standard method of incubation of two days at 37° C., gave counts that were very low, namely 900, 1,500, 2,000, 2,800, 3,000, and 13,000 per cc., respectively. While the matter was not tested further, the reason for these low counts at that time was undoubtedly because the water organism noted above did not grow at the warmer temperature of incubation. Such milk would have passed as very high grade milk by the official method of counting, while as a matter of fact it probably contained relatively large numbers of bacteria for fresh milk. From these observations it has been concluded that, whereas the cold water method of caring for the tubes is undoubtedly a clean and satisfactory procedure under some conditions, it nevertheless offers greater possi-
Table 2.—Amount of Bacterial Contamination from B-L-K Tubes Kept in Running Water. Agar Plate Counts per cc. from Sterile Water "Milked" thru the Tubes.

Data secured by Finch.

<table>
<thead>
<tr>
<th>Date, 1920</th>
<th>Tubes Attached to Faucet and Water Allowed to Run Thru Them†</th>
<th>Tubes Rinsed with Hypochlorite Solution Just Before and Just After Each Milking in Addition to Being Kept in Running Water‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monday</td>
<td>Tuesday</td>
</tr>
<tr>
<td>July 19 to 23...</td>
<td></td>
<td>7,100,000</td>
</tr>
<tr>
<td>July 26 to 30...</td>
<td>3,600,000</td>
<td>6,200,000</td>
</tr>
<tr>
<td>Aug. 2 to 6...</td>
<td>370,000</td>
<td>890,000</td>
</tr>
<tr>
<td>Aug. 9 to 13...</td>
<td>130,000</td>
<td>9,300,000</td>
</tr>
</tbody>
</table>

† Temperature of water varied between 65° and 67° F.
‡ Available chlorine in rinsing solution varied from 105 to 493 parts per million. Rinsing solution was made fresh each day.
ilities of failure than the other methods even when conditions are apparently good. For this reason it is not recommended for general use.

3. CHEMICAL STERILIZATION

Sterilization by chemicals is the method most widely used in this State for keeping down to a minimum the bacterial contamination in the milker tubes. To secure the maximum effect of the sterilizing action, the milker teat-cups and tubes are usually submerged in a solution in a crock between milkings.

The substances ordinarily used in preparing these solutions are salt, chloride of lime (bleaching powder), liquid hypochlorites, and, more recently, chloramine powders. Lime water, while reasonably satisfactory in its action, has not found favor for various reasons.

*Observations on the effectiveness of saturated brine to which is added, at frequent intervals, a solution of calcium hypochlorite (chloride of lime).*—In Bulletin No. 450 it was reported that the most satisfactory sterilizing solution for use on milker teat-cups and tubes was a brine-hypochlorite mixture. This mixture is suitable for use in all cases where the teat-cups are made of resistant metals or alloys that do not corrode. Such metal parts are now furnished on all milkers that have been on the market for any length of time.

Between January, 1919, and July, 1920, one set of B-L-K tubes was kept in a brine and hypochlorite mixture. The bacterial count of the milk drawn thru these tubes was examined 38 times during this period with the result that only nine of the counts were found to exceed 10,000 per cc., the maximum count being 62,000 per cc. Plates were incubated in each case for five days at $21^\circ$ C. From the fact that the samples examined were of milk taken in such a way that contaminations from other sources than the tubes were known to be present, no satisfactory conclusion regarding the condition of the tubes can be drawn. During July and August, 1920, 16 trials were made with one set of these tubes where sterile water was “milked” thru them. The results, as given in the first part of Table 3, may be compared exactly with those given in Bulletin No. 450, Table 14. It will be seen that even in the hot summer weather, the counts from these tubes remained low, the only counts above 1,000 per cc. being one of 3,100 and another of 3,200 per cc. The tubes were at all times in satisfactory condition for use in the production of certified milk, notwithstanding the fact that the care
given them was nothing more than could be given on any dairy farm. The result of this long continued observation of the condition of these tubes in our own stable, combined with numerous field observations on dairy farms of all types from certified to others very poorly equipped, has been to convince the authors that there is no more satisfactory solution for use in sterilizing milker tubes than a combination of brine and chloride of lime.

**Table 3.—Amount of Bacterial Contamination from B-L-K Tubes Immersed in a Solution of Brine and Chloride of Lime. Agar Plate Counts per cc. from Sterile Water "Milked" thru the Tubes.**

Data secured by Finch.

<table>
<thead>
<tr>
<th>Date, 1920</th>
<th>Tubes kept in crock between milkings, no other treatment †</th>
<th>Tubes taken from same crock and rinsed with a hypochlorite solution just before and just after each milking ‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 19 to 23</td>
<td>3,200</td>
<td>900</td>
</tr>
<tr>
<td>July 26 to 30</td>
<td>20</td>
<td>690</td>
</tr>
<tr>
<td>Aug. 2 to 6.</td>
<td>480</td>
<td>320</td>
</tr>
<tr>
<td>Aug. 9 to 13</td>
<td>5</td>
<td>3,100</td>
</tr>
</tbody>
</table>

† Available chlorine in the solution in the crock varied from 80 to 338 parts per million.
‡ Available chlorine in the rinsing solution varied from 105 to 493 parts per million. Rinsing solution was made fresh each day.

Inasmuch as many dairymen, using this sterilizing solution, also frequently supplement the action of the solution in the crock by adding some of the hypochlorite solution to clear water drawn thru the tubes after cleaning them and again just before milking, a series of tests was made in July and August, 1920, on a second pair of B-L-K tubes to determine the effectiveness of this procedure. The tubes used were duplicates of those used for the tests given in the the first part of Table 3. By comparing the counts given in this table it will be seen that drawing a rinsing solution of chloride of lime thru the tubes before and after each milking did have the effect of reducing the counts from these tubes still further. Thus out of the 17 counts given in the second part of Table 3, the highest is only 380 per cc. For all practical purposes, the tubes might be considered to have been sterile.

Inasmuch as the addition of chloride of lime solutions to the rinsing water is a very simple and inexpensive procedure, it should be done in all cases where there is reason for producing a low count milk.
Observations on the effectiveness of hypochlorite rinsing solutions as a sole means of sterilizing the teat-cups.—Inspectors have frequently reported finding dairymen that cared for their milker tubes by hanging them in the milk room after they were cleaned and leaving them until the next milking. While many of these tubes appear clean to the naked eye there has been much complaint regarding the milk in such cases because it is badly contaminated with bacteria. The question has therefore been asked whether drawing strong rinsing solutions of chloride of lime or other hypochlorite solutions thru the tubes would sterilize them satisfactorily.

For this reason two sets of teat-cups were treated as follows during October and November, 1920: Immediately after milking they

Table 4.—Amount of Bacterial Contamination from B-L-K Tubes Rinsed with a Chloride of Lime Solution and Hung in a Clean Cupboard. Agar Plate Counts per cc. from Sterile Water “Milked” thru the Tubes.

Data secured by Finch.

<table>
<thead>
<tr>
<th>Date, 1920</th>
<th>Tubes Rinsed with Chloride of Lime Solution Before Each Milking†</th>
<th>Tubes Rinsed with Chloride of Lime Solution Before and After Each Milking†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mon-</td>
<td>Tues-</td>
</tr>
<tr>
<td>Oct. 18 to 22</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Oct. 25 to 29</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Nov. 1 to 5</td>
<td>11</td>
<td>180</td>
</tr>
<tr>
<td>Nov. 8 to 12</td>
<td>11</td>
<td>45</td>
</tr>
<tr>
<td>Nov. 15 to 19</td>
<td>76</td>
<td>94</td>
</tr>
<tr>
<td>Nov. 22 to 26</td>
<td>50</td>
<td>30</td>
</tr>
</tbody>
</table>

†Available chlorine in rinsing solution varied from 116 to 326 parts per million. Rinsing solution was made fresh each day.

were cleaned by sucking cold water, hot alkali water, and clean hot water thru the tubes. These three pails of water were then followed by an additional rinse containing chloride of lime solution (from 116 to 326 parts of available chlorine per million) in the case of one set of the teat-cups and tubes. The two sets of tubes were then hung in a clean cupboard in the dairy room until the next milking. Just before the next milking a similar rinsing solution of chloride of lime was drawn thru both sets of tubes. Thus one set of tubes received but two rinses with the sterilizing solution daily, while the other received four rinses daily.

The results secured from “milking” sterile water thru the tubes that received two and four rinses daily are given in the first and second parts of Table 4, respectively. The counts are surprisingly
low and show that the tubes were kept in almost as sterile a condition as when they were submerged in a brine-hypochlorite solution between milkings. Thus out of the 22 tests made on the tubes receiving two rinses daily, the count does not exceed 250 per cc. except in one instance where it reached 2,100 per cc. Where four rinses were given daily, the results are even better. In this case the counts are remarkably low as none of the 22 counts exceeded 500 cc.

These splendid results should be interpreted with care, however, as the experiment was not continued more than a few weeks during the cool fall weather. It should also be noted that the tubes themselves were kept truly clean and free from milk remnants and accumulations of foul material. Moreover, the strength of the sterilizing solution was controlled carefully by frequent chemical tests. Nevertheless, the results do suggest that there is a real possibility of doing away with the use of crocks. The corrosive action of the brine-hypochlorite mixture would also be very much lessened if this procedure proves usable under practical conditions. Because of its promise, more extended tests are under way at the Station at the present time.

Observations on the effectiveness of two commercial hypochlorite solutions.—There has been a growing conviction among many investigators of the chemical sterilization of milking machine parts that users of the much-advertised commercial hypochlorite solutions who follow the directions put out by the manufacturers are not getting satisfactory results under practical farm conditions. The majority of these solutions, which sell from $1.00 to $3.50 per gallon, contain sodium hypochlorite, a compound similar but not identical with the calcium hypochlorite obtained from putting water on chloride of lime (bleaching powder). As shown in the previous pages, the latter compound is entirely effective for the purpose of sterilizing milker parts and costs only a small fraction of the price asked for these commercial solutions. Moreover, manufacturers selling electrolytic apparatus for manufacturing sodium hypochlorite from salt water claim to be able to produce the sodium hypochlorite in soluble form at a cost of 2 or 3 cents a gallon. For these reasons some laboratories maintained by milk companies are manufacturing these solutions for their patrons and furnishing them either free or at cost. Such a practice helps materially to secure better sterilization of milkers.
The tests of the two commercial hypochlorite compounds given here were not made to determine whether they could be used to sterilize milker tubes with success. There is little question on this point, for sodium hypochlorite, like the calcium compound, is one of our best sterilizing agents, and there is no reason to question that it can be used effectively for this purpose if used as it should be. The tests were made merely to determine whether a dairyman would succeed in sterilizing his tubes if he followed implicitly the directions given on the containers. The tests, while limited in number, were carried on long enough to justify certain conclusions. It should be noted that they were made during the relatively cool spring weather, and do not show how badly the solutions tested would have failed to sterilize during the hot weather.

So far as known none of the companies selling the commonly used preparations recommend that these solutions be used in connection with brine, as will be seen from the directions taken from the labels of two of the most commonly used of these solutions.

Directions for using Hypochlorite Solution No. 1 are as follows:

"After milking—first rinse tubes and teat-cups in cold water, second rinse or brush with warm water and dairy washing powder; third wholly submerge them in a solution of 2 ounces of the hypochlorite solution in a 5-gallon jar of water. Shake tubes to dislodge air. Add 1 ounce of the hypochlorite solution daily and mix fresh solution weekly."

Directions for using Hypochlorite Solution No. 2 are as follows:

"After use rinse with clean cold water and then brush with your soda solution, and then rinse or submerge in a solution of 1 part of the hypochlorite solution to 640 parts water (1 ounce to 5 gallons). Shake tubes for a few seconds. Rinse with the above solution if you do not keep submerged. Mix new batch of solution at least every four days."

The available chlorine content of Hypochlorite Solution No. 1 in the crock was found to vary between 87 and 260 parts per million in the fresh solution (Table 8, Column 6). The strength of the solutions after use as directed was reduced to between 65 and 182 parts per million when samples were taken directly from the crocks in which the tubes were kept. When samples of the solution were taken from the interior of the long rubber tubes, however, it was found that the solution was so reduced in strength that it showed only a very small amount of available chlorine. In 12 cases out of
15 the strength was found to be less than 9 parts per million, and it
never exceeded 23 parts per million. These figures illustrate, in a
striking way, the fallacy involved in judging the effective strength
of these hypochlorite solutions from samples taken directly from the
crock. The main part of the solution in the jars may be strong and
active, while that part of it in contact with the interior of the tubes
may be entirely ineffective as a sterilizing agent.

In view of these chemical tests of the strength of the solution, it
is not surprising to find that the bacterial counts from the sterile
water "milked" thru the tubes kept in Hypochlorite Solution No. 1,
prepared according to the directions on the container, were not as
low as those reported for the brine-hypochlorite mixture (Table 3).
The counts are given in the first part of Table 5. In the 13 trials
made in May, 1921, the counts from the tubes varied from 44 to
7,400 per cc.

While these counts were not excessive, they are not as good as
have been obtained under more severe conditions where brine was
used, or where stronger hypochlorite solutions were used.

The same commercial solution was also tried on a second set of
tubes in combination with 10 per cent brine under duplicate con-
ditions and during the same period of time (May, 1921). The
results appear in the second part of Table 5. The available chlorine
content of the solution under these conditions was very much as
before. After the first few days, the counts obtained with brine
were about the same as those obtained without brine. They varied
from 36 to 89,000 per cc. and did not exceed 2,200 after the first
ten days.

From observations made with other hypochlorite solutions, how-
ever, it is not probable that the good results obtained in the solution
without brine would have continued thru the hot summer weather.

Hypochlorite Solution No. 2, when made up according to directions,
was much weaker than Hypochlorite Solution No. 1. Even when
made twice the strength recommended on the label, the fresh solution
showed only from 64 to 79 parts of available chlorine per million.
According to direction, fresh solution was added twice weekly as shown
in Column 12 of Table 8. Samples of the old solution taken from the
crock just before the new solution was added showed a strength vary-
ing from 0 to 33 parts of available chlorine per million. Moreover,
samples taken from the interior of the tubes even on the days when
Table 5.—Amount of Bacterial Contamination from B-L-K Tubes Immersed in Hypochlorite Solution No. 1. Agar Plate Counts per cc. from Sterile Water “Milked” thru the Tubes.

Data secured by Robertson.

<table>
<thead>
<tr>
<th>Date, 1921</th>
<th>Tubes kept in crock containing a solution made according to manufacturer’s directions†</th>
<th>Tubes kept in crock containing a solution made according to directions and with 10 per cent brine added†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monday</td>
<td>Tuesday</td>
</tr>
<tr>
<td>May 2 to 7</td>
<td>6,600</td>
<td>5,300</td>
</tr>
<tr>
<td>May 9 to 14</td>
<td>2,100</td>
<td>1,400</td>
</tr>
<tr>
<td>May 16 to 21</td>
<td>1,100</td>
<td>2,700</td>
</tr>
<tr>
<td>June 7 to 11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

†Variations in the strength of the hypochlorite solutions are recorded in Table 8.
fresh solution was added never showed a strength greater than 8 parts of available chlorine per million and usually showed only a trace of available chlorine.

Between April 18 and May 3, 1921, ten tests were made of the germ content of sterile water "milked" thru tubes kept in a solution of the strength recommended. These counts, as will be seen from the upper part of Table 6, were never satisfactory, varying from 44,000 to 11,000,000 per cc. On May 4 the strength of the solution was made double that recommended by the manufacturers. In the 13 tests made under these conditions, the germ content of the water "milked" thru the tubes varied from 460 to 160,000 per cc. (lower part of Table 6). Altho these counts are much better than those obtained with the weaker solution they are still only occasionally satisfactory, and no dairyman could hope to produce consistently a high grade milk even using double the strength recommended for this commercial preparation. In hot weather the conditions would undoubtedly have been very bad.

Table 6.—Amount of Bacterial Contamination from B-L-K Tubes Immersed in Hypochlorite Solution No. 2. Agar Plate Counts per cc. from Sterile Water "Milked" thru the Tubes.

Data secured by Robertson.

<table>
<thead>
<tr>
<th>Date, 1921</th>
<th>Tubes kept in crock containing a solution made according to the manufacturer's directions †</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monday</td>
</tr>
<tr>
<td>April 18 to 22</td>
<td>80,000</td>
</tr>
<tr>
<td>April 25 to 29</td>
<td>160,000</td>
</tr>
<tr>
<td>May 2 to 3</td>
<td></td>
</tr>
</tbody>
</table>

Strength of solution double that recommended †

<table>
<thead>
<tr>
<th></th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 4 to 7</td>
<td></td>
<td></td>
<td>69,000</td>
<td>35,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 9 to 14</td>
<td>72,000</td>
<td>160,000</td>
<td>12,000</td>
<td>13,000</td>
<td>8,100</td>
<td></td>
</tr>
<tr>
<td>May 16 to 21</td>
<td>14,000</td>
<td>1,100</td>
<td>3,100</td>
<td>840</td>
<td>460</td>
<td>1,100</td>
</tr>
<tr>
<td>June 7 to 11</td>
<td>16,000</td>
<td>44,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Variations in the strength of the hypochlorite solution are recorded in the last three columns of Table 8.

The fact that the hypochlorites lose their effective strength in the interior of the rubber tubing, where their sterilizing action is most needed, emphasizes the importance of using these solutions in combination with brine.
Observations on the effectiveness of a commercial chloramine preparation.—Since the close of the war, a new chlorine disinfectant developed in connection with war surgery has been recommended for the sterilization of milker tubes. It has come on the market in the form of a white powder costing about $3.00 for 10 ounces. This powder is stated to consist chiefly of chlorazene with some halozone and calcium carbonate. The chloramines differ widely in their nature from the hypochlorites that have just been discussed, altho the essential sterilizing agent is chlorine as in the case of the hypochlorites. Because solutions of this powder do not lose their strength as rapidly as do the hypochlorite solutions, it has been claimed that this new sterilizing agent is much more useful than the hypochlorites for sterilizing milker tubes.

For all of these reasons, more extended tests were made with Chloramine Solution No. 1 than with the two commercial hypochlorite solutions. A solution of this preparation was used in a crock in our stable from February 7 to April 11, 1921, no new material having been added during that time. Under these conditions the available chlorine content decreased from 247 parts per million at the beginning to 147 parts at the end of the period. During this time also, the counts obtained from the water "milked" thru the tubes as shown in the upper part of Table 7 were excellent at times and were never more than 21,000 per cc.

After April 11, enough salt was added to the crock to make a 10 per cent brine. The same solution was then used until May 20, 1921. During this period the available chlorine dropped from 142 parts to 85 parts per million. The bacterial counts obtained from the water drawn thru the tubes, as shown in the second part of Table 7, were excellent, all of the 24 tests showing counts under 980 per cc.

As noted, the strength of the chloramine solution dropped slowly during the course of the experiment. The changes observed between May 3 and May 21, 1921, are recorded in detail in Column 2 of Table 8. In the adjoining column of the same table are recorded the tests of the solution as drained from the interior of the long tubes. The available chlorine in this part of the solution was always less than that in the main part of the jar. The highest observed strength of the solution from the interior of the tubes was 74 parts of available chlorine per million taken at the beginning of the period when the
Table 7.—Amount of Bacterial Contamination from B-L-K Tubes Immersed in Chloramine Solution No. 1. Agar Plate Counts per cc. from Sterile Water “Milked” thru the Tubes.

Data secured by Robertson and Finch.

<table>
<thead>
<tr>
<th>Date</th>
<th>Tubes kept in crock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monday</td>
</tr>
<tr>
<td>Feb. 7 to 11</td>
<td></td>
</tr>
<tr>
<td>Feb. 14 to 18</td>
<td></td>
</tr>
<tr>
<td>Feb. 21 to 25</td>
<td></td>
</tr>
<tr>
<td>Feb. 28 to Mar. 4</td>
<td></td>
</tr>
<tr>
<td>Mar. 7 to 11</td>
<td></td>
</tr>
<tr>
<td>Mar. 14 to 18</td>
<td></td>
</tr>
<tr>
<td>Mar. 21 to 25</td>
<td></td>
</tr>
<tr>
<td>Mar. 28 to April 1</td>
<td></td>
</tr>
<tr>
<td>April 4 to 9</td>
<td></td>
</tr>
<tr>
<td>April 11</td>
<td>1,600</td>
</tr>
</tbody>
</table>

Plain chloramine solution †

<table>
<thead>
<tr>
<th>Date</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>April 12 to 15</td>
<td>320</td>
</tr>
<tr>
<td>April 18 to 22</td>
<td>310 86 620 170</td>
</tr>
<tr>
<td>April 25 to 29</td>
<td>340 200 140 570</td>
</tr>
<tr>
<td>May 2 to 6</td>
<td>400 320 210 140</td>
</tr>
<tr>
<td>May 9 to 13</td>
<td>470 30 360 280</td>
</tr>
<tr>
<td>June 7 to 11</td>
<td>960 90 360 280</td>
</tr>
</tbody>
</table>

Solution on in 10 per cent brine ‡

<table>
<thead>
<tr>
<th>Date</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 13 to 17</td>
<td>830 420 190 200</td>
</tr>
<tr>
<td>Dec. 20 to 24</td>
<td>1,500 440 55</td>
</tr>
<tr>
<td>1921</td>
<td></td>
</tr>
</tbody>
</table>

Solution in saturated brine §

<table>
<thead>
<tr>
<th>Date</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 13 to 17</td>
<td>830 420 190 200</td>
</tr>
<tr>
<td>Dec. 20 to 24</td>
<td>1,500 440 55</td>
</tr>
<tr>
<td>1921</td>
<td></td>
</tr>
</tbody>
</table>

† Available chlorine in crock decreased from 247 to 147 parts per million. Solution was made up Feb. 7, 1921.

‡ Available chlorine in crock decreased from 142 to 85 parts per million. Same solution as used in No. 1 except that enough salt was added to make a 10 per cent brine.

§ Available chlorine in crock decreased from 184 to 122 parts per million.

solution in the jar showed 115 parts of available chlorine. The lowest observed strength of the solution from the interior of the tubes was 28 parts, at a time when the solution in the jar had become reduced to a strength of 89 parts per million.

The results obtained with the brine-chloramine solution in sterilizing the tubes also correspond to those obtained during the previous December. The latter results are given in the third part of Table 7.
In this experiment a saturated brine solution was used as a base for the solution in the crock, and the sterilizing solution added an available chlorine content varying from 184 parts per million at the beginning of the experiment to 122 parts at the end. As seen from Table 7 the bacterial counts from the water drawn thru the tubes were low in all cases, all being less than 1,500 per cc. The results with brine all indicate that the addition of salt is an improvement in this case as also in the case of the hypochlorite solutions. It is claimed, however, that the chloramine powder does not dissolve as well in a saturated brine as in a 10 per cent brine, so that if this compound is used, it is recommended that no more than 10 per cent of brine be used with it.

**Observations on the effectiveness of chloramine rinsing solutions as a sole means of sterilizing the teat-cups.**— When this chloramine solution was first put into use in our stable, experiments were in progress as reported on page 19 to test the effectiveness of hypochlorite solutions when used as rinsing solutions only. For this reason the chloramine compound was first put into use as a rinsing solution in November, 1920. Two sets of teat-cups and tubes were used for the experiment. One set was treated by drawing a pail full of the rinsing solution
thru it just after cleaning in the usual way, and again just before milking. The second set was treated by drawing the solution thru the tubes just before each milking only.

On account of the fact that this solution is more stable than the hypochlorites, it was renewed only once in two weeks, being used over and over. The available chlorine in the rinsing solutions varied under these conditions from 74 to 309 parts per million.

The bacterial counts from the sterile water "milked" thru the tubes varied in this experiment as shown in Table 9. When the rinse was applied but twice daily, as shown in the first part of the table, the lowest count obtained in 36 trials was 36 per cc., while the majority of the counts were in excess of 10,000 per cc., the highest reaching 650,000 per cc.

Where the rinse was used four times daily, in 26 determinations of the bacterial count, as shown in the second part of Table 9, the lowest count was 21 per cc. As before, the majority of the counts were in excess of 10,000 per cc., the highest one being 640,000 per cc. Apparently the extra rinsing of the tubes failed to improve the situation materially.

During March, 1921, the test with a chloramine solution used as a rinse two and four times daily was repeated, a fresh solution being used each day. The available chlorine content of the rinse solution varied from 65 to 107 parts per million. The bacterial counts obtained in 21 trials when the tubes were rinsed twice daily are given in the first part of Table 10. As before, the counts are not low enough to be considered satisfactory, varying from 1,600 to 200,000 per cc., only three of them being less than 10,000 per cc. When the tubes were rinsed four times daily, the counts varied from 1,700 to 140,000 per cc., only nine of the 21 counts being less than 10,000 per cc.

Both of these trials were made during the cold weather when conditions were favorable for maintaining the strength of the sterilizing solution. Evidently, in the strength used and under the conditions maintained, the chloramine compound was not nearly so effective as a rinsing solution as was the chloride of lime solution discussed on page 19. Stronger solutions, changed more frequently, might have produced better results, but apparently these compounds are not well adapted for use in this way. Probably the fact that these chloramines are more stable than the hypochlorites (an advan-
Table 9.—*Amount of Bacterial Contamination from B-L-K Tubes Rinsed with Chloramine Solution No. 1 and Hung in Cupboard. Agar Plate Counts per cc. from Sterile Water “Milked” thru the Tubes.*

Data secured by Finch and Robertson.

<table>
<thead>
<tr>
<th>Date</th>
<th>Tubes Rinsed with Chloramine Solution Before Each Milking†</th>
<th>Tubes Rinsed with Chloramine Solution Before and After Each Milking†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monday</td>
<td>Tuesday</td>
</tr>
<tr>
<td>1920</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov. 29 to Dec. 3</td>
<td>3,900</td>
<td>390</td>
</tr>
<tr>
<td>Dec. 13 to 17</td>
<td>170</td>
<td>92</td>
</tr>
<tr>
<td>Dec. 20 to 24</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>1921</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan. 31 to Feb. 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb. 7 to 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb. 14 to 18</td>
<td>50,000</td>
<td>2,500</td>
</tr>
<tr>
<td>Feb. 21 to 25</td>
<td>12,000</td>
<td>160,000</td>
</tr>
<tr>
<td>Feb. 28 to Mar. 4</td>
<td>220,000</td>
<td>560,000</td>
</tr>
<tr>
<td>Mar. 7 to 11</td>
<td>330,000</td>
<td>550,000</td>
</tr>
<tr>
<td>Mar. 14 to 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar. 21 to 25</td>
<td>650,000</td>
<td>1,500</td>
</tr>
</tbody>
</table>

†Available chlorine in rinsing solution varied from 74 to 309 parts per million. Rinsing solution was made fresh bi-weekly.
tage under some conditions) makes them less satisfactory for use as rinsing solutions.

The conclusions reached from this work on proprietary compounds are that when chloramines are used under proper conditions they can be made to sterilize milker tubes effectively, a fact that is true also of the hypochlorite solutions tested. None of the results secured from either the hypochlorite or chloramine commercial preparations are better than those secured from the much less expensive homemade solutions prepared from salt and chloride of lime. Because of this there seems to be no good reason for recommending that dairymen use any of the prepared compounds. The best results are secured with hypochlorite and chloramine compounds when they are used in brine. In the case of the chloramine compounds, this should be a brine prepared by adding 10 pounds of salt per 100 pounds of water (12½ gallons). In the case of the hypochlorite solutions add salt until it remains undissolved on the bottom of the jar. Change solutions at once when they get dirty. If protected from dirty material this need not be more frequently than once in six weeks. Brines never lose their strength and are themselves sufficient to keep the tubes in good condition.

4. REMOVAL OF BACTERIA BY SCRUBBING AND POLISHING PARTS

Observations on the effectiveness of daily taking apart and scrubbing.—Additional data have been gathered to show the results obtained where the care given consisted in cleaning the tubes thoroly without supplementing this cleaning by any additional method of destroying the bacteria present. This experiment was carried out during February, March, and April, 1921, when low temperatures helped to prevent the growth of bacteria. After the usual cleaning which followed the morning milking immediately, the teat-cups and tubes were sent to the dairy, taken apart completely, and subjected to a thoroly scrubbing and polishing. The parts were then reassembled and hung in a clean cupboard in a place where low, but not freezing temperatures prevailed.

The results secured by "milking" sterile water thru the tubes during this period are given in Table 11. The lowest counts obtained were secured during the first week, the lowest of these being 37,000 per cc. As the experiment continued the counts soon became so bad that every cubic centimeter of sterile water passed thru the
<table>
<thead>
<tr>
<th>Date, 1921</th>
<th>Tubes rinsed with chloramine solution before each milking†</th>
<th>Tubes rinsed with chloramine solution before and after each milking†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monday</td>
<td>Tuesday</td>
</tr>
<tr>
<td>Mar. 21 to 25</td>
<td></td>
<td>12,000</td>
</tr>
<tr>
<td>Mar. 28 to Apr. 1</td>
<td>120,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Apr. 4 to 8</td>
<td>26,000</td>
<td>120,000</td>
</tr>
<tr>
<td>Apr. 11 to 15</td>
<td>72,000</td>
<td>26,000</td>
</tr>
<tr>
<td>Apr. 18 to 22</td>
<td>24,000</td>
<td>72,000</td>
</tr>
<tr>
<td>Apr. 25 to 29</td>
<td>24,000</td>
<td>24,000</td>
</tr>
<tr>
<td>May 2 to 6</td>
<td>23,000</td>
<td>24,000</td>
</tr>
</tbody>
</table>

† Available chlorine in rinsing solution varied from 65 to 107 parts per million. Rinsing solution made fresh each day.
tubes gave counts in excess of 1,000,000, some of them even exceeding 10,000,000. During all of this time these tubes appeared immaculately clean to the eye, but the odor from the interior of the tubes was stale and sour. A microscopic examination of the drops of water that collected at the lower end of the tubes as they hung in the cupboard showed that this water contained incredible numbers of bacteria of the micrococcus type.

As these tubes were in such bad shape even during the cold weather, it was decided not to continue the experiment into the hot summer weather when they would undoubtedly have been much more thoroughly seeded with bacteria.

<table>
<thead>
<tr>
<th>TABLE 11.—AMOUNT OF BACTERIAL CONTAMINATION FROM B-L-K TUBES WHEN SCRUBBED ONCE DAILY AND HUNG IN CUPBOARD BETWEEN MILKINGS. AGAR PLATE COUNTS PER CC. FROM STERILE WATER &quot;MILKED&quot; THRU THE TUBES. Data secured by Robertson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date, 1921</td>
</tr>
<tr>
<td>Feb. 28 to Mar. 4</td>
</tr>
<tr>
<td>Mar. 7 to 11</td>
</tr>
<tr>
<td>Mar. 14 to 18</td>
</tr>
<tr>
<td>Mar. 21 to 25</td>
</tr>
<tr>
<td>Mar. 28 to Apr. 1</td>
</tr>
<tr>
<td>Apr. 4 to 9</td>
</tr>
<tr>
<td>Apr. 11 to 15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 12.—BACTERIAL CONTAMINATION FROM B-L-K TUBES ON THE DAY BEFORE THE TUBES WERE CLEANED CONTRASTED WITH THAT ON THE DAY ON WHICH THEY WERE CLEANED. AGAR PLATE COUNTS PER CC. FROM STERILE WATER &quot;MILKED&quot; THRU THE TUBES.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Secured by Ruehle, 1916-17</td>
</tr>
<tr>
<td>Average of 22 tests (all counts less than 1,000 per cc.)</td>
</tr>
<tr>
<td>Average of 9 tests (all counts more than 1,000 per cc.)</td>
</tr>
<tr>
<td>Average of 31 tests</td>
</tr>
<tr>
<td>Data Secured by Robertson, 1920-21</td>
</tr>
<tr>
<td>Average of 24 tests (all counts less than 1,000 per cc.)</td>
</tr>
<tr>
<td>Average of 27 tests (all counts more than 1,000 per cc.)</td>
</tr>
<tr>
<td>Average of 51 tests</td>
</tr>
<tr>
<td>Average of all data</td>
</tr>
<tr>
<td>Average of 46 tests (all counts less than 1,000 per cc.)</td>
</tr>
<tr>
<td>Average of 36 tests (all counts more than 1,000 per cc.)</td>
</tr>
<tr>
<td>Average of 82 tests</td>
</tr>
</tbody>
</table>
Observations on the effectiveness of weekly taking apart and scrubbing.—By comparing the results secured on Mondays with those secured on Tuesdays, additional evidence bearing on the effectiveness of scrubbing will be found in various tables given throughout the bulletin. Except as noted, the teat-cups and tubes were invariably brought to the dairy for a thorough cleaning on Tuesday morning. When these were reassembled they were returned to the barn where they were placed in the sterilizing solution or hung in the cupboard. In a few cases there was such delay that they did not get back into the sterilizing solutions before they were used for the evening milking. The teat-cups and tubes were then used until the following Tuesday without being again taken apart so that results of analyses taken on Mondays show the bacteriological condition of the tubes at the end of the week.

In the records given in the tables of the present bulletin, there are 51 instances in which counts taken on Monday were followed by counts taken from the same tubes on Tuesday. When these were tabulated it was found that in 27 instances the counts obtained on Tuesday were higher than those obtained on Monday. The average size of the counts obtained are given in Table 12. Data obtained from 31 similar comparisons published in Bulletin No. 450 are also included in this table with the averages for all. In all except one pair of the averages it will be seen that the counts obtained on the days when the tubes had just been given a thorough cleaning were higher than those obtained from the tubes after they had been in use for a week without having been taken apart and scrubbed.

These results ought not to be interpreted to mean that it is desirable to leave the tubes indefinitely without taking them apart, but rather that milker tubes cannot be regarded as bacteriologically clean just because they are clean to the eye. Milker teat-cups and tubes are not satisfactory for use in connection with such a highly perishable and important food as milk until they are both physically and bacteriologically clean. Just as Prucha, Weeter, and Chambers 4 have shown that metal utensils are not really satisfactorily cleaned without drying to kill the bacteria after the utensils are scalded or steamed, so rubber tubing can not be regarded as clean until it has been sterilized in some way after cleaning.

CONCLUSIONS

The most important new finding reported in this bulletin is the fact that properly rinsed and cleaned milker teat-cups and tubes appear to be kept in excellent bacteriological condition by rinsing them thoroly with a strong hypochlorite solution and hanging them in a clean place. This is a much more simple and convenient means of caring for these milker parts than any method thus far suggested, but dairymen wishing to try this method should remember that it has not yet been tested under practical field conditions and that results obtained under field conditions may not be as good as those obtained in the Station dairy. For those who wish to follow well-tried and proved methods or who may not be in a position to have frequent bacterial analyses made from their milk, it is recommended that the instructions quoted below be observed.

These instructions were drawn up in their present form by a conference of experiment station workers, practical milking machine men from various companies, and chemists familiar with disinfectants, at Ames, Iowa, in February, 1922.

The directions as given are, themselves, revised from similar directions issued by the Milking Machine Manufacturers Association and published in many farm dairy papers during January, 1922. These directions were in turn based on the discussions at a conference held at Geneva, N. Y., in May, 1921, at which time workers from the Ohio, Illinois, Cornell, and Geneva Experiment Stations and from the United States Department of Agriculture presented their latest findings.
INSTRUCTIONS FOR CLEANING AND CARE OF MILKING MACHINES

Washing of Milking Machines

First: Immediately after the last cow is milked, draw a pailful of clean cold water through the milk passages, using fresh water for each unit.

Second: Draw through the passages a pailful of scalding water to which has been added one-half cup of cleansing powder (use a dairy cleanser, not a soap powder).

Third: Draw through the passages a pailful of cold water containing one-half cup of a home-made hypochlorite solution* or commercial hypochlorite solutions in amounts recommended by the manufacturer. Clean hot water may be used in place of the hypochlorite solutions.

While the teat-cups are being rinsed, they should be doused up and down completely in and out of the water so that air and water may surge alternately through the tubes. This will increase the contraction and expansion of the inflations and tubes and therefore help to release the milk and bacteria from the inner surfaces of the rubber parts. All adhering dirt, milk, bedding, and the like, should be washed from the outside of the tubes and teat-cups.

Care of Machines After Washing

The two general methods for sterilizing milking machine teat-cups and tubes after washing are the chemical method and the hot water method. These methods are not equally valuable for all types of milkers because of differences in construction. Each user should therefore consult with the manufacturer if in doubt regarding the method to use for his machine.

1. Chemical Method

After the teat-cups and rubber tubes have been flushed as above directed, put them into the sterilizing solution (instructions for the preparation of which follow) and leave them immersed from one milking to the next. Care should be exercised in placing tubes and teat-cups in the solution that no air becomes entrapped in them, for wherever there is air no solution will come in contact with the rubber surfaces. Put the teat-cups in the solution while holding the rubber milk tube straight up so the air can escape through it.

Sterilizing Solution

Place 50 pounds of salt in a 20-gallon jar and fill with clean water to within 6 or 8 inches of the top. To this salt solution add 1 quart of the home-made hypochlorite solution when the salt solution is first prepared, and add 1 pint weekly in winter and 1 pint twice weekly in summer, or add commercial hypochlorite or chloramine solutions according to the directions of the manufacturer. Maintain the sterilizing solution at the original water level by adding salt and clean water as necessary. Make up an entirely new jar of sterilizing solution as soon as the old solution ceases to be

*The home-made hypochlorite solution is made by mixing the contents of one 12-ounce can of chloride of lime with 1 gallon of water in a 2-gallon covered crock. Be sure the chloride of lime is in a clean fresh-looking container, plainly marked as to the content of available chlorine. If the label does not have this information, or if the contents look old and caked, the material is worthless. In preparing the hypochlorite solution, first add just enough water to the chloride of lime to make a paste. Stir well and add the balance of the gallon of water. The clear solution which collects is the portion that should be used. This home-made solution is equally as effective as the hypochlorite solutions and chloramine powders and costs very much less than any of the commercial preparations.
clean. Never use a solution for more than six weeks. Care must be observed to see that at no time any dirt or foreign material gets into the solution. In case of such accident empty the solution at once and fill the crock with a fresh solution.

2. HOT WATER TREATMENT

In place of the chemical method, hot water may be used to sterilize the teat-cups and rubberware. In employing this method either put the teat-cups and rubber tubes into a vessel of clean water, bring this water to a temperature of at least 160° to 170° F. (use a thermometer to get the temperature) by running steam into it, or bring a pail of water to the boiling temperature, remove it from the fire, and immerse the parts. At a temperature of 170° F. the life of good quality rubber tubing is not materially shortened.

CARE OF METAL PARTS, STANCHION HOSE, AND VACUUM LINE

Of course clean milk can not be produced unless the pails, lids, and milk spigots are washed, and then steamed or scalded, and dried. If the machine has a moisture trap or check valve this should be taken apart and cleaned after each milking. In machines having a check valve on the pail lid, the stanchion hose should be kept clean by washing and passing brushes through it. This hose should not be put in the sterilizing solution nor in hot water. In machines operated by individual pumps in which there is no valve between the pump and the milk chamber, the stanchion hose must be kept clean, and must be sterilized with chemicals or hot water as specified for the teat-cups and tubes. Moisture continually passes into the stanchion hose during the milking in machines of this type and on condensing runs back into the milk so that it is necessary to keep this hose properly cleaned and sterilized.

WASHING TEAT-CUPS AND RUBBER TUBES

Even if the foregoing instructions are carefully followed, it is necessary to take the teat-cups and rubber tubes apart to be scrubbed frequently. Under no conditions should they be allowed to go more than three days in summer or seven days in winter. In scrubbing the individual parts the teat-cups and rubber tubes should be placed in hot water to which a cleansing powder has been added at the rate of one-half cup per pail of water. The parts should be scrubbed inside and out with brushes provided for this purpose. After scrubbing thoroughly, rinse in clean water and dry and polish the metal parts. It is well to soak the rubber tubes for a time in a strong hypochlorite solution, using one-half cup of the home-made hypochlorite solution per pail of water or commercial hypochlorite solutions according to the directions of the manufacturer.

Great care should be taken to prevent the accidental dropping of the teat-cups on the floor during milking as dirt is thereby readily drawn into the milk. In case any such accident occurs, the cups must be taken apart, freed from any coarse dirt and then thoroughly cleaned.

IMPORTANCE OF THE CLEANING OF MILKING MACHINES

It is easy to clean a milking machine and do it right, but it must not be neglected. The above described methods are practical on any farm and are in daily use on many farms that are producing a very high grade milk.