Bacteriological Investigations

OF

Milking Machines

BY

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DIVISION OF BACTERIOLOGY
DOMINION EXPERIMENTAL FARMS

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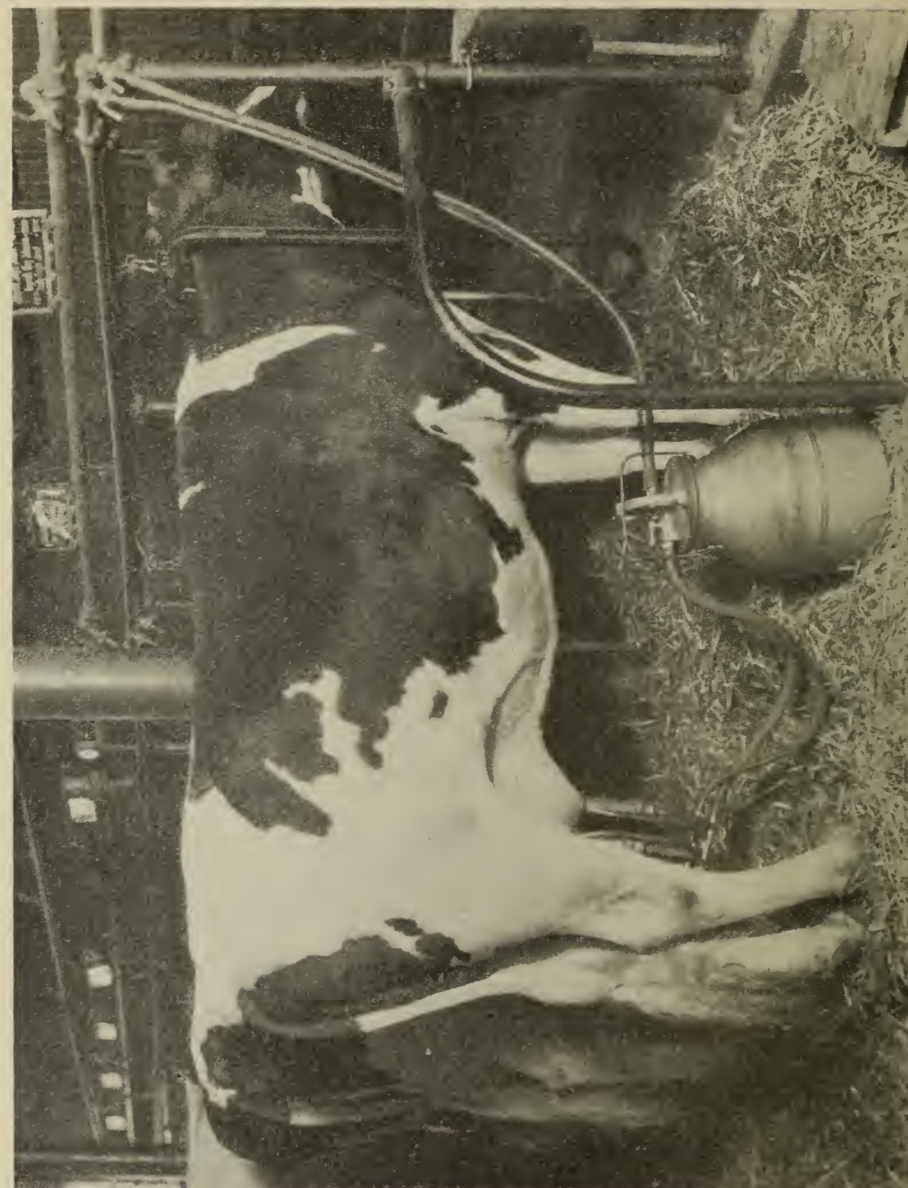

BACTERIOLOGICAL INVESTIGATIONS OF MILKING MACHINES

BY

A. G. LOCHHEAD and C. K. JOHNS

INTRODUCTION

There are few questions interesting milk producers and distributors about which there is more conflict of opinion than that concerning the ability of the milking machine to produce high grade milk of low bacterial contamination, comparable with the product of good hand milking. Among those concerned with producing and handling milk the most divergent opinions are expressed with regard to the effect of the machine upon the sanitary quality of the milk, a state of affairs which renders it difficult for the individual producer to know whether the cleanliness and keeping quality of his product will suffer by the introduction of a system of machine milking.

Viewed from the standpoint of sanitation, the milking machine possesses certain obvious advantages over hand milking, and it was rightly assumed, when the machine was first introduced, that certain sources of germ infection, to which milk drawn by hand is subject, would be eliminated. In a method which receives the milk through a closed system from udder to pail it is indeed reasonable to expect, with proper handling, little or no contamination by dirt from the flank of the animal, from dust and straw and from the hands of the milker, all of these being sources of contamination when cows are milked by hand.

In spite of these advantages, however, it was soon found that machine-drawn milk generally showed greater contamination than where careful hand milking was practised. As a result, a more or less widespread belief gained ground that the machine was unsuited to the production of milk of the highest sanitary grade, and the mechanical milker came to be viewed with general disfavour. Indeed, many instances have occurred where producers have found such difficulty in obtaining milk of satisfactory grade with the milking machine that they have discarded it in favour of hand-milking, often on the insistence of distributors or public health authorities whose sanitary requirements could not otherwise be met.

The unsatisfactory results obtained by milking machine users in the past are to be ascribed in no small degree to the early emphasis laid by machine manufacturers upon the labour-saving possibilities of their product with an attendant disregard of the sanitary factors. Of late years, however, it has been more generally recognized that a machine, to be successful, must not only produce milk economically, but must also draw a milk with low bacterial contamination, at least equal in sanitary quality to that drawn by careful hand-milking. This need has led to a number of investigations of methods for maintaining the sanitary quality of machine drawn milk.

Not a few of the methods advocated for handling the machine, however, though effective from a sanitary standpoint, are feasible only on dairy farms where extra premiums for milk of low germ content make their employment practicable. On the average farm, where the machine is installed for its labour-saving possibilities, such methods are often ill adapted on account of their extensive demands on time and labour. Consequently, even though premium milk can be and is being consistently produced by machine, yet without doubt the bulk of the machine-drawn milk brought to our receiving stations is heavily contaminated.

With the steadily increasing recognition of the importance of clean milk and the greater insistence which distributors and the public at large are placing upon sanitary quality, it is becoming more and more incumbent on milk producers to improve the general quality of machine-drawn milk. With the hope of aiding in this direction through a study of the sanitary aspects of the milking machine problem facing Canadian producers, the investigations outlined in the present bulletin were undertaken at the Central Experimental Farm and continued from 1926 to 1928. It was planned to study the relative importance of the various factors concerned in the production of high grade milk by machine, and to compare and develop methods for the satisfactory control of bacterial contamination.[1]

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[1] We wish to acknowledge the generous co-operation and assistance of the staff of the Division of Animal Husbandry, accorded us throughout the period of the investigations here reported. That division has been conducting economic trials of all makes of mechanical milkers found on our markets since the year 1913.

EXPERIMENTAL STUDIES

PART I.—THE INFLUENCE OF THE MAKE OF MACHINE UPON THE BACTERIAL CONTAMINATION OF MILK

This series of tests had for its object the comparing of milking machines of different makes to note whether bacterial contamination of the milk was significantly affected by the design of the machine when properly handled and maintained under sanitary conditions. Since the various makes of mechanical milkers differ from each other in certain features, it is conceivable that contamination may vary with the machine type. At the time of the experiment there were available four different makes, the B.L.K., De Laval, Empire and McCartney machines. Ten cows[1] were used in the tests, two being milked daily by each of the above machines while the remaining pair was milked by hand. The machines were rotated so that each pair of cows was milked an equal number of times by each machine and by hand as outlined in table 1. A separate milker had charge of each pair of cows throughout the experiment, each man therefore milking by each machine and by hand.

TABLE 1.—PLAN OF ROTATION OF MACHINES

Cow No.	First week	Second week	Third week	Fourth week	Fifth week
1	Machine A	Machine B	Machine C	Machine D	Hand
2	"	"	"	"	"
3	Machine B	Machine C	Machine D	Hand	Machine A
4	"	"	"	"	"
5	Machine C	Machine D	Hand	Machine A	Machine B
6	"	"	"	"	"
7	Machine D	Hand	Machine A	Machine B	Machine C
8	"	"	"	"	"
9	Hand	Machine A	Machine B	Machine C	Machine D
10	"	"	"	"	"

The machines were uniformly treated. Immediately after milking, cold water was drawn through each unit, using suction. They were then removed to the dairy, where the parts coming in contact with the milk were detached and given a thorough brushing, using hot water and dairy cleanser. The parts were then rinsed and reassembled. The milk tube system, consisting of long and short milk tubes and teatcups, together with the metal claw, was then immersed in water heated to 170°F. in a covered container. This temperature was maintained for 20 minutes, after which the water was allowed to cool, the parts remaining immersed until the next milking. The milker buckets and pail heads were likewise washed, brushed and rinsed, the buckets being, in addition, sterilized[2] by steam. Small-top milking pails, used for the hand milking, were given a similar treatment. The cows used in the experiment were kept clean by daily grooming, the udders being in addition wiped with a damp cloth immediately before milking.

Samples for analysis were taken at the evening milking, Monday to Friday inclusive, and determinations of bacterial counts made without delay.[3] Daily plate counts were made using purple-lactose agar (Difco), which medium was

[1] One cow, No. 9, developed udder trouble during the course of the experiment and was removed. Results from this cow were therefore not included in table 2.

[2] Sterilization, as understood by the bacteriologist, means the complete destruction of all germ life. In the dairy industry, however, the term is used to denote the destruction of all but an insignificant number of highly resistant bacteria, thus rendering the utensil or machine satisfactory from a sanitary standpoint. It is in this latter sense that the term sterilization is employed in this bulletin.

[3] We are indebted to Mr. G. S. Fraser, B.S.A., for assistance in the analytical work in connection with Parts I and II.

selected as favouring the growth of the largest numbers of organisms. In addition, semi-weekly counts were made on nutrient agar in order to judge the milk by the Standard Methods of Milk Analysis (1)[1] which alone have official standing on this continent for milk control work. Purple lactose agar plates were held at room temperature for 5 days, while those made with nutrient agar were incubated at 37°C. for 48 hours before counting.

TABLE 2.—BACTERIAL CONTAMINATION OF MILK DRAWN BY FOUR DIFFERENT MACHINES AND BY HAND (AVERAGE OF 9 COWS)

—	Machine A	Machine B	Machine C	Machine D	Hand
Purple-lactose agar—					
Average count per c.c.	5,180	2,740	3,840	4,140	1,950
Range of counts	500–11,550	950– 6,850	900–14,800	600–11,700	350–6,600
Per cent counts under 10,000	91·9	100·0	93·0	97·4	100·0
Nutrient agar.—					
Average count per c.c.	2,150	2,560	2,450	3,510	2,130
Range of counts	400– 3,450	650– 4,700	800– 4,800	1,050–9,250	500–4,750
Per cent counts under 10,000	100·0	100·0	100·0	100·0	100·0

RESULTS AND DISCUSSION

It will be observed, from the data presented in Table 2, that all four machines were found capable of producing milk of low contamination. The variations in the counts obtained are not considered sufficient to warrant making any distinction between the different makes, particularly in view of the fact that the ranking according to bacterial counts was not the same with the two media employed. This is further borne out when the counts from the individual cows are considered with respect to the type of machine. Each machine was found to have the lowest average bacterial count in at least one instance. It is safe to assume that differences in contamination due to the machines tested, should such exist, are quite insignificant with proper treatment, and are obscured by other variable factors inherent in experiments of this type.

When the results of machine milking and hand milking are compared, it will be noted that the hand-drawn milk showed a somewhat lower contamination, the bacterial counts being, in fact, particularly low.[2] We are inclined to attribute this, at least in part, to the fact that the five employees in this test were not only desirous of " beating the machine," but also vied with each other in producing the hand-drawn milk of lowest contamination. Furthermore, the adoption of the suction method of washing the machine (see Part III) in preference to the brushing method used in this experiment would undoubtedly have effected some reduction in the contamination of the machine-drawn milk. Further data to be presented in Part IV of this bulletin, in which a comparison of machine and hand-drawn milk is made, support the view that high grade milk may be consistently produced with either method.

When the plate counts on purple-lactose agar and nutrient agar are compared, it is seen that with machine-drawn milk the " official plate count " (nutrient agar, 37°C., 48 hours) is in all cases lower, with practically no difference in the case of hand-drawn milk. From this it would appear that bacteria capable of growing at blood heat form a larger proportion of the organisms encountered in hand-drawn milk than in milk of correspondingly low grade produced by machine.

In summing up the results obtained from the four machines it is evident that heavy bacterial contamination, often encountered in machine-drawn milk, is a question of machine treatment rather than machine make, and consequently further tests were designed to study the effect of various methods of handling.

[1] For references, see p. 28.

[2] For a detailed study of contamination of hand-drawn milk see Dominion of Canada, Dept. of Agriculture, Pamphlet No. 79, N.S. entitled "Producing Clean Milk."

PART II.—THE INFLUENCE OF FACTORS OTHER THAN THE SANITARY CONDITION OF THE MACHINE

To study the influence of various factors not directly connected with the machine or its state of cleanliness, the following series of tests was conducted. Two single units (De Laval) were used, being better suited to the requirements of the investigation than a double unit. In all cases both units were kept in first-class condition, the rubber parts, after thorough washing, being sterilized by flowing steam for 15 minutes and the milker buckets by steaming at 5 pounds pressure for 20 minutes. Four cows were used in this series, each cow being milked four times in each of seven tests. In studying each particular factor one unit was so handled as to act as a control, while the other was varied in accordance with the plan of the experiment.

Samples were taken with sterile pipettes directly from the milker buckets before the addition of the strippings. Plating was done immediately, using purple-lactose agar (Difco) and incubating at room temperature for 5 days.

TABLE 3.—EFFECT OF FACTORS OTHER THAN SANITARY CONDITION OF MACHINE

Effect of factor under test	Exp. No.	Stable handling										Average bacterial count
		Udder not wiped	Wiped water and dried	Wiped water not dried	Wiped disinfectant	Foremilk not discarded	Foremilk discarded	Cups put on carelessly	Cups put on carefully	Cups dropped or litter	Cups not dropped	
Not washing cow's udder......	1	×	—	—	—	—	×	—	×	—	×	4,570
	2 (check)	—	×	—	—	—	×	—	×	—	×	1,820
Washing and not drying.........	3	—	—	×	—	—	×	—	×	—	×	2,880
	4 (check)	—	×	—	—	—	×	—	×	—	×	1,150
Using disinfectant (½% lysol) to wash udder.	5	—	—	—	×	—	×	—	×	—	×	1,020
	6 (check)	—	×	—	—	—	×	—	×	—	×	2,240
Discarding foremilk............	7	—	×	—	—	×	—	—	×	—	×	1,930
	8 (check)	—	×	—	—	—	×	—	×	—	×	1,840
Putting teatcups on carelessly (udder washed)	9	—	×	—	—	—	×	×	—	—	×	3,430
	10 (check)	—	×	—	—	—	×	—	×	—	×	2,620
Putting teatcups on carelessly (udder not washed)	11	×	—	—	—	—	×	×	—	—	×	5,960
	12 (check)	×	—	—	—	—	×	—	×	—	×	3,700
Dropping teatcups on bedding for 10 seconds	13	—	×	—	—	—	×	—	×	×	—	5,600
	14 (check)	—	×	—	—	—	×	—	×	—	×	2,260

× Denotes conditions observed during tests.

RESULTS AND DISCUSSION

It would appear from the results outlined in Table 3 that carelessness in regard to any or all of the factors considered here fails to account for any considerable proportion of the tremendous bacterial contamination frequently encountered in machine-drawn milk. Even such gross carelessness as dropping the teatcups into the bedding for a 10-second period adds relatively few bacteria. The contamination from this source will naturally vary with the time of exposure and the state of the bedding, and though every care should be taken to avoid it, the dropping of the teatcups on the litter will rarely result in the introduction of an excessive number of bacteria into the milk. On the other hand, it may result, as Ruehle, Breed and Smith (10) point out, in the addition of dirt which in itself is objectionable in milk, and may interfere with the action of the machine.

While the effect will vary with the individual cow and her state of cleanliness, discarding the foremilk of well-kept animals is considered of minor importance in affecting the bacterial content of the milk. In the present experiment the cows normally gave low count milk, and were kept clean, hence the small advantage obtained through discarding the foremilk. Nevertheless, the practice of drawing a stream of milk from each teat into a container covered with fine-mesh wire gauze or black cloth is to be recommended as being invaluable in the early detection of abnormal milk resulting from mastitis, etc.

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In the use of a germicide with a strong odour for washing the udder, such as Lysol, there is a possibility of the odour being absorbed by the milk. We have never detected this during these tests, although under hand-milking conditions, with much greater exposure of the milk, the probability would be considerably increased. The use of a hypochlorite solution in place of Lysol would avoid such a possible tainting of the milk.

The factors studied in this experiment exert in themselves but a relatively small influence upon the germ content of machine-drawn milk. It is not to be assumed, however, that the handling of the machine is of no importance, or that care should not be exercised. These factors become important only if the other, more serious sources of contamination are kept in control and cannot, therefore, be neglected if the highest grade of milk is to be obtained by machine.

PART III.—THE INFLUENCE OF METHODS OF CLEANING AND STERILIZING THE RUBBER PARTS

Factors concerned with the stable handling of the machine, as reported under Part II, having been shown to be of minor importance, attention was given to the relative values of different methods of cleaning and sterilizing the machine in reducing bacterial contamination. The metal milker bucket does not present any special difficulties and can be cleaned and sterilized almost as readily as the ordinary milk pail.[1] The rubber parts, on the other hand, are much more difficult to treat, particularly old liners and tubes showing abundant cracks and crevices. The interior of the long rubber tubes usually remains moist from one milking to the next, necessitating special care to remove completely all traces of milk and to destroy any remaining bacteria. Where such precautions are neglected, bacteria find ample food and moisture within the tubes and are able to multiply at an astonishing rate at ordinary room temperature. Then at the next milking many of these bacteria are washed out of the tubes by the freshly drawn milk passing through, thus contaminating the milk to the extent of thousands, often millions, per cubic centimeter. Such contamination may occur even when the tubes appear " clean ", their appearance being no reliable guide to their capacity for germ infection. Consequently the problem of producing low-count milk with the machine resolves itself mainly into a question of adequate, yet practicable methods for cleaning and sterilizing the rubber parts. In the studies reported here stress was laid upon methods which would be most convenient and time-saving under average farm conditions, bearing in mind that but few users of milking machines are producing milk for a market where a low bacterial content commands a premium. Methods advocated by previous workers were tested out under conditions as uniform as possible, and were frequently modified in the light of our experience. Two standard makes of machine, Empire and De Laval, were used in these tests, in order to determine whether there would be any significant differences between them in regard to the effectiveness of any given treatment. The employment of a new set of rubber parts for each individual test was not feasible. However, observations were made as to whether any treatment was damaging the rubber parts, and replacements were made when necessary.

In earlier work not reported here it was observed that conditions beyond our control, such as variations in the bacterial content of the milk from certain cows, sometimes tended to obscure the effect of different methods of treatment, making reliable comparisons difficult. To reduce this possibility, for this series of tests heifers in their first lactation period, giving low count milk, were selected, and a check on the udder flora maintained by semi-weekly plating of the fore-milk from each cow. In addition to the milk samples, further samples for analysis were secured by " milking " sterile water from an artificial udder similar to that devised by Ruehle, Breed and Smith (10).[2] By this means we were able to obtain a better idea of the amount of bacterial contamination properly chargeable to the machine itself.

PLAN OF EXPERIMENT

An Empire double unit machine with a divided pail and two De Laval single unit machines were operated throughout the experiment. One unit of each make " milked " 5 liters of sterile water from the previously sterilized artificial udder,

[1] Detailed instructions for treating ordinary metal utensils are given in Dominion of Canada Dept. of Agriculture, Circular No. 64, entitled "The Washing and Sterilization of Farm Dairy Utensils."

[2] We are indebted to Dr. A. H. Robertson, formerly of the New York Agricultural Experiment Station, Geneva, N.Y., for having kindly provided us with specifications of the artificial udder used at that station.

as illustrated in fig. 1. The remaining units each milked two heifers from a group of four, the different makes alternating from one pair to the other each day. The units which " milked " the artificial udder, together with the other two units, were afterwards used to milk a number of other cows, so that they would all be on a par from the standpoint of cleanliness before washing. Samples for analysis were obtained from the evening milking only, being taken directly from the milker bucket before the addition of the strippings. The cows' udders were washed with a 0·5 per cent solution of Lysol immediately before milking; the foremilk was not removed by hand except on Mondays and Thursdays, when it was plated out as a check upon the udder flora of each individual cow.

Plate counts were made as described on p. , using purple-lactose agar. In addition 1·0 c.c. and 0·1 c.c. quantities of milk were inoculated into lactose bile broth and incubated for 48 hours at 37° C. The formation of 10 per cent

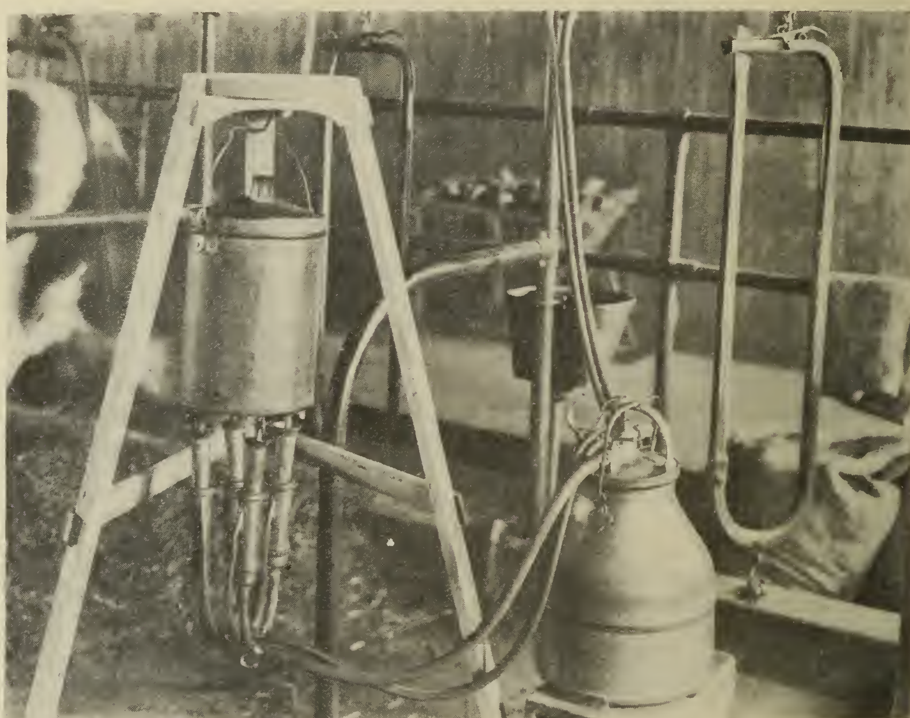

Fig. 1.—Artificial udder in operation. Sterile water is "milked" by the machine in order that contamination from the cow may be eliminated, and that due only to the machine itself estimated.

or more of gas was considered a positive presumptive test for the presence of organisms of the colon-aerogenes group. This latter test was introduced for the purpose of ascertaining to what extent the machine is responsible for the introduction of gas-forming organisms into the milk.

In addition to the bacteriological tests outlined above, determinations were made, where hypochlorite solutions were employed, of the available chlorine (expressed as parts per million) of the solutions in the crock at 9.00 a.m. and 3.30 p.m. At the latter hour the solution inside the teatcups and tubing was drained out and tested separately.

In this experiment it was considered necessary to test out, not only the relative value of different methods of sterilizing the rubber parts, but also the influence of the washing preliminary to sterilization. Accordingly the various treatments were divided into two sections. In the first section treatments followed a thorough washing, while in the second, representative treatments were repeated, following an inadequate washing, as described in detail below:—

A. Sterilizing Treatments Following Thorough Washing.—Except where otherwise stated, all units were washed in the following manner: Immediately after milking, cold water was drawn through the machines, using a pailful for each two units (see fig. 2). This was followed by an equal quantity of hot water containing tri-sodium phosphate, a rinse with clear hot water completing the process. The machines were then taken to the dairy, where any dirt on the outside of the rubber parts was washed off, and the sterilizing treatments administered. The milker pails and pailheads were thoroughly washed and the check valves cleaned. The pailheads were then hung up, while the milker pails were sterilized with steam at 5 pounds pressure for 20 minutes. Neither for washing nor for sterilization was the milk tube system (teatcups, claw, and milk tubes) taken apart, except that once a week only (Thursday a.m.) the liners and tubes were detached, given a thorough brushing, rinsed and then reassembled before sterilization. A brief description of the various sterilizing treatments given the assembled milk tube system follows:—

(1) Immersion in water at 170° F. in a covered boiler (see fig. 6), the temperature being maintained for 20 minutes. The water was then allowed to cool down, the parts remaining immersed until required.

(2) Immersion as in (1) but with water at 160° F.

(3) Immersion as in (1) but after 20 minutes parts removed and hung up in the dairy to drain and dry. (See fig. 7).

(3 br)[1] Immersion as in (3) but preliminary cleaning by a cold water suction rinse. In place of further rinses with dairy cleanser and hot water the machines were removed to the dairy. Rubber parts were then detached and thoroughly brushed with hot water and cleanser, rinsed in hot water and reassembled for sterilizing.

(4) Immersion for 1 minute in water heated to approximately 200° F., then parts removed and hung up to drain and dry.

(5) Treatment with flowing steam for 15 minutes, the parts remaining in the steam chest until required.

(6 w) No sterilizing treatment given after washing, parts merely hung up to dry. Test conducted in February.

(6 s) As with (6 w) but conducted in July.

(6 br) As with (6 w) but preliminary washing performed as described under (3 br).

(7) Immersion in cold water in a covered boiler, the water not being changed throughout the week.

(7 s) Immersion as in (7) but with the water changed each morning.

(8) Immersion in a crock containing a hypochlorite solution made up to 200 parts per million (p.p.m.) available chlorine at start. New solution made up each week.[2] (See figs. 8 and 9.)

(9) As with (8) but strength of solution maintained by the addition of concentrated hypochlorite each morning. New solution made up each week.

(10) As with (8) but with sufficient common salt added to make a saturated brine. New solution made up each week.

(11) After the usual preliminary rinsing with cold water and hot cleanser solution, a cold water solution of hypochlorite (200-300 p.p.m. available chlorine) drawn through in place of the usual final rinse with clear hot water. Parts hung up to dry without further treatment.

(12) As in (11) but with cold hypochlorite rinse given immediately before the next milking instead of at the time of washing.

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[1] The abbreviations, br, w, s, stand for brushed, winter, summer respectively.

[2] For details regarding the preparation and use of hypochlorite solutions, see Appendix A.

B. Sterilizing Treatments Following Inadequate Washing.—All units received a cold water suction rinse only, immediately following milking. The milk tube system then received treatment at the dairy as follows:—

(1) Immersion in water at approximately 200° F. for 1 minute, parts then hung up to dry.

(2) Immersion in hypochlorite and saturated brine, strength of solution maintained by addition of concentrated hypochlorite each morning.

(3) Immersion in cold water, fresh each morning.

(4) Parts hung up to dry without further treatment.

RESULTS AND DISCUSSION

Table 4 gives a summary of results of analyses of sterile water drawn through units treated as described, while corresponding data obtained from milk are presented in table 5.

It will be noted that the tests in this series extended from December to July and consequently were not conducted under uniform external temperature conditions. As the efficiency of the chemical methods might be expected to be deleteriously affected by higher temperatures, as reported by Burgwald (3) these treatments were reserved for the warmer months of spring and early summer. Had the order been reversed, it is not improbable that the slight advantage would have been in favour of the chemical methods. However, it is unlikely that, following a good sterilizing treatment, the temperatures encountered would be responsible for any significant difference such as appears where the "no treatment" method (A 6 w) is repeated under summer conditions (A 6 s). Data to be presented in Part IV tend to substantiate this.

It would appear from the results reported in (A 6 w) that little bacterial growth takes place in the rubber tubes of a well-washed milker when held at low temperatures. However, the same test repeated in July (A 6 s), showed that considerable growth was taking place in the tubes, one milk count reaching 105,000 per c.c. Consequently this method cannot be depended upon to keep the milk-tube system sufficiently free from bacteria to insure low counts at all seasons.

Immersion in cold water gave unsatisfactory results, whether or not the water was changed daily. Although the first few counts obtained were reasonably low, subsequent ones showed a rapid increase in bacterial contamination which pointed to a probable cumulative effect with this method. The weakness of this procedure lies in the fact that it depends solely upon the low temperature of the water to inhibit bacterial growth: to accomplish this purpose it should remain below 45° F. at all times. While in some parts of the country water fresh from the well or spring is always below this temperature, yet over large sections the water during the summer months is well above this limit. Furthermore, during warmer weather the water, though sufficiently cold when drawn, soon rises to a temperature which permits of fairly rapid bacterial growth. Although the practice of immersing machine rubber parts is one which may appeal to machine users on account of its simplicity, yet it is one which cannot be relied upon.

The feasibility of allowing a continuous stream of cold water to run through the units between milkings has been studied by several investigators, notably Ruehle, Breed and Smith (10), Robertson, Finch and Breed (9) and Fisher and White (4). The few tests made by us have yielded results agreeing with the above authors. Although the method could be depended upon as long as the temperature of the water remained low (under 55°F), yet during the warmer weather when the temperature of the water exceeded this limit, the noticeably increased counts revealed a failure of this method to suppress

TABLE 4.—ANALYSES OF STERILE WATER "MILKED" BY MACHINES RECEIVING VARIOUS TREATMENTS

Treatment	Month	Number of counts	Bacterial counts (both machines)		Percentage distribution of bacterial counts					Percentage positive tests, lactose bile	
			Average	Median	0–100	101–500	501-1000	1001-10,000	over 10,000	1·0 c.c.	0·1 c.c.
A. *Adequate Washing*—											
(1) Water 170° remaining	Dec.	17	150	42	70·6	21·2	0·0	2·3	5·9	0·0	0·0
(2) Water 160° remaining	Jan.	18	952	144	50·0	27·7	11·1	11·1	0·0	0·0	0·0
(3) Water 170°, 20 minutes only	Jan.	18	335	46	77·8	11·1	0·0	11·1	0·0	0·0	0·0
(3br) Water 170°, 20 minutes only (brushed)	Mar.	10	1,854	1,166	0·0	20·0	30·0	50·0	0·0	20·0	20·0
(4) Water 200°, 1 minute	Jan.-Feb.	20	465	25	70·0	25·0	0·0	5·0	0·0	0·0	0·0
(5) Flowing steam, 15 minutes	Mar.	8	66	52	87·5	12·5	0·0	0·0	0·0	12·5	12·5
(6w) Hung up to dry	Feb.	20	204	114	45·0	40·0	10·0	5·0	0·0	0·0	0·0
(6s) Hung up to dry	July	7	10,836	3,050	14·3	14·3	0·0	57·1	14·3	14·3	14·3
(6br) Hung up to dry (brushed)	Feb.-Mar.	10	5,605	4,455	0·0	0·0	0·0	90·0	10·0	20·0	0·0
(7) Cold water, not changed	Mar.-Apr.	12	71,850	65,400	16·7	8·3	8·3	0·0	66·7	16·7	8·3
(7s) Cold water, changed daily	June	6	46,733	16,225	0·0	16·7	0·0	33·3	50·0	16·7	16·7
(8) Hypochlorite	Apr.	20	1,278	135	45·0	20·0	5·0	30·0	0·0	5·0	0·0
(9) Hypochlorite strengthened daily	May	20	361	114	45·0	40·0	0·0	15·0	0·0	5·0	0·0
(10) Hypochlorite and saturated brine	May	18	600	285	38·9	38·9	5·6	16·6	0·0	0·0	0·0
(11) Hypochlorite rinse after wash	May	8	1,107	708	0·0	50·0	0·0	50·0	0·0	12·5	0·0
(12) Hypochlorite rinse before milking	June-July	18	2,595	325	27·8	27·8	22·2	11·1	11·1	0·0	0·0
B. *Inadequate Washing*—											
(1) Water 200°, 1 minute	June	8	2,286	1,308	0·0	12·5	37·5	50·0	0·0	0·0	0·0
(2) Hypochlorite and sat'd brine	June	10	4,740	1,930	30·0	0·0	10·0	50·0	10·0	10·0	10·0
(3) Cold water, changed daily	June	10	661,220	570,250	0·0	0·0	0·0	0 0	100·0	90·0	90·0
(4) Hung up to dry	Mar.	10	2,088,820	629,600	0·0	0·0	0·0	0·0	100·0	100·0	80·0

TABLE 5.—ANALYSES OF MILK DRAWN BY MACHINES RECEIVING VARIOUS TREATMENTS

Treatment	Month	Number of counts	Bacterial counts (both machines)		Percentage distribution of bacterial counts					Percentage positive tests, lactose bile.	
			Average	Median	0-1000	1001-2000	2001-5000	5001-10,000	over 10,000	1·0 c.c.	0·1 c.c.
A. *Adequate Washing*—											
(1) Water 170°, remaining	Dec.	34	1,659	1,100	44·1	36·1	13·9	5·9	0·0	29·4	8·8
(2) Water 160°, remaining	Jan.	35	1,835	1,365	31·4	28·6	37·1	2·9	0·0	2·8	0·0
(3) Water 170°, 20 minutes only	Jan.	36	875	550	69·4	25·0	5·6	0·0	0·0	2·8	0·0
(3br) Water 170°, 20 minutes only (brushed)	Mar.	20	1,692	1,090	45·0	30·0	20·0	5·0	0·0	55·0	40·0
(4) Water 200,° 1 minute	Jan.-Feb.	40	1,342	800	55·0	27·5	10·0	7·5	0·0	15·4	0·0
(5) Flowing steam, 15 minutes	Mar.	15	1,581	1,040	46·7	26·6	26·7	0·0	0·0	13·3	6·7
(6w) Hung up to dry	Feb.	40	1,268	925	57·5	25·0	15·0	2·5	0·0	7·5	2·5
(6s) Hung up to dry	July	16	13,689	4,925	6·3	18·8	31·2	18·7	25·0	43·8	18·8
(6br) Hung up to dry (brushed)	Feb.-Mar.	20	6,965	6,400	0·0	5·0	20·0	55·0	20·0	55·0	40·0
(7) Cold water, not changed	Mar.-Apr.	24	90,767	38,350	0·0	25·0	8·3	4·2	62·5	29·2	0·0
(7s) Cold water, changed daily	June	12	42,500	8,200	0·0	0·0	8·3	50·0	41·7	50·0	50·0
(8) Hypochlorite	Apr.	37	1,767	1,045	46·0	32·4	16·2	2·7	2·7	13·5	0·0
(9) Hypochlorite, strengthened daily	Apr.-May	40	3,085	2,290	2·5	32·5	55·0	10·0	0·0	25·0	22·5
(10) Hypochlorite and saturated brine	May	36	1,609	1,405	30·6	44·4	25·0	0·0	0·0	36·1	19·4
(11) Hypochlorite rinse after wash	May	16	2,768	2,125	6·3	25·0	62·5	6·2	0·0	37·5	0·0
(12) Hypochlorite rinse before milking	June-July	36	29,889	10,865	0·0	0·0	13·9	33·3	52·8	33·3	16·7
B. *Inadequate Washing*—											
(1) Water 200°, 1 minute	June	15	9,126	7,050	0·0	6·7	33·3	20·0	40·0	6·7	0·0
(2) Hypochlorite and saturated brine	June	20	5,750	5,025	5·0	5·0	40·0	35·0	15·0	20·0	5·0
(3) Cold water, changed daily	June	20	706,880	359,000	0·0	0·0	0·0	0·0	100·0	90·0	90·0
(4) Hung up to dry	Mar.	20	1,321,265	288,800	0·0	0·0	0·0	0·0	100·0	85·0	80·0

TABLE 6.—AVAILABLE CHLORINE IN HYPOCHLORITE SOLUTIONS

—	A. Adequate Washing									B. Inadequate Washing		
	Hypochlorite solution not reinforced daily			Hypochlorite solution reinforced daily			Hypochlorite and brine not reinforced daily			Hypochlorite and brine reinforced daily		
	Temperature (°F.)	Available chlorine[1]		Temperature (°F.)	Available chlorine		Temperature (°F.)	Available chlorine		Temperature (°F.)	Available chlorine	
		In crock	In tubes		In crock	In tubes		In crock	In tube		In crock	In tube
1st day—9.00 a.m.	40	225	....	40	222	....	43	213	....	69	151	....
3.30 p.m.	56	188	173	56	200	116	53	181	145	....	131	51
2nd day—9.00 a.m.	63	149	....	66	187	....	62	116	....	67	127	....
3.30 p.m.	65	129	106	66	169	101	62	91	69	70	105	51
3rd day—9.00 a.m.	68	87	....	68	163	....	65	56	....	68	103	....
3.30 p.m.	66	87	60	70	148	88	67	40	15	73	83	37
4th day—9.00 a.m.	71	51	....	71	149	....	68	7	....	74	93	....
3.30 p.m.	72	43	21	73	131	80	64	5	0	75	71	27
5th day—9.00 a.m.	67	27	....	72	135	....	65	1	....	68	89	....
3.30 p.m.	67	11	6	72	115	76	67	trace	0	68	66	34

[1] Results expressed in parts per million of available chlorine.

the growth of bacteria inside the tubes. As running water at sufficiently low temperature is available on few farms this method was not considered worthy of extended study.

The heat treatments tested out were all adequate for the practical sterilization of the rubber parts. However, in the case of (A1), (A2) and (A5), the treatment had a decidedly detrimental effect upon the elasticity of the De Laval rubber tubing where this was in contact with the metal. This can be avoided by removing the tubing from the metal before giving the sterilizing treatment, but the time required to do this and to reassemble the units before milking renders such methods less attractive to the majority of milking machine users. Recognizing the need for simple methods of sterilization, we sought a way of utilizing a heat treatment for the rubber parts while still assembled, which would not be so hard on the tubing and yet adequate from a bacteriological standpoint. These desiderata were most successfully met by treatment (A3). Since steam is rarely available on any but the larger dairy farms in Canada, while hot water is more easily obtainable, this method (A3) has much to commend it. Treatment (A4) was highly satisfactory, but required more fuel for heating the water an extra 30°.

While treatment with flowing steam for 15 minutes was found to be adequate in reducing bacterial contamination, the rubber parts of both machines suffered to a greater extent than with the hot water treatment (A3), which was equally as effective in sterilizing the tubes. This is in agreement with results reported by Fisher and White (4).

Well-washed rubber parts may be kept in excellent bacteriological condition by immersion in hypochlorite solutions, our findings corroborating those of Wing (11) and the New York and Connecticut workers referred to above. The differences found between the plain hypochlorite (A8), hypochlorite reinforced daily (A9) and hypochlorite and brine (A10) are hardly large enough to be considered significant under the conditions of the tests, made in the months of April and May. It will be observed from Table 6, in which determinations of available chlorine are tabulated, that even at the moderate temperatures encountered, the strength of the non-reinforced solutions declined rapidly. It is therefore to be expected that under hot weather conditions methods (A8) and (A10) would be less effective in controlling bacterial growth inside the tubes than methods in which the solution is regularly strengthened.

The results obtained with (A11), where a cold hypochlorite rinse was drawn through in place of the final hot water rinse, would indicate that for the farmer with a limited supply of hot water this treatment might be successfully adopted, at least in the cooler months. However, until it has been tested out more extensively, particularly under hot weather conditions we prefer not to give this method an unqualified recommendation. Where the rinse with cold hypochlorite was deferred until immediately before the next milking (A12) the results were less satisfactory, particularly in the case of those tests where milk was drawn through the machines (table 5), and this procedure cannot be recommended.

In comparing the results obtained with the two machines used, Empire and De Laval, no significant difference in bacterial contamination could be discovered, both machines reacting similarly to both heat and chemical treatments.

Regarding the influence of the manner of washing, bacterial contamination was found, without exception, to be definitely greater, under otherwise similar procedure when washing was inadequate than when it was carried out thoroughly. This is clearly shown in table 7, in which are presented increases in bacterial contamination (as measured by " milking " sterile water through the machines) following the substitution of an inadequate method of washing for the more thorough system described on p. 11.

TABLE 7.—EFFECT OF CARELESS WASHING UPON CONTAMINATION FROM MILK TUBE SYSTEM

Treatment following washing	Increased contamination per cc. sterile water "milked" through machine following inadequate washing
Hot water, 200°F. 1 minute	1,821
Hypochlorite and brine[1]	4,140
Cold water, changed daily	614,487
Hung up to dry	2,008,616

[1] Where this treatment followed inadequate washing, the hypochlorite was reinforced daily, a procedure not carried out in the corresponding test following adequate washing. Had this strengthening of the solution been omitted in the first-mentioned case, the increased contamination following careless washing would doubtless have been much greater.

It will be noted from the table that even with satisfactory sterilizing treatments (e.g. hot water and hypochlorite-brine), careless washing methods are reflected in an increased contamination. In such cases, naturally, the increase is much less than where less satisfactory methods of treatment following washing (e.g. cold water and hung up to dry) are employed. Here, with no positive destruction of bacteria, the ill effects of careless washing, whereby large numbers of germs are permitted to remain and multiply in the tubes, are shown to the full. Not only is there an added contamination due to careless washing but, as will be shown in Part V, the proportion of the more undesirable types of bacteria is increased.

In addition to the increased bacterial counts following inadequate washing, where a cold water rinse only was employed, the incomplete removal of the butterfat led to a noticeable softening and deterioration of the rubber parts, rendering proper cleaning and sterilizing extremely difficult, and shortening considerably the life of these parts. In addition, the less complete removal of the milk residue led to a much more rapid decline in the strength of the hypochlorite solution (see table 6). If these difficulties are to be avoided, it is imperative that a sufficient supply of hot water for washing the milker be available.

Special mention may be made of the advantages of the suction method of washing immediately after milking as compared with the more laborious and time-consuming brushing method conducted at the dairy later on. Apart from the convenience and saving of time, the former method leaves the rubber parts in much better condition from a bacteriological standpoint both as regards total numbers and also gas-producing organisms. Data in illustration of this point are presented in table 8, which gives the results of the analysis of sterile water "milked" by machine. Further evidence in favour of the suction washing is given in Part V in which the types of organisms surviving treatments are reported.

TABLE 8.—BRUSH VERSUS SUCTION WASHING

Treatment following washing	Suction washing			Brush washing		
	Average count	Per cent positive tests lactose bile		Average count	Per cent positive tests lactose bile	
		1·0 cc.	0·1 cc.		1·0 cc.	0·1 cc.
Hot water, 170°F. 20 minutes	335	0	0	1,854	20·0	20·0
Hung up to dry	204	0	0	5,605	20·0	0·0

FURTHER OBSERVATIONS ON THE USE OF CHLORINE COMPOUNDS FOR MACHINE STERILIZATION

Although hypochlorite solutions, correctly employed, are satisfactory for the sterilization of the rubber parts, yet various investigators as Bright (2) and Matthews, Shaw and Weaver (7) have noted that in the hands of some farmers, they are not always successful. Among the reasons to which may be ascribed the lack of success are the following:—

(*a*) Introduction of dirt adhering to the rubber parts.

(*b*) Solution not made up to the correct strength, either due to disregard of instructions or to the use of a product of weak disinfecting power.

(*c*) Solution used long after its strength has declined.

(*d*) Container not covered to prevent entry of dust and dirt.

(*e*) Improper immersion of tubes, whereby air pockets occur inside tubes, preventing contact of sterilizing solution with inner surface. (See figs. 8 and 9).

Apart from that last mentioned, the above causes for lack of success with hypochlorites are all due to insufficient strength of the sterilizing solution. Hypochlorite solutions depend for their sterilizing power upon their content of so-called " free " or " available " chlorine. This tends to diminish of its own accord, the rate being accelerated by higher temperature. This loss, moreover, is also much hastened by the introduction of organic matter into the solution, so that the presence of milk residue, dirt or manure seriously interferes with the sterilizing efficiency. In addition, the mere presence of rubber is responsible for considerable diminution in the strength of hypochlorites, as is evidenced by the fact, first pointed out by Prucha, Weeter and Chambers (8), that the solution inside the tubes is always considerably weaker in available chlorine than the main body of the solution in the crock. This has been found to be the case with our experiments as already indicated in table 6, where determinations of the available chlorine content of the solutions in the tubes themselves and in the crock are given.

Under hot weather conditions particularly it is necessary to have a wide margin of safety when employing hypochlorites. Thus Fisher and White (4) working with a proprietary hypochlorite compound, B-K, found that when the temperature of the solution exceeded 60° F., the strength recommended by the manufacturers was quite ineffective; used in double strength, however, or with daily reinforcements, the solution gave consistently good results. This illustrates the greatest source of trouble which users of hypochlorites have to encounter, namely the danger that by using too weak solutions to commence with, or by omitting to renew or reinforce regularly, their " disinfectants " may become actual breeding places for bacteria. In addition, chloride of lime, as ordinarily used for home-made hypochlorite solutions, varies greatly in strength[1] and hence the danger of a weak disinfecting solution unless the available chlorine content is guaranteed.

Since the bacteria ordinarily found in milking machine tubes are rarely able to grow in a strong brine solution, Ruehle, Breed and Smith (10) have advocated the employment of a saturated salt solution combined with the hypochlorite as affording greater safety than the plain hypochlorite solution. Burgwald (3) also noted a considerable advantage in the use of brine during the warm months, but attributed this to the salt acting as a stabilizer in preventing the available chlorine from being given off too rapidly. In our own tests, where warm weather was not encountered, no significant difference in favour of the brine was noted. On the other hand, the available chlorine decreased more rapidly in the brine solution (A10) than in the plain hypochlorite (A8) as

[1] See Appendix B for analyses of chloride of lime.

shown in table 6. It would appear, therefore, that the reason given at the beginning of the paragraph is the correct explanation of the superiority of the solution containing brine.

To test the validity of possible objections to the use of hypochlorite solutions on the grounds that small quantities of the chemical are added to the milk, tests were conducted on the sterile water drawn through the machine to determine the amount of chlorine added. The amount of available chlorine found in no case exceeded one part in two million (using but five liters of water). This small amount would be still further reduced by dilution in proportion to the number of cows milked so there appears to be no grounds for apprehension on this point.

PART IV.—THE EFFICIENCY OF HOT WATER AND CHEMICAL TREATMENTS UNDER PRACTICAL CONDITIONS, WITH A COMPARISON OF MACHINE AND HAND-DRAWN MILK

Although a number of workers have experimented with methods of caring for the milking machine rubber parts, not a few of them have advocated methods which are hardly likely to be adopted by many farmers. For instance, Burgwald (3), in comparing the relative efficiency of hot water and chemical methods, immersed the rubber parts in water at 160-165° F. for 20-30 minutes just before milking. The impracticability of such a method for the morning milking is obvious. Again, Mattick and Procter (7) report "an experiment planned with the primary object of discovering whether or not it was possible by practical methods to produce milk of consistently low bacterial content and good keeping quality." As a preliminary to sterilization with steam these workers rinsed the machine with cold water, using suction, then all rubber parts were detached, thoroughly washed and brushed with hot water. After sterilization, [illegible] be assembled again before the next milking. Our own experience has convinced us that such methods, requiring the taking apart of the rubber tubes, teatcups, etc. for washing and sterilizing, consume far too much time to appeal to the average farmer. We felt, as a result of our experience as reported in Part III, that simpler methods are available which are equally successful in reducing bacterial contamination from the rubber parts, and which would be more economically feasible. The experiment reported here was planned to test out hot water versus chemical methods during the warmer months, and to compare their efficiency with that of hand milking for the production of milk of a reasonably low, though not the minimum, bacterial content.

As the hot water immersion method (A 3 in table 4) was the most generally satisfactory of the heat treatments in the previous tests it was selected as representative. In deciding upon the chemical method to use, tests were made of the comparative stability of hypochlorites and chloramines at higher temperatures, the results of which favoured the latter type of compound. Chloramines had been studied in another series of tests run concurrently with those reported in Part III, and had proved highly satisfactory for sterilizing rubber parts. It was therefore decided to use a chloramine solution with 10 per cent brine in this experiment, as representing the most satisfactory chemical method tried by us.[1]

In addition to the use of simple methods in the washing and sterilization of the rubber parts, a number of refinements were eliminated which, though of value in the production of especially low count milk, rarely repay the average producer for the extra trouble involved. Among these may be mentioned: (*a*) the practice of rinsing the rubber parts by drawing clean hot (or cold) water through them immediately before milking, (*b*) the use of a disinfectant in washing the cows' udders, (*c*) the drying of the udder with a clean cloth after washing, (*d*) the discarding of the foremilk, (*e*) the taking apart and brushing of the teatcups, tubes, etc., every day, (*f*) the cleaning of the vacuum line weekly. On the other hand, in order to facilitate comparison between machine-drawn and hand-drawn milk, and between rubber parts treated differently, pails, cans, etc., were sterilized by steam under pressure to eliminate an extremely variable source of contamination common to both methods of milking.

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[1] Chloramine and brine has been found by Robertson, Finch and Breed (9) to effect satisfactory sterilization. Hypochlorite and brine, however, is recommended in preference by them for use by dairymen on the basis of economy. In our tests the cost of the chloramine used was estimated at 11 cents per week for the two units.

PLAN OF EXPERIMENT

Two De Laval units were employed, both receiving the suction washing described on p...... The rubber parts of one unit (C) were sterilized by immersion in a crock containing a solution of a commercial chloramine product (Sterilac) to which was added sufficient salt to make 10 per cent brine. This solution was made up to contain approximately 100 parts per 1,000,000 of available chlorine, and received no attention except that once each week it was again adjusted to near the above-mentioned strength. The rubber parts of the other unit (HW) were immersed in water at 170° F. for 20 minutes, then hung up to dry until the next milking.

Except for the weekly adjustment of the chloramine-brine solution, everything in connection with the preparation and handling of the machines was left in the hands of the regular employees, no direct supervision of any kind being maintained by us. During the period of this experiment four different men looked after the washing and sterilization, two of whom had had no previous experience.

Every Thursday morning the teatcup liners were removed, trimmed to the proper length to maintain their mechanical efficiency, reversed and assembled again. Apart from this adjustment, the milk tube system was at no time taken apart, suction washing alone being relied upon to remove completely the milk residue.[1] The vacuum pipe line received no attention during the test period, and had not been cleaned during the previous six months.

For this investigation twelve cows were selected, and divided into three groups of four each. The experiment was so arranged that each group was milked an equal number of times under each method, the rotations made being shown in table 9. Separate milkers were employed for each group, each man milking under all three methods.

TABLE 9.—PLAN OF ROTATION OF MACHINES

Period (1928)	Cow groups		
	No. 1	No. 2	No. 3
July 30–Aug. 4	(HW)	(C)	(H)
Aug. 6-11	(C)	(H)	(HW)
Aug. 13-18	(H)	(HW)	(C)
Aug. 27–Sept. 1	(HW)	(C)	(H)
Sept. 3–8	(H)	(HW)	(C)
Sept. 10–15	(C)	(H)	(HW)

(HW) = Hot water treated machine.
(C) = Chemically treated machine.
(H) = Hand.

Immediately before milking, the cows' udders were washed with a wet cloth, no disinfectant being used in the water. No attempt was made to dry them by wiping. At no time was the foremilk discarded. Rinsing of the machines with clean water just before milking, as advocated by Fisher and White (4), was not practised. Small-top pails were used for the hand milking and for stripping after the machines. The milk from each group of cows, including the strippings in all cases, was poured into separate 8-gallon cans fitted with strainers.

[1] Although this test demonstrates that low count milk may be obtained without disassembling the milk tube system for regular brushing, having been planned to test this point, yet it is recommended, from other than strictly bacteriological considerations, that the system be taken apart once a week and brushed. This is necessary to remove small deposits of dirt tending to accumulate where metal and rubber are in contact and cannot otherwise be reached.

TABLE 10.—ANALYSES OF MILK DRAWN BY MACHINE AND BY HAND—SUMMARY OF WEEKLY AVERAGES

Period	Aver. max. temp. (F)	Machine-drawn milk								Hand-drawn milk		
		Hot water treated			Chemically treated							
		Official plate count	Lactose bile % positive tubes		Official plate count	Lactose bile % positive tubes		Available chlorine p.p.m.		Official plate count	Lactose bile % positive tubes	
			1·0 cc.	0·1 cc.		1·0 cc.	0·1 cc.	Crock	Tubes		1·0 cc.	0·1 cc.
July 30–Aug. 4	73·6	2,244	55·6	0·0	2,031	72·7	18·2	82	....	3,163	50·0	20·0
Aug. 6–Aug. 11	77·4	5,868	80·0	0·0	5,711	75·0	50·0	80	50	3,029	50·0	10·0
Aug. 13–Aug. 18	85·2	3,719	60·0	10·0	2,436	60·0	40·0	73	56	9,313	90·0	40·0
Aug. 27–Sept. 1	78·2	6,560	40·0	10·0	6,448	80·0	10·0	91	81	4,771	50·0	20·0
Sept. 3–Sept. 8	69·4	2,969	30·0	0·0	5,738	30·0	10·0	93	84	1,549	66·7	11·1
Sept. 10–Sept. 15	62·6	5,322	72·7	27·3	3,408	40·0	10·0	81	74	3,558	40·0	10·0
Grand average (59 counts each)	....	4,484	57·6	6·8	4,209	59·3	22·0	....	....	4,276	57·6	18·6

Samples were taken from the bulk milk in the cans after each milking from Monday evening to Saturday morning inclusive, and were placed in the regular cooling tank containing ice water. Plating was done at 10.30 a.m., at which time the evening milk was 18 hours, and the morning milk 4 hours old, approxi-

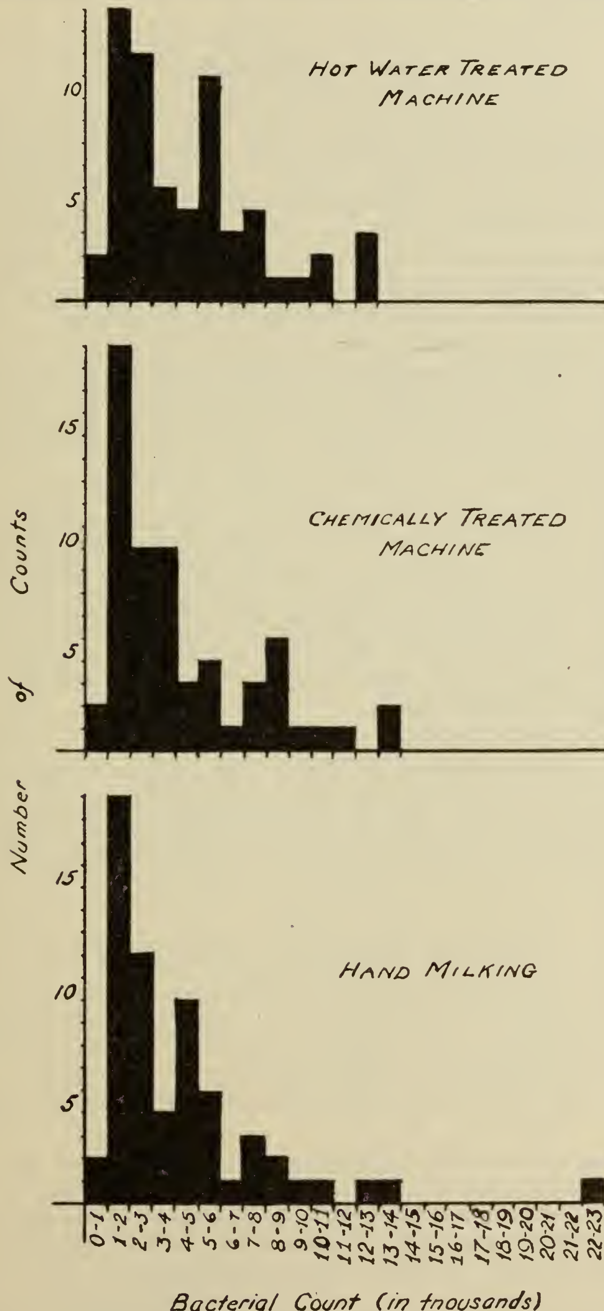

Chart I.—Chart distribution of bacterial counts of machine and hand-drawn milk.

mating the age of milk arriving at the average city milk plant. In this experiment, a change was made from the methods of analysis followed in Parts II and III, our object here being to judge the milk in strict accordance with the Standard Methods of Milk Analysis of the American Public Health Association (1). Triplicate plates were poured with nutrient agar, and incubated at 37° C. for 48 hours. In addition, lactose bile fermentation tubes were inoculated with 1·0 and 0·1 c.c. portions of milk respectively, and incubated at 37° C. for 48 hours. Ten per cent or more of gas was recorded as positive, no attempt being made to confirm such presumptive tests.

RESULTS AND DISCUSSION

From the data presented in table 10 and chart 1 it would appear that the milk drawn through the rubber parts of the machines treated as previously described compares most favourably with the product of careful hand milking even during the warm weather. The results obtained will also stand comparison with those reported by other investigators where less practicable and economical methods have been followed. It cannot be over-emphasized, however, that the rubber parts were thoroughly cleaned after each milking by means of the suction method previously described, prior to the sterilizing treatment.

While both heat and chemical methods have proved adequate for sterilizing the rubber parts (despite the contention of Hart and Stabler (5) that the heat treatment is alone successful under practical conditions), yet, from the standpoint of economy, the considerable saving in time and fuel made possible by the chemical method entitles it to preference.

That chemical solutions, properly prepared, may be depended upon during warm weather is seen from the results obtained during the week August 13 to 18. Between these dates, the average daily maximum temperature was 85·2° F., yet all ten counts from the chemically treated unit were below 4000 per c.c. During this period the available chlorine content of the chloramine and brine solution decreased to 41 parts per 1,000,000 on August 15 p.m. and was reinforced to 117 p.p.m. the next day. These low counts were obtained by a milker who was strongly prejudiced against milking machines and who had never operated one until the previous week.

While on the point of stability of chloramine solutions, we might say that at the end of the experiment reported above, the solution was not strengthened after September 6. Analyses conducted upon milk drawn by the chemically treated unit on October 3 and 4 gave counts of 1350 and 2850 per c.c. respectively. By this time the available chlorine in the solution had decreased to 9 and 8 p.p.m. respectively, and a bacterial count made of the solution itself showed but 23 per c.c., mostly spore-formers. It would seem, therefore, that a sterilizing solution composed of chloramine and brine affords a wide margin of safety in the event of the farmer neglecting to strengthen it once a week.

Contamination from lactose-fermenting organisms, as revealed by positive tests in lactose bile broth, is slightly less for the hot water treated unit. That the milk tube system in itself, when adequately washed and sterilized, contributes comparatively few lactose-fermenting organisms is suggested by the results obtained in Part III, where sterile water was drawn through the tubes, etc. (see table 4).

During the experiment, careful observations were made of the effect of the different treatments upon the life of the rubber tubing and teatcup liners. Both units were equipped with new rubber parts on July 21. The rubber tubing in all cases lost its elasticity more rapidly when submitted to the hot water treatment. By September 13 it had been found necessary to replace all four short milk tubes on the hot water treated unit, while on October 1, one of the teatcup liners was replaced. On the other hand, the rubber parts on the chemically treated unit appeared to be in good condition after three months' use.

PART V.—QUALITATIVE STUDIES OF BACTERIA IN MILKING MACHINES

(A) Bacterial Types Isolated from Machines given Various Treatments

Concurrent with the quantitative studies of bacterial contamination in relation to milking machine treatment as outlined in Part III, studies of the various bacterial types surviving the different methods of handling were carried out. For this purpose, the purple lactose agar plates prepared from sterile water "milked" through the machines as previously described, were employed. From representative plates all colonies, or all colonies on segments of plates, depending upon the number, were picked off and inoculated into tubes of sterile milk containing brom-cresol-purple as indicator. After incubation at room temperature for fourteen days the tubes were examined to note the effect of the bacteria upon the milk, and the types classified as follows: acid forming, acid curdling, alkali forming, digesting and inert types producing no visible change. In this manner, 3,537 tubes were examined and their action recorded.

In table 11 are presented data showing the percentage of the various bacterial types, as related to their effect on milk, which were found to survive different machine treatments. Only those results where the treatments employed are strictly comparable have been included, in order that the data might be given in such a manner that the effect of individual factors would be more clearly illustrated.

It will be noted that not only do various treatments differ as to the numbers of bacteria surviving, as shown previously in table 4, but in addition they vary in their influence upon the types of organisms present. Quite apart from the absolute numbers of bacteria involved, inadequate washing of the milk tube system results in an increase in the proportion of the particularly undesirable alkaline and digesting types, while the percentage of inert bacteria, producing no visible change, is considerably reduced. Furthermore the brush method of washing is less satisfactory from a qualitative standpoint than the suction method, revealing a much higher percentage of alkaline types and a lesser proportion of inert bacteria. Regarding the effect of methods of treatment after thorough washing there are fewer definite conclusions to be drawn in regard to the types of bacteria. In considering differences in the percentage of various types, however, it is important to keep in mind the differences in the absolute contamination.

TABLE 11.—BACTERIAL TYPES IN RELATION TO MACHINE TREATMENT

Studying effect of	Method used	Average bacterial count per c.c. sterile water	Percentage bacterial types as related to their effect on milk				
			Acid	Acid curdling	Alkaline	Digesting	No change
Preliminary cleaning.........	Adequate washing .... (A4, A6w, A7a, A 10)	12,000	10·8	10·7	14·6	15·7	48·2
	Inadequate washing........... (B1, B2, B3, B4)	689,267	2·8	13·8	45·1	32·0	6·3
Suction versus brush washing	Suction washing (A3, A6w)...	270	4·2	17·5	6·7	13·7	57·9
	Brush washing (A3br, A6br)..	3,730	1·9	15·3	51·7	7·5	23·6
Treatment following careful washing.	Hot water sterilization....... (A1, A2, A3, A4.)	426	2·7	2·6	14·3	12·2	68·2
	Hypochlorite sterilization.... (A8, A9, A10)	746	9·2	5·6	18·7	30·9	35·6
	Cold water immersion(A7,A7a)	59,292	2·3	0·6	27·4	21·4	48·3
	Hung up to dry (A6w, A6s)...	5,520	7·4	32·2	4·4	11·3	44·7

(B) Types of Bacteria in Low Count Milk drawn by Machine and by Hand

A study of bacterial types was also conducted in conjunction with the tests outlined in Part IV, in which milk obtained by machines treated by heat and by chemicals respectively was compared with milk drawn by hand. Since the average counts obtained under all three methods were under 5,000 per c.c. even when the evening milk was 18 hours old, this represents a high grade of milk. Daily inoculations were made from plates representing all methods into tubes of sterile milk as described in section A, above. In all, 2,580 tubes were prepared and classifications made as above, depending upon the effect of the inoculated bacteria upon the milk.

TABLE 12.—BACTERIAL TYPES IN LOW COUNT MILK DRAWN BY MACHINE AND BY HAND

Treatment	Average bacterial count of milk	Percentage bacterial types, as related to their effect on milk				
		Acid	Acid curding	Alkaline	Digesting	No change
Machine (hot water treatment).........	4,484	18·9	56·4	6·5	3·4	14·8
Machine (chemical treatment)..........	4,20[illegible]	20·5	58·4	3·6	3·6	13·9
Hand-drawn milk.....................	4,276	19·9	63·3	4·5	1·4	10·9

The results, summarized in table 12, do not reveal any outstanding differences in the types of organisms under the conditions of the experiment. While the studies in the preceding section dealt with bacteria coming solely from the milking machine, in the present case the bacteria found represent those isolated from milk itself, after the usual handling and straining into 8-gallon cans. Consequently the results include contamination from a number of sources which were excluded in the preceding experiment. This, together with the fact that different media and plating methods were employed, precludes, naturally, direct comparison with table 11. From the findings, however, it appears that low count milk drawn by machine shows no significant difference in types of organisms present from milk of similar bacterial content drawn by hand.

SUMMARY AND CONCLUSIONS

With the modern milking machine the type or design is of minor importance from a bacteriological standpoint. When properly cared for, all four makes of machines tested out proved to be capable of producing consistently milk of low bacterial content.

Factors concerned with the stable handling of the machine, such as the washing and drying of the cow's udder, the use of disinfectants to wash the udder, discarding the foremilk and the manner of handling the teatcups, were studied. While these were not without influence on the bacterial count, they were considered as minor factors in the contamination of machine-drawn milk, assuming importance only when the machine itself is in strictly sanitary condition.

The sanitary condition of the rubber parts is the chief factor affecting the bacterial content of machine-drawn milk. Satisfactory control of contamination depends upon adequate cleaning and sterilizing of the machine. The efficiency of a sterilizing treatment is dependent upon the thoroughness of the preliminary washing. On the other hand, it is unsafe to rely upon a thorough washing alone; to insure a constant supply of low count milk, especially during hot weather, some method of positive sterilization must be employed.

Washing with cold water, followed by hot cleanser solution and clear hot water, is necessary for optimum results. Where cold water alone is relied upon, not only are the bacterial counts higher, but the life of the rubber parts is materially shortened. Suction washing at the barn immediately after milking resulted in the more complete removal of the milk residue and bacteria than the more laborious and time-consuming brush washing at the dairy.

Sterilization of milking machine parts may be satisfactorily effected by treatment with steam, hot water or chemical solutions. While heat and chemical methods are both effective from a bacteriological standpoint, the former were found to have a more deleterious effect upon the rubber parts, necessitating more frequent replacement. This is particularly true of the steam method and hot water methods in which the tubes are allowed to remain immersed between milkings. Consequently the heat treatment deemed the most satisfactory from all considerations consisted in immersion in water at 170° F. for 20 minutes only, after which the parts were hung up to drain and dry.

Immersion of the rubber parts in solutions of hypochlorite gave good results. Daily reinforcement during the warmer months and the employment of a strong brine are recommended as providing a wider margin of safety against the decline in strength of the solution. Failure with hypochlorites is due chiefly to the use of too weak solutions, generally resulting from a neglect to follow directions. Sterilization by the use of chemicals, in addition to being as effective as that by heat, results not only in a saving of time and fuel, but is also less destructive of the rubber parts.

Treatments depending upon immersion in cold water proved unsatisfactory. While the practice of hanging the parts up to dry without further treatment after washing gave good results during cold weather, it failed to prevent marked contamination in the warmer months. The insufficiency of these methods is but to be expected as they depend on low temperature to inhibit bacterial growth in contrast to the positive germ destruction effected by the chemical and hot water methods.

In a special series of tests, conducted under warm weather conditions, in which the milking machines were handled entirely by the regular employees, it was demonstrated that contamination could be effectively controlled by simple, practicable methods. Milk drawn by machines sterilized by representative hot water and chemical methods respectively was found to be equal in sanitary quality to that produced by careful hand milking. The chloramine-brine treatment used here, because of its stability, is regarded as the best chemical method used by us.

Studies on the influence of various treatments upon the types of bacteria surviving indicate that in general those treatments which were less successful from a quantitative standpoint were also less satisfactory from a qualitative point of view, permitting the survival of greater proportions of the least desirable types as determined by their effect on milk. No significant differences in bacterial flora were found when low count milk drawn by machines treated with hot water and chemicals respectively was compared with hand-drawn milk of similar grade.

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APPENDIX A

DIRECTIONS FOR WASHING AND STERILIZING MILKING MACHINES

WASHING

1. Immediately after milking the last cow, draw at least a gallon of clean cold water through the units (fig. 2) using a fresh quantity for each unit. Douse the teatcups up and down in the water during the rinsing, so that air and water alternately surge through the tubes. This increases the contraction and expansion of the rubber parts and assists in removing the milk residue and accompanying bacteria from the inner surfaces. Pass a brush around the inner surfaces of the pail and pailhead (fig. 3), and also brush off any dirt, milk, bedding, etc., adhering to the outside of the pail or milk tube system. Empty out the milky rinse water into the stripping pail and rinse it.

2. Follow the cold water with a rinse of scalding hot water, using a gallon or more for each unit.[1] The removal of fat and other residue will be more easily accomplished if a half cupful of dairy cleanser be added to each pailful of hot water. Do not douse the teatcups up and down, as this tends to cool off the water. Brush the inner surfaces of the pail and pailhead with this hot cleanser solution, and treat the stripping pails, etc., in a similar manner.

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[1] Milking machines cannot be successfully operated without an adequate supply of hot water. In order that sufficient quantities of hot water may be available for washing the machines, some form of hot water heater should be installed at the most convenient point. At least one manufacturer is putting out an exhaust water heater for those farms where a gasoline engine is used to operate the milking machine. Where an electric motor is employed, some form of electric, oil or coal heater is necessary. In some cases it is more convenient to wash the machines along with the other utensils at the milk house. To do this it is only necessary to extend the vacuum pipe line from the stable to the milk house, and to have the hot water supply located there.

FIG. 2.—Cleaning should commence without delay immediately the last cow is milked, cold water being first drawn through by suction to remove the milk residue. After brushing as in figure 3, an additional rinsing with hot water, preferably with dairy cleanser, is made.

FIG. 3.—Brushing after the cold water rinse helps to remove milk residue from pail and pail-head. Stripping pails, etc., may be similarly treated.

FIG. 4.—Milker buckets, pails, etc., should be sterilized after washing. This may be effected by the use of scalding hot water, as above, or by employing a hypochlorite solution as rinse.

FIG. 5.—Metal utensils, after sterilization, should be inverted to drain and diry, preferably outdoors in the sun, to check growth of surviving bacteria.

FIG. 6.—Hot water sterilization. The milk-tube system is immersed in hot water at 170°F. for 20 minutes, then removed and hung up to drain and dry.

FIG. 7.—Milk tubes, after hot water sterilization, should be hung up to drain and dry in a place free from dust. A rack such as illustrated can be easily constructed.

FIG. 8.—Sterilization by immersion in chlorine solution. Tubes should be lowered gradually into the crock with the long milk tubes held upright as in above illustration. This insures expulsion of air inside tubes allowing disinfecting solution to come in contact with whole of inner surface.

FIG. 9.—Incorrect method of immersion. When tubes are placed in solution folded up as above, the solution cannot come in contact with the whole of inner surface owing to pockets of air remaining in the tubes.

3. During the warmer months, or where an especially low count milk is desired, a third rinse of scalding hot water or hypochlorite should be given before the sterilizing treatment. Whether or not the rubber parts receive this final rinse, it should be given to the metal parts (fig. 4) which are then placed where they will readily drain and dry (fig. 5) thus checking the growth of bacteria upon their inner surfaces. A screened outdoor draining rack placed in the sun is an excellent arrangement.

TREATMENT FOLLOWING WASHING

The hot water and chemical methods of sterilization described below have given good satisfaction with the machines used at the Central Experimental Farm. It is however conceivable that with other makes of machine, one or the other of these methods may prove to be decidedly superior. It is therefore desirable that the owner of a milking machine consult with the manufacturer if in doubt as to the suitability of either method. This applies particularly to the hot water method, since the rubber in some machines is less heat resistant than in others.

1. Hot Water Method.—Following the washing described above, immerse the assembled milk tube system in water at 170° F. in a covered vessel, taking care to ensure that all air is expelled from the tubes (fig. 6). Maintain the temperature for at least 20 minutes, then remove the parts and hang up in a clean dark[1] place to drain and dry (fig. 7).

2. Chemical Method.—Immerse the washed milk tube system in the sterilizing solution, which should be kept in a covered earthenware crock of suitable size. (Do not use metal or wooden containers, since the former will be corroded while the latter destroys the strength of the solution.) By holding the long milk tube upright while the teatcups and claw are lowered into the solution (figs. 8 and 9) the air is forced out as the solution rises in the tubes. Keep the crock of solution in as cool a place as possible, and protected by a tightly fitting cover against the entry of dust or dirt.

STERILIZING SOLUTION

Various sterilizing solutions using chlorine compounds may be prepared. Commercial hypochlorite solutions (such as B-K, etc.) powders containing hypochlorite (Diversol), chloramine-T powders (Santamine, Sterilac, etc.) or home-made preparations of sodium or calcium hypochlorite have all proved useful, although an mentioned in Part IV, the chloramine plus 10 per cent brine is considered by us to be the most satisfactory because of its greater margin of safety during warm weather. The commercial products are naturally more expensive, but against this must be weighed their convenience and standardized available chlorine content. The home-made preparations require some time and care in making up, and while cheaper, have the disadvantage of variable strength (see page 18). This unavoidably follows the marked differences in strength between different brands of chloride of lime and even between various packages of the same brand, as will be noted in the table in Appendix B. In the directions which follow, some allowance has been made for the variations in strength of the chloride of lime, yet there is always a possibility of obtaining a package whose contents of which are so far below the average strength as to be practically worthless.

If a commercial product is used, the solution should be made up to at least the strength recommended by the manufacturers. In the case of hypochlorites,

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[1] Exposure of rubber parts to sunlight for long periods leads to their cracking and deterioration.

it is wise during the warmer months to use either double strength solution or else reinforce it every day. With chloramines, there is less need for such precautions, as they are much more stable. In making up solutions from products made in the U.S.A. it is well to remember that the directions refer to the American gallon, which is only five-sixths the volume of the Imperial gallon.

The addition of common salt to either hypochlorite or chloramine solutions has been recommended as an additional safeguard in case of a rapid decline in the available chlorine content. For hypochlorites clean salt should be added until some remains undissolved after stirring. Chloramines, however, are soluble with difficulty in anything stronger than a 10 per cent brine.

PREPARING A HOME-MADE HYPOCHLORITE SOLUTION

Obtain a 12-ounce package of the very best chloride of lime. It should be fresh, non-caked and preferably marked with the available chlorine content. Mix the contents with just enough water to form a moist paste, then add the remainder of 1 gallon of water, breaking up the lumps and straining through screen wire, into a glass or earthenware container. Dissolve 1 pound of washing soda in a gallon of water, then add this to the chloride of lime solution, stirring thoroughly. Allow the mixture to stand overnight, then draw off the clear greenish liquid on top. This is known as the *Stock Solution,* and should be stored in a tightly stoppered brown glass or earthenware jar in a cool place. This stock solution may also be used to make up sterilizing rinses for metal utensils, and for washing the cows' udders before milking.

To sterilize the milk tube system, obtain a large earthenware crock[1] of sufficient capacity to hold the tubes from all the units without crowding. Construct a tightly fitting lid to keep out dust and dirt. For a 10-gallon crock, place 30 pounds of clean salt in the bottom, and fill the crock with clean cold water to within six inches of the top. To the brine thus formed add 1 quart of the stock solution of hypochlorite at the start, and an additional four-ounce charge every day in summer, and every other day in winter. Add salt and clean water as necessary to maintain the original level of the solution. As soon as the solution begins to look dirty, discard it and make up a fresh one. No solution should be kept in use for longer than six weeks.

ADDITIONAL POINTS REQUIRING ATTENTION

Moisture traps or check valves should be cleaned out regularly, preferably after each milking. Stanchion hose should be brushed and rinsed at least once a week. The vacuum line should be cared for in the manner recommended by the manufacturer.

At least once a week it is well to disassemble the milk tube system and to brush the rubber parts where they have been in contact with the metal. This is done in order to remove accumulations of insoluble dirt which may lodge between the tubes and their metal connections. At the same time the outside of the liners and the inside of the metal teat cup shells should be brushed and rinsed clean, as cow hairs, dust, etc., frequently collect there. Should the teat cups be kicked off or fall into the bedding during milking the unit should be taken apart and all parts given a thorough brushing and rinsing to remove dirt, straw, etc., which may have been drawn up into the milk tube system.

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[1] DeLaval users would be well advised to employ one of the new solution racks instead, since these possess several important advantages over the crock immersion method.

APPENDIX B

ANALYSES OF CHLORIDE OF LIME

To obtain information concerning the quality of chloride of lime as ordinarily retailed, a survey was made of the supply available to farmers through the analysis of samples obtained in small towns and villages within a radius of 50 miles of Ottawa. In all, 50 samples were obtained over the counter of retail stores and determinations made of their content of available chlorine using the sodium thiosulphate titration method.

It will be observed from the table that considerable variations may be encountered not only between different brands but also between different packages of the same brand, the contents of which were usually of identical appearance. It will furthermore be seen that there is no apparent correlation between the length of time the package has been on the retail store shelf and the available chlorine content. It is probable that the figures do not represent the relative ages of the samples, as the period of storage in warehouses, etc., previous to delivery to the retailer is unknown.

AVAILABLE CHLORINE CONTENT OF CHLORINATED LIME IN SMALL PACKAGES OBTAINED IN THE OTTAWA DISTRICT, JULY 25-28, 1928

Acme		Bee		Bulldog		H.O.		Moody's Royal		Star	
Time on shelf (weeks)	Per cent available chlorine	Time on shelf (weeks)	Per cent available chlorine	Time on shelf (weeks)	Per cent available chlorine	Time on shelf (weeks)	Per cent available chlorine	Time on shelf (weeks)	Per cent available chlorine	Time on shelf (weeks)	Per cent available chlorine
2	24·10	4	21·06	2	15·54	15	17·19	8	11·34	8	12·28
–	21·77	8	18·79	1	15·78[1]			–	12·41	4	18·05
11	18·59							13	2·44	34	17·51
–	22·35							4	11·53	3	8·05
13	15·71							3	12·10	–	14·72
2	21·38							2	11·71	16	19·17
26	19·11							2	12·63	8	10·95[2]
1	18·43							9	12·61	3	16·69
1	21·96							2	12·02	3	17·21
4	22·06							6	11·34	4	0·54
8	18·60							4	10·14		
13	26·49							3	12·48		
4	23·45							5	7·94		
2	22·80										
3	16·55										
13	24·15										
5	23·11										
9	22·73										
3	22·57										
6	20·51										
–	20·80										
6	21·55										
Aver. 7	21·31	6	19·53	1·5	15·66	15	17·19	5	10·82	9	13·52
Max. 26	26·49	8	21·06	2	15·78			13	12·63	34	18·05
Min. 1	15·71	4	18·79	1	15·54			2	2·44	3	0·54

Average for all samples— 6·8 weeks on shelf.
18·50 per cent available chlorine.

[1]Damp, caked. [2]Caked.

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