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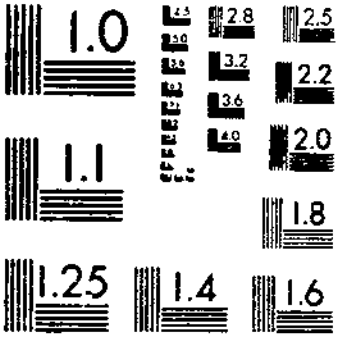

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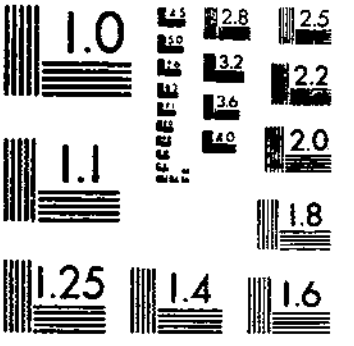

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NATIONAL BUREAU OF STANDARDS-1963-A

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The Relationship of Machine Milking to the Incidence and Severity of Mastitis[1]

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INTRODUCTION

An epidemic of mastitis developed in the herd maintained by the Bureau of Dairy Industry for nutritional investigations at Beltsville, Md., within 2 months after machine milking was introduced in October 1933. By December of that year, several of the Holsteins that had been on excellent rations (liberal quantities of a good grain mixture and alfalfa hay of good quality) for several years, and that were giving large amounts of milk, showed marked symptoms of mastitis. Numerous clots appeared in the milk and their yields diminished rapidly.

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[2] Died November 5, 1940.

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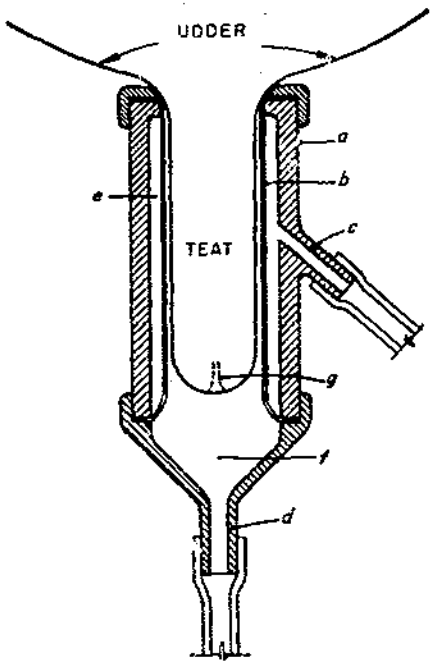


FIGURE 1.—Longitudinal section of teat cup, with teat inserted, showing *a*, metal cup; *b*, rubber cuff; *c*, side tube, through which pressure in space *e* is made to alternate between atmospheric pressure and vacuum; *d*, tube through which milk is drawn by means of vacuum; *f*, space in which vacuum is constantly maintained; *g*, teat canal.

Machine milking differs radically from hand milking in that in hand milking no vacuum is applied at any time to the end of the teat canal. The action of the milking machine simulates as nearly as possible the natural withdrawing of milk by the calf during nursing, provided that excess vacuum is not employed and that the machine is not left working on the udder beyond the time when all the milk has been withdrawn.

METHODS OF USING THE MACHINE[5]

ROUTINE-MACHINE MILKING

The method used in milking by machine from October 1933 until August 1936 was as follows: The vacuum maintained in the reservoir above the milk pail was slightly more than 16 inches of mercury, or about 1 inch more than claimed by the manufacturer. There were 48 cycles of change from atmospheric pressure to a vacuum of 16 inches and back again per minute in space *e* (fig. 1). The machine was left working on the cows' udders for an indeterminate period at each milking. Numerous observations were made of the time that

[5] In all methods of using the milking machine described in this bulletin, all the precautions recommended by the manufacturer for keeping the equipment clean and free of bacteria were followed carefully.

the machine was left working on the udder, and it was found that the time varied from 5 to 18 minutes, usually averaging not more than 14 minutes, depending entirely on the particular worker who was handling the machine.

The amount of milk being taken out by the machine was observed now and then through the glass window in the milk tube, but no special care was taken to bring the milking process to a close as soon as most of the milk had been withdrawn. When it was observed that the quantity of milk being drawn past the window had become small, the udder was massaged by hand for a minute or more, while the machine was still working on it, and the milking process was then brought to a close by taking off the teat cups without any hand stripping. In the following pages, this method will be called "routine-machine milking." This method of milking was discontinued in February 1936 for all cows that freshened after that time.

SEVERE-MACHINE MILKING

Beginning in May 1936, certain cows were milked by machine according to a method that differed from routine-machine milking only in that the machine was left working on the udder regularly for 20 minutes at each milking. After 20 minutes the udder was massaged by hand for another minute or two with the machine still working on it, as had been done on routine-machine milking, and the process was brought to a close by removing the teat cups without hand stripping. In the following discussion this method will be called "severe-machine milking."

MILD-MACHINE MILKING

Experiments were conducted to determine how long it took to withdraw most of the milk from the udder when the vacuum was maintained at 16 inches and at various lower levels. The results showed that the udder was emptied of milk nearly as quickly with a 12-inch vacuum as with a 16-inch vacuum, and that the time required for getting the udder nearly emptied of milk was usually about 5 minutes, as Dahlberg (*5*) had reported.

In view of the results of these preliminary experiments, a number of cows were put on a modified method of machine milking after August 11, 1936. The method differed from routine-machine and severe-machine milking as follows: The amount of vacuum was reduced to 12 inches. The removal of milk from the udder was observed carefully through the glass window in the milking tube. When the quantity of milk being drawn past the window was small, the teat cups were removed and the cow was stripped by hand. The time of machine milking by this method was usually about 5 minutes. In the following discussion this method will be called "mild-machine milking."

SELECTION OF ANIMALS AND ALTERNATIONS OF METHODS OF MILKING

In studying the results of this investigation it must be remembered that the herd was already severely affected with mastitis, and that this occurred on routine-machine milking. While no data from con-

trolled experiments were then available, the comparatively high incidence of mastitis occurring in the herd on routine-machine milking, as compared with the previous history on hand milking, indicated that hand milking was less likely to produce pathological conditions in the udder than machine milking. Therefore, in order to have available some normal mastitis-free animals for experimental work, most of the cows that freshened during the first 6 months of the investigation were put on hand milking. These included some cows that had had severe mastitis in their previous lactation periods, and also some first-calf heifers.

In general, when an animal freshened, she was milked by hand for about 10 days after the colostral period; during this time bacteriological and chemical analyses of the milk were made to determine whether or not the characteristics were those of normal milk, and if the characteristics of the milk were found to be normal the cow was selected for further experiments on different types of milking.

It was desirable to use different animals as experimental controls on hand milking, but because enough animals were not available the same animal was changed from hand milking to machine milking, serving as a control for the effects of machine milking when put back on hand milking. This procedure of alternation of methods of milking was followed with some animals in the same lactation and in others it was continued in the succeeding lactation.

There was some reason to believe, from the previous history of the herd, that rations deficient in vitamin A and other indispensable nutrients predispose an animal to mastitic infections and other diseases. Therefore, only animals that were being fed good rations were selected for the experiments with machine milking.

A brief history of the 25 cows in this investigation is included in the data in table 11. The breed is indicated by number. Cows N–100 to N–199 were grade Holsteins; N–200 to N–299, registered Holsteins; N–300 to N–399, grade Jerseys; and N–400 to N–499, registered Jerseys.

Testing the Milk For Evidence of Mastitis

Bacteriological and chemical tests on samples of foremilk from the individual quarters of each cow were the principal means used for detecting evidences of mastitis. In some cases tests were conducted each week throughout the lactation period, but in most cases tests were conducted once every 2 weeks. The usual procedure was to lengthen the interval between tests when there was no evidence of change in the milk and, conversely, to make tests more frequently when the milk showed evidence of rapid changes in mastitic characteristics. Among a number of cows on which detailed studies were made during one lactation, examination of the milk at monthly intervals in subsequent lactations was made to determine the extent of permanent injury incurred from mastitis in the previous lactation.

Pint samples of milk were collected from each quarter at the beginning of the morning milking. The udders and teats were washed first with water and then with a disinfectant, and were then wiped practically dry. The first few streams of milk from each quarter were discarded, after which a sterilized pint bottle was filled and capped

immediately. The samples were packed in cracked ice immediately, except in extremely cold weather, and were sent to the laboratory. The tests were begun within 5 hours after the samples were drawn. Particular precautions were taken to prevent contamination throughout the process of obtaining the samples and during testing.

Each sample was tested by the following methods: Microscopic determination of the number of cells (leucocytes and body cells); determination of the number of *Streptococcus agalactiae* or other causative bacteria; and determination of the percentage of chlorides (*9*). These three tests were the principal means used for detecting evidence of mastitis.

Additional correlative tests were used in examining a majority of the samples, but since in most cases the results obtained by them contribute no further information for the purpose of this report, they are referred to only where the data from the above-mentioned tests were not sufficiently complete. Such correlative tests, however, served as a useful check on the diagnostic results. The correlative tests used included the strip-cup test for milk clots, a modified Hill curd test using rennet (*10*) for the determination of curd tension, the rennet coagulation time (*10*), and the pH value. The acidity, the percentage of casein (by both the Kjeldahl and the formaldehyde titration methods), and the percentage of total nitrogen were also determined on a number of the samples.

The strip-cup test was used to determine evidence of mastitis in all the cows in the herd for a number of years preceding this study, and its use was continued as a routine test during the epidemic. From November 1933 to December 1935 strip-cup tests were made on the milk of all the cows, usually about once a week. From December 1935 to December 1938, the period included in this study, strip-cup tests were made regularly twice a week on all cows, and the milk of any cow that contained clots was tested every day. However, because the severity of mastitis is difficult to evaluate quantitatively by this test and because it fails to show accurately indications of the disease when it is of mild character, the strip-cup test was not relied on as a criterion of mastitis except as a correlative test and in cases of previous mastitis where other data were not available.

LEUCOCYTE COUNTS

The number of cells was determined by a direct microscopic count by the Breed method. Cell counts included leucocytes and body cells, but in the majority of samples more than 90 percent of the cells were leucocytes.

BACTERIAL COUNTS

The number of *Streptococcus agalactiae* and of other bacteria was determined by the following procedure: The samples were plated in appropriate dilution on a modified Edwards' aesculin agar medium, having the following composition:

	Quantity
Distilled water	500 milliliters
Peptone (Parke, Davis)	10 grams
Beef infusion base	500 milliliters
Sodium chloride	5 grams
Agar (Bacto-Difco, granulated)	15 grams
Aesculin	1 gram

For the first few months of the investigation, Liebig's beef extract was used instead of beef infusion base. Substitution of the latter improved the medium by enlarging the size of the colonies and making the studies of hemolysis easier and more dependable.

To this mixture were added crystal violet (1 to 1,000,000, calculated on the basis of 100 percent dry dye content) and 5 percent of sterile defibrinated bovine blood. The pH was adjusted to 7.4 before autoclaving; after autoclaving, it was 7.1 to 7.2. The plates were incubated for 48 hours at 37.5° C.

The medium described above is favorable for the growth of *Streptococcus agalactiae* and other mastitis-producing streptococci but less favorable for the growth of many other bacteria. In all cases in which a large number of leucocytes and a high percentage of chlorides were found in the milk, accompanied by few or no streptococci, other samples from the same cows were plated on media without crystal violet, sometimes under both aerobic and anaerobic conditions. In the great majority of these cases, no organisms that could be held responsible for mastitis were found, and in none of these cases were organisms of any kind present in large numbers. The lowest dilution used was 1 : 100, and therefore the method of plating did not show bacteria in numbers less than 100 per milliliter.

The identification of *Streptococcus agalactiae* was based on the following characteristics: Weakly beta hemolytic, but never complete lysis of all erythrocytes; failure to grow at 45° C. and at 10° C.; failure to reduce Avery's methylene blue, 1:20,000; nonfibrinolytic in ox plasma; hydrolysis of sodium hippurate; coagulation of litmus milk with partial reduction at the extreme bottom of the tube within 48 hours; fermentation of maltose, lactose, sucrose, and trehalose; and failure to ferment aesculin, starch, inulin, mannitol, raffinose, or sorbitol. In addition, some of the cultures were tested with bacteriophage [6] and were precipitin-tested. They were found to be Lancefield group B organisms identical with *S. agalactiae*. *S. uberis* was identified by its ability to ferment aesculin, inulin, mannitol, sorbitol, and sodium hippurate, but not raffinose; *S. viridans*, by its ability to ferment raffinose but not sodium hippurate; and *S. fecalis*, primarily by its ability to grow at 45° C. and also by its inability to ferment sodium hippurate readily.

PERCENTAGE OF CHLORIDES

Chlorides were determined in undigested samples by the Volhard titration method, modified as a special method for milk. It has been shown by results of exhaustive, comparative analyses (*9*) that the method used is quantitatively accurate. The percentage values obtained by it are about 0.02 to 0.04 lower than the erroneously high values obtained by direct titration with silver nitrate and chromate indicator.

[6] Dr. Alice C. Evans, National Institute of Health, Bethesda, Md., made the tests.

Criteria of Mastitis and of Normality

In order to make a fair interpretation of the effects of the different methods of milking on udder injury, as determined by the characteristics of the foremilk of individual quarters (table 11), and in order to designate the previous mastitic conditions of the various cows for which data are presented, it was considered essential to propose criteria of mastitis. The criteria used were based on the number of leucocytes, the number of infecting bacteria, and the percentage of chlorides in the foremilk samples of the individual quarters. In addition, in order to evaluate previous mastitic conditions in a few cows in which other information was not available, it was desirable to propose also a tentative criterion based on the presence of clots observed in the strip-cup test.

It is recognized that the designation of a normal and of a mastitic condition by numerical data, such as number of streptococci, number of leucocytes, and percentage of chlorides, is to some extent an arbitrary procedure. It is not uncommon for the data for one of these constituents to be abnormally high, either temporarily or in some instances for an extended period, without any other apparent evidence of active infection or of inflammation of the mammary gland. Also, the number of leucocytes and the percentage of chlorides increase normally during the latter part of the lactation, and are higher in the milk of older cows than in the milk of younger cows, even in normal healthy animals. In general, the percentage of chlorides in the milk of Holstein cows is normally higher than in the milk of Jersey cows. Furthermore, individual cows differ in their defense mechanism against infection. In spite of the disadvantages in the use of more or less rigid criteria, some simple and quantitative means for designating the severity of the disease is necessary in order to present a summary of results that would be obvious were it possible to present the data in complete detail.

In formulating criteria to designate the severity of mastitis, it was considered that the presence of increasing numbers of infecting bacteria and of leucocytes, and high chloride values, are direct indications of increasing severity of the inflammatory condition, whether the data represent a number of progressive stages in one quarter or the high points of severity among a number of quarters. An increase in the pH value of the milk is a direct symptom of mastitis and may often show close correlation with the severity of mastitis, but in this study the pH values were used chiefly as supporting evidence.

The following criteria were used to present an evaluation of mastitic conditions as determined by tests of samples of foremilk from the individual quarters:

Normal: Milk containing less than 100 (lower limit of quantitative count used) infecting bacteria regularly and never more than 1,000 per milliliter, less than 500,000 leucocytes per milliliter, and less than 0.09 percent of chlorides.

Mastitis (+): Milk containing more than 100 infecting bacteria regularly but not more than 10,000 per milliliter, more than 500,000 leucocytes but rarely more than 1,500,000 per milliliter, and more than 0.09 but rarely more than 0.12 percent of chlorides.

Mastitis (++): Milk containing more than 1,000 infecting bacteria regularly but not more than 100,000 per milliliter, more than 1,500,000 leucocytes but rarely more than 3,000,000 per milliliter, and more than 0.11 but not more than 0.14 percent of chlorides.

Mastitis (+++): Milk containing more than 10,000 infecting bacteria per milliliter regularly, more than 5,000,000 leucocytes per milliliter regularly, and more than 0.13 percent of chlorides.

Mastitis (++++): Individual quarters that had a mastitic condition of ++ or +++ and that as a result ceased functioning during the lactation or at the beginning of the next lactation.

The strip-cup test, referred to previously as a correlative test, was relied on particularly as one of the criteria in designating the previous mastitic condition of some cows before this investigation was begun. In recording the strip-cup results, the size and number of clots are designated by the figures 1, 2, 3, and 4. The figure 1 denotes the appearance of a few small clots; 4, numerous large and small clots; and 2 and 3, intermediate conditions. In cases in which strip-cup data were used as the criterion for designating the severity of previous mastitis, the figure 2 denotes mastitis +; 3, mastitis ++; and 4, mastitis +++. The figure 1 was not considered significant except that it called for more frequent testing.

UDDER TROUBLE ASSOCIATED WITH THE EARLY USE OF THE MILKING MACHINE IN THIS HERD

Routine machine milking, as described previously, was the usual method of milking in this herd from October 1933 to August 1936. During this period of 35 months, approximately 50 cows were milked by this method. The data obtained on mastitis consisted mainly of the results of the strip-cup test. This test was made regularly, at least weekly on all cows that were producing milk, and the results were recorded. Although the test is inadequate as an accurate criterion of mastitis, it gives a fairly reliable indication, particularly with quarters that are severely abnormal. When interpreted according to standard criteria, as described previously, the test provides a useful, comparative evaluation of the severity of mastitis. Strip-cup test data presented in table 1 show the mastitic conditions of the individual cows of the herd from the time machine milking was begun in October 1933 until the routine method of machine milking was discontinued in August 1936. The severity designated was the maximum observed in the milk of one or more quarters of each cow during each calendar year, without regard to changes in lactation.

During this period there was a general deterioration of the herd, beginning within 2 months after the introduction of machine milking, although 14 of the 50 cows were affected only slightly. Additional data, not possible to present in this table, revealed that 22 of the 50 cows, or 44 percent, developed severe mastitis in two or more quarters, which in most cases resulted either in loss of the affected quarters or complete loss of the animal for future milk production.

TABLE 1.—*Incidence and severity of mastitis among cows on routine-machine milking, as determined by the strip-cup test, October 1933 through 1936*

Cow No.	Date of birth	Strip-cup test data, indicative of mastitis [1]			
		1933 (3 mo.)	1934	1935	1936
N–106	Jan. 23, 1930	+	+++	+++	+++
N–107	July 29, 1930	+	+	—	—
N–108	1930	—	+	+++	++
N–110		—	+	+++	—
N–111	Aug. 2, 1932	—	—	0	++
N–113		—	—	+	—
N–114	Feb. 9, 1933	—	—	+++	+++
N–212	Feb. 5, 1927	+++	+++	—	—
N–213	Mar. 12, 1927	0	+++	++++	—
N–215	Feb. 6, 1928	+	++++	—	—
N–216	Jan. 26, 1929	+	+	+++	+
N–218	Aug. 7, 1929	0	+++	—	—
N–219	Jan. 9, 1931	—	+	+++	—
N–220	Nov. 25, 1931	—	+	+++	—
N–222	Jan. 17, 1931	—	+	++	++
N–225	Feb. 23, 1931	—	+	+++	—
N–226	Mar. 17, 1931	+	+++	++	+
N–227	Mar. 28, 1931	—	—	+++	+++
N–228	May 10, 1931	—	+++	+++	—
N–229	May 10, 1931	—	+	+++	—
N–230	May 20, 1931	—	++	++	—
N–231	May 27, 1931	—	—	+++	—
N–232		—	—	++	—
N–233		—	+	+++	—
N–234	Dec. 15, 1932	—	—	++++	—
N–303	June 9, 1926	0	++++	—	—
N–304	Dec. 10, 1928	+	+	+++	—
N–305	Apr. 21, 1930	+	+	+	—
N–308	Dec. 5, 1931	—	+	0	—
N–309	Dec. 16, 1931	—	+	+	—
N–310	Apr. 5, 1932	—	+	+++	+++
N–402	May 2, 1926	+++	++++	++++	++++
N–404	Jan. 7, 1928	0	+++	+++	++++
N–405	Oct. 1, 1928	+	+	+	—
N–406	Oct. 1, 1928	+	+	—	—
N–407	Nov. 17, 1928	+	+	+++	—
N–408	Feb. 16, 1930	0	+	0	—
N–409	Mar. 1, 1930	+	+++	++++	—
N–411	Aug. 7, 1930	+	+++	+++	—
N–412	July 7, 1931	++++	+++	+++	—
N–414	Oct. 1, 1931	—	+	+++	—
N–415	Dec. 16, 1930	+	+++	++++	—
N–416	Jan. 1, 1931	+	+	+++	—
N–418	Mar. 11, 1931	+	++	+++	—
N–419	Apr. 2, 1931	—	+	+++	—
N–420	Aug. 3, 1931	—	+++	+++	—
N–421	Aug. 3, 1931	—	—	+++	—
N–422	Aug. 9, 1931	—	+	+	—
N–423	Aug. 19, 1931	—	0	++	—
N–424	Dec. 6, 1932	—	—	—	++++

[1] Increasing number of plus signs indicates increasing severity; 0, free of mastitis; ++++, very severe mastitis with loss of function in one or more quarters. A dash indicates that cow was not giving milk or was not milked by routine-machine method.

CHARACTERISTICS OF THE MILK OF THE COWS ON ROUTINE-MACHINE MILKING

Early in 1935 in conjunction with studies of cows in other herds of this Bureau at Beltsville, Md., that were affected with mastitis, detailed studies were begun of the milk of 3 first-calf heifers (N–111, N–114, and N–227) in this herd shortly after they freshened, to determine the sequence of changes coincident with the onset of mastitis. Samples of foremilk from their individual quarters were obtained at weekly intervals during most of the first lactation, and determinations were made of the number of leucocytes and of mastitis-causative organisms, percentage of chlorides, pH values, and rennet-coagulation properties.

These 3 heifers were among 11 cows continued on routine-machine milking during a part of 1936, and the detailed data obtained from the study of them formed an additional background for the comparative studies on different methods of milking initiated in February 1936. During the experiments with these 3 animals on routine-machine milking, 2 developed severe mastitis—N–114 in 3 months, and N–227 in 6 months. The third (N–111) developed mild mastitis after 7 months.

Within 1 month after cow N–227 was placed on routine-machine milking, the milk from the right front and left rear quarters began to show an excessively high number of leucocytes, and *Streptococcus agalactiae* was present regularly in the milk of both front quarters. These symptoms of mastitis became continually more severe. At the same time, the milk from all the quarters showed a gradual loss of the rennet-coagulation property, and the percentage of chlorides and the pH value increased. At the beginning of the sixth month of lactation, the milk from both right quarters became severely mastitic; there were many clots, the number of leucocytes and the number of *S. agalactiae* was larger than 50 million, the percentage of chlorides was higher than 0.20, and the milk would not coagulate with rennet.

The pH of the milk of the right front quarter exceeded 6.8 by the end of the sixth month, and that of the right rear quarter exceeded 6.8, 2 weeks after the onset of severe mastitis. These quarters continued to be affected severely for the remainder of the lactation. On the other hand, the left front and left rear quarters were affected less severely, although both were infected with *S. agalactiae*.

A summary of the detailed data on the characteristics of milk from this cow is presented in table 2. She was milked by hand during the succeeding lactation, and a summary of the data on the characteristics of her milk when hand milking was done is also presented in table 2. These data show that there was a marked improvement during the period when hand milking was done.

TABLE 2.—*Effects of routine-machine milking, and of hand milking in the following lactation, on characteristics of the milk from individual quarters of cow N–227*

Method of milking, and quarter	Days in lactation period covered by sample	Number of udder-quarter samples tested	Leucocytes (thousands per milliliter)			*S. agalactiae* (thousands per milliliter)			Chlorides (percent)		
			Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Routine-machine milking:											
Right front	11th to 67th	9	2,131	70	628	20.00	0.60	52.10	0.108	0.091	0.102
	81st to 137th	8	3,741	418	1,783	7.30	.80	39.30	.127	.113	.114
	172d to 221st	5	103,000	26,000	85,800	125,000.00	1,600.00	47,940.00	.245	.122	.197
	234th to 306th	7	60,465	4,785	22,817	324.00	10.00	101.40	.230	.100	.188
Right rear	11th to 157th	16	174	6	65	.80	0	.10	.120	.092	.105
	172d to 206th	5	100,000	40,000	68,000	53,000.00	.10	19,260.00	.335	.153	.265
	221st to 306th	8	11,658	6,090	8,103	1.80	0	.23	.245	.204	.224
Left front	11th to 219th	21	748	5	117	5.10	0	1.29	.119	.090	.105
	234th to 306th	8	2,469	168	895	6.30	.60	2.93	.133	.094	.107
Left rear	11th to 67th	9	2,759	78	569	.30	0	.03	.110	.090	.103
	81st to 306th	20	3,010	64	752	4.00	0	.25	.129	.082	.125
Hand milking during following lactation:											
Right front	13th to 281st	8	297	7	53	[1].70	0	.09	.130	.090	.116
Right rear	13th to 281st	8	166	8	57	[1].30	0	.04	.140	.090	.119
Left front	13th to 281st	8	103	8	46	.00	0	0	.140	.110	.119
Left rear	13th to 281st	8	103	6	29	.00	0	0	.130	.110	.118

[1] Streptococci other than *S. agalactiae*.

TABLE 3.—*Effects of routine-machine milking, and of subsequent hand milking, on characteristics of the milk of cow N–114* [1]

Lactation, method of milking, and sampling date	Right front quarter				Right rear quarter				Left front quarter				Left rear quarter			
	Strip-cup test data [2]	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)	Strip-cup test data [2]	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)	Strip-cup test data [2]	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)	Strip-cup test data [2]	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)
First lactation:																
Routine machine—																
1935																
Aug. 14		9	0	0.14		56	0	0.12		35	0	0.13		29	0.20	0.13
Aug. 17	0				0				0				0			
Aug. 20		22	0	.12		34	0	.12		11	0	.12		10	0	.12
Aug. 28		27	0	.12		29	0	.12		48	0	.12		33	.20	.12
Sept. 11		287	.20	.11		17	0	.11		435	0	.11		313	0	.11
Sept. 14	0				0				0				0			
Sept. 25		24	0	.12		70	0	.12		48	0	.12		77	0	.12
Oct. 9	0	73	0		0	82	.50		0	92	0		0	67	.80	
Oct. 18	0				4				0				4			
Oct. 23		55	6.50	.12		8,084	1,700	.16		17,794	3,300	.21		25,800	10,300	.18
Oct. 25	3				3				3				3			
Nov. 5	4				3				3				3			
Nov. 6		12,900	2,900	.17		10,922	800	.20		17,400	19,400	.23		18,060	1,700	.24
Nov. 19		10,824	500	.14		1,740	1.00	.12		15,260	680	.16		14,790	21.00	.17
Nov. 20	4				0				3				2			
Dec. 4		1,653	2.90	.15		8,178	1.20	.16		2,436	8.40	.12		2,157	1.00	.16
Dec. 12	1				1				1				1			
Dec. 18	0	2,376	1.40	.15	4	14,432	.20	.18	0	3,115	1.00	.16	2	12,104	.20	.17
1936																
Jan. 6	1				0				0				0			
Jan. 8		744	11.00	.13		635	0	.14		2,580	3.00	.15		1,932	2.00	.14
Jan. 31	0				0				0				1			

Feb. 3		950	9.20	.12		613	0	.13		1,674	1.80	.14		1,206	1.80	.15
Feb. 19	0	2,314	.30	.15	0	583	0	.14	0	3,053	2.90	.16	0	4,924	.30	.17
Mar. 4	0	12,480	.70	.15	0	461	0	.13	0	2,044	11.90	.16	0	4,042	8.90	.15
Mar. 19	1	4,350	.40	.16	0	652	0	.14	0	1,462	3.20	.16	1	10,701	.30	.17
Mar. 30	0	957	140	.13	0	533	0	.14	0	1,418	18.20	.14	0	3,480	78.00	.17
Apr. 14		28,480	1.00	.15		470	0	.12		2,001	5.00	.14		3,480	14.00	.16
Apr. 16	0				0				0				2			
Hand—																
Apr. 28	0	870	2.70	.13	0	382	0	.12	0	1,009	3.20	.14	0	2,144	15.20	.13
May 12	0	809	3.60	.11	0	221	0	.10	0	1,044	6.60	.12	0	1,740	12.00	.12
May 26	0	368	3.20	.10	0	235	2.20	.11	0	1,035	12.00	.12	0	1,322	20.00	.12
June 3	0	502	3.00	.10	0	435	0	.11	0	1,118	12.00	.11	0	1,496	9.60	.12
June 9		250	1.50	.12		296	0	.12		565	11.00	.13		870	3.80	.13
June 23	0	957	4.90	.12	0	487	0	.13	0	2,436	9.80	.13	2	2,566	6.50	.14
July 7		403	8.30	.11		310	0	.11		800	25.30	.12		1,651	7.80	.12
July 20	0				0				0				0			
July 21		623	12.90	.10		612	0	.12		1,550	37.50	.13		1,723	13.40	.13
Second lactation:																
Hand—																
1936																
Nov. 11		30	0	.12		25	0	.11		27	0	.11		83	0	.12
Nov. 12	0				0				0				0			
Dec. 2	0	8	0	.12	0	15	0	.12	0	63	0	.13	0	16	0	.12
Dec. 9	0	15	0	.12	0	16	0	.13	0	135	0	.13	0	23	0	.13
Dec. 16	0	69	0	.12		71	0	.11		257	0	.11		495	0	.11
1937																
Jan. 6	0	66	0	.11	0	318	0	.12	0	264	.05	.11	0	230	0	.11
Jan. 19	0	33	0	.12	0	24	0	.11	0	69	0	.11	0	109	0	.12
Feb. 2	0	21	0	.12	0	73	0	.11	0	197	0	.12	0	243	0	.11
Feb. 24	0	23	0	.11	0	24	0	.12	0	158	0	.12	0	167	0	.11
Mar. 8	0	32	0	.12	0	115	0	.12	0	71	0	.12	0	179	0	.12
Mar. 29	0	47	0	.12	0	91	0	.11	0	83	0	.12	0	68	0	.12
May 3	0	47	0	.12	0		0	.13	0	253	0	.13	0	127	0	.12
June 15	0	253	0	.12	0	158	0	.12	0	178	0	.12	0	89	0	.12
Sept. 30	0	57	0	.12	0	280	0	.12	0	450	0	.12	0	550	0	.12
Dec. 6	0	15		.13	0	317		.13	0	286		.12	0	1,386		.13
Dec. 16	0	150	0	.12	0	415	0	.14	0	472	0	.13	0	503	0	.14

[1] First lactation—calved July 31, 1935, dry Aug. 1, 1936; second lactation—calved Nov. 3, 1936, dry Jan. 1, 1938.
[2] The figure 0 indicates no clots; 1, a few small clots; 4. numerous large and small clots; and 2 and 3, intermediate conditions.

Additional information on the effect of machine milking at 16 inches of vacuum (routine method) was obtained in a similar study of cow N–114. She developed mastitis suddenly in all four quarters 3 months after the beginning of her first lactation. The infection, which was due to *Streptococcus agalactiae*, subsided somewhat a month later, but the milk continued to be decidedly abnormal. Machine milking was replaced by hand milking during the eighth month of lactation, and a marked improvement in the characteristics of the milk occurred after the change, although three of the quarters remained infected and the milk from all the quarters continued to show an abnormally high percentage of chlorides and an excessive number of leucocytes during the remainder of the lactation. During the succeeding lactation, this cow was milked by hand for 13 months, and no infection or other symptoms of mastitis were noted except that the percentage of chlorides was slightly higher than normal. The detailed results obtained in the study of her milk during the first and second lactations are presented in table 3. It is apparent from these results that the recovery from mastitis made by cow N–114 occurred largely as a result of the change to hand milking.

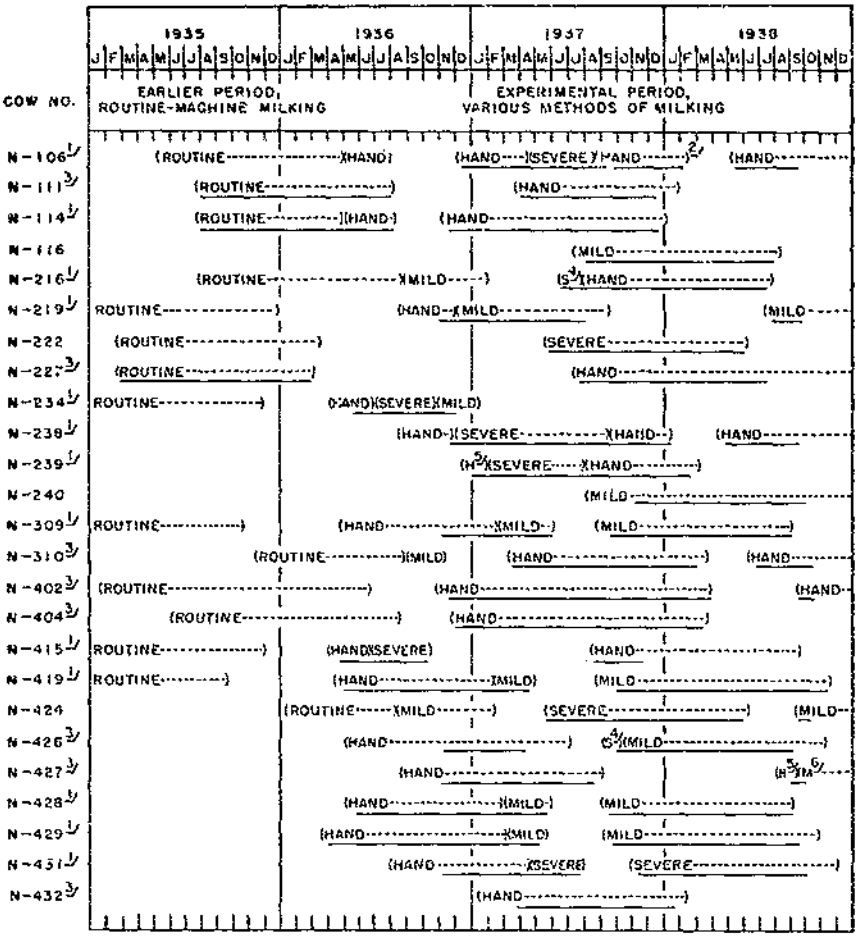
Coincident with these results, a similar alleviating effect as a result of hand milking was observed in five other cows that likewise had become mastitic on machine milking. Also, three additional first-calf heifers remained free of mastitis on hand milking during this period. It was apparent, therefore, that hand milking was the method least likely to provoke conditions predisposing to mastitis and that it offered the best control method for use in evaluating the effects of different methods of machine milking.

PLAN OF SUCCEEDING EXPERIMENTS

The wide prevalence of mastitis among the cows of this herd during the period of 35 months when they were milked by the routine-machine method indicated that the milking machine had caused injury to the teats and udders, predisposing the cows to mastitis; and it was believed that this injury was the result either of excessive vacuum or of leaving the machine working on the udder too long. Experiments were begun, therefore, in 1936 (a few weeks earlier with some cows) to determine the comparative injurious effects of machine milking at 16 inches of vacuum for 20 minutes (severe-machine milking) and machine milking at 12 inches of vacuum for 5 minutes (mild-machine milking), and to compare the effects of machine milking with those of hand milking.

During the succeeding 30 months, 9 cows were milked by the severe-machine method for a part or all of a lactation. Three of the 9 cows were milked by hand preceding and following the period on severe-machine milking; 2 were milked by hand preceding severe-machine milking; 2 were not milked by hand; 1 was milked by hand after the period on severe-machine milking; and 1 cow was milked by hand preceding, and by the mild-machine method following, the period on severe-machine milking. During the same period, 12 cows were milked by the mild-machine method during a part or all of a lactation. Three of the 12 cows were milked by the mild-machine method following routine-machine milking; 4 were milked by hand

preceding mild-machine milking and mild-machine milking was continued during the succeeding lactation; 3 were not milked by hand; 1 was milked by hand preceding mild-machine milking; and 1 cow was milked by the mild-machine method following severe-machine milking. In addition to the use of hand milking preceding and following machine milking on many of the cows, 10 cows were milked by hand for a complete lactation during this period of 30 months. The plan of the experiments on the 25 cows studied in detail is presented in figure 2.



1/ THIRTEEN COWS THAT WERE MILKED BY HAND AND BY MACHINE DURING THE SAME LACTATION.

2/ PORTIONS OF LACTATIONS UNDERLINED WITH A HEAVY LINE WERE THE PERIODS DURING WHICH DETAILED STUDIES WERE MADE.

3/ EIGHT COWS THAT WERE MILKED BY HAND DURING A COMPLETE LACTATION.

4/ SEVERE-MACHINE MILKING.

5/ HAND MILKING.

6/ MILD-MACHINE MILKING.

FIGURE 2.—Chronological information indicating plan of experiments.

CHARACTERISTICS OF THE MILK OF THE COWS ON SEVERE-MACHINE MILKING

As described above, the only difference between the usual routine-machine method and the severe-machine method was that in the latter method the machine was operated on the udder for 20 minutes uniformly, which was a longer time than was used always in routine-machine milking.

Provision was made for adequate controls on hand milking. Some cows were milked by hand throughout the lactation. Others were milked by hand for varying periods before they were put on severe-machine milking in the same lactation and, when they developed mastitis on severe-machine milking, they were put on hand milking again during the same lactation.

Nine cows were milked by the severe-machine method. Six of them developed severe mastitis, two developed mild cases of mastitis, and one remained free of mastitis during the period on severe-machine milking. Of the six cows severely affected with mastitis, two (N–238 and N–239) were first-calf heifers, two (N–234 and N–415) were in their second lactation, one (N–106) was in her fourth lactation, and one (N–216) was in her fifth lactation. The latter four had been severely mastitic previously on routine-machine milking, and two of these (N–234 and N–415) had each lost two quarters during that period. However, all the quarters of these four cows that continued to give milk had apparently recovered from mastitis during the preceding dry periods or while they were milked by hand or by the mild-machine method. Three of the six cows (N–106, N–238, and N–239) with four functioning quarters and the two with two functioning quarters (N–234 and N–415) were milked by hand for 2 to 4 months at the beginning of the lactation before they were milked by the severe-machine method, and their milk during this preliminary period on hand milking was free of mastitic characteristics.

Following the beginning of severe-machine milking, four of the six cows (N–106, N–234, N–239, and N–415) showed symptoms of mastitis in their milk within 1 month, but significant symptoms did not occur in the milk of cow N–238 until after 5 months. The onset of severe mastitis appeared in the milk of cow N–234 within 1 month, in that of cow N–415 within 2 months, and in that of cow N–106 within 3 months; but symptoms of severe mastitis did not become evident in the milk of cows N–239 and N–238 until after 5 and 6 months, respectively. The sixth cow (N–216) was milked by the severe-machine method immediately after freshening without a preliminary period on hand milking, and symptoms of severe mastitis occurred in her milk within 30 days. These results indicated that with severe-machine milking the onset of severe mastitis occurred relatively quickly in the cows not subjected to a period of preliminary hand milking and in the older cows that had been mastitic previously.

Subsequent to the period of severe-machine milking, which varied in length of time with the different cows, four cows (N–106, N–216, N–238, and N–239) were changed to hand milking, cow N–234 was put on mild-machine milking, and cow N–415 was continued on severe-machine milking until the end of the lactation. In all of the cows changed to hand milking there was an immediate improvement

in the characteristics of the milk, and the improvement continued until almost complete recovery from the mastitic conditions was reached at or near the end of the lactation period. A similar but less rapid improvement occurred in cow N–234 after she was changed to mild-machine milking. Cow N–415, which was continued on severe-machine milking, showed continued severity of mastitis until the end of the lactation. However, during the succeeding lactation when she was milked by hand, the milk of the two functioning quarters showed only slight abnormality and was free of infection.

A summary of the detailed data on the milk of three of the cows (N–106, N–238, and N–239) that developed severe mastitis on severe-machine milking is presented in table 4, showing the markedly mastitic characteristics of their milk that resulted from severe-machine milking and the general alleviation that occurred on hand milking.

The two cows (N–222 and N–424) that developed only mild cases of mastitis on severe-machine milking were 6 and 4 years of age, respectively, and had remained relatively free of mastitis during their previous lactations on routine-machine milking. The right front quarter of cow N–424 had become mildly mastitic early in that lactation and after the third month ceased to function. The three other quarters had remained free of mastitis during 7 months on routine-machine milking and 6 months on mild-machine milking of that lactation. During the period on severe-machine milking, the milk of the seven functioning quarters of these two cows frequently contained *Streptococcus agalactiae* and several other species of streptococci, but the percentage of chlorides rarely exceeded 0.11, and the leucocyte count rarely exceeded 500,000 except in the left rear quarter of cow N–222, in which it exceeded 5 million in three scattered samples. However, during the succeeding lactation, the milk of cow N–222 was found to be infected with *Pseudomonas aeruginosa*, which was later found associated with mastitic conditions in the milk of machine-milked cows in the herds at Beltsville (*3*). The results indicated that some injury had resulted from severe-machine milking during this period.

The ninth cow (N–431) subjected to severe-machine milking was a first-calf heifer. She had been milked by hand for 8½ months from the beginning of her first lactation, and on hand milking her milk was free of symptoms of mastitis. During the last 4 months of this lactation, she was milked by the severe-machine method, and her milk remained free of symptoms of mastitis. She was put again on severe-machine milking at the beginning of her second lactation and was continued on this method for the subsequent 13 months; during the first 9 months the samples contained *Streptococcus agalactiae* and other streptococci occasionally, the leucocyte count was rather excessive but rarely exceeded 1 million, and the percentage of chlorides was slightly higher than normal. Finally, during the last 4 months of the lactation, marked increases occurred in the number of streptococci other than *S. agalactiae* in her milk, continued increases occurred in the percentage of chlorides, and the left rear quarter became infected with *Pseudomonas aeruginosa*.

TABLE 4.—*Effects of severe-machine milking following hand milking, and of subsequent hand milking, on characteristics of the milk of cows N–238, N–239, and N–106*

Cow, calving date, and quarter	Days in lactation period covered by samples	Method of milking	Number of udder-quarter samples tested	Leucocytes (thousands per milliliter)			*S. agalactiae* (thousands per milliliter)			Other streptococci (thousands per milliliter)			Chlorides (percent)		
				Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Cow N–238, calved Aug. 28, 1936:															
	74th–77th	Hand	2	783	54	418	0	0	0	0	0	0	0.094	0.084	0.09
Right front	81st–256th	Severe machine	34	548	8	176	.20	0	.03	0	0	0	.11	.078	.09
	259th–381st	do	22	69,420	1,587	20,054	200.00	0	14.50	.20	0	.02	.17	.10	.13
	387th–431st	Hand	5	7,221	632	2,202	15.00	1.00	5.03	0	0	0	.11	.09	.10
	74th–77th	do	2	268	142	215	.25	0	.12	0	0	0	.09	.086	.09
	81st–262d	Severe machine	38	2,006	58	401	.15	0	.01	.50	0	.02	.10	.074	.085
Right rear	263d–381st	do	18	26,500	979	4,172	158.00	0	10.14	1.00	0	.01	.13	.09	.10
	387th–431st	Hand	5	338	120	236	1.10	0	.53	0	0	0	.09	.07	.078
	74th–77th	do	2	8	7	7	.05	0	.03	0	0	0	.09	.084	.083
	81st–243d	Severe machine	32	355	5	68	.50	0	.03	20.50	0	.65	.10	.07	.085
Left front	251st–381st	do	24	60,000	311	16,840	18.00	0	2.68	.30	0	.01	.18	.09	.126
	387th–431st	Hand	5	2,080	490	1,234	9.30	.40	5.53	0	0	0	.11	.08	.098
	74th–77th	do	2	12	8	10	0	0	0	0	0	0	.083	.073	.078
	81st–327th	Severe machine	52	266	7	84	17.00	0	.04	.20	0	.01	.10	.067	.08
Left rear	333d–381st	do	4	2,720	400	1,618	5.00	0	2.15	0	0	0	.10	.08	.087
	387th–431st	Hand	5	237	20	130	5.20	0	2.00	0	0	0	.08	.07	.074
Cow N–239, calved Dec. 7, 1936:															
	31st–53d	do	5	267	32	113	0	0	0	0	0	0	.09	.07	.08
Right front	58th–206th	Severe machine	19	4,564	398	1,547	.10	0	.01	.25	0	.02	.11	.08	.093
	218th–232d	do	3	46,200	22,611	37,070	200.00	155.00	178.00	0	0	0	.13	.13	.13
	242d–431st	Hand	7	6,811	435	1,959	3.00	.40	1.38	0	0	0	.14	.09	.107
	31st–53d	do	5	68	31	48	0	0	0	0	0	0	.08	.06	.074
Right rear	58th–232d	Severe machine	22	5,183	288	1,500	0	0	0	.50	0	.02	.11	.08	.093
	243d–431st	Hand	7	528	52	230	0	0	0	0	0	0	.11	.08	.096
	31st–53d	do	5	525	16	134	0	0	0	0	0	0	.08	.06	.074
	58th–218th	Severe machine	20	3,798	203	1,328	1.50	0	.01	.70	0	.04	.11	.08	.093
Left front	227th–232d	do	2	100,000	48,000	74,000	3,770.00	.....	.....	0	0	0	.....	.11	.....
	242d–255th	Hand	3	38,000	2,059	14,322	12.00	1.50	5.53	0	0	0	.15	.12	.14
	285th–431st	do	4	1,632	672	956	4.40	1.30	2.52	0	0	0	.125	.11	.116
	31st–53d	do	5	132	15	54	0	0	0	.90	0	.24	.08	.06	.073
Left rear	58th–232d	Severe machine	22	6,098	59	1,047	.30	0	.02	.70	0	.04	.10	.07	.088
	242d–431st	Hand	7	268	16	134	0	0	0	0	0	0	.11	.08	.09
Cow N–106, calved Dec. 4, 1936:															
	126th–130th	do	7	1,430	7	396	.10	0	.01	0	0	0	.11	.075	.087
Right front	132d–203d	Severe machine	11	4,045	851	2,039	9.60	0	1.35	.30	0	.03	.10	.08	.09
	217th–245th	do	6	100,000	20,735	59,651	100.00	10.00	48.00	18.00	8.50	5.30	.30	.108	.215
	249th–336th	Hand	6	54,600	4,000	18,329	32.00	1.90	11.12	7.00	1.70	1.74	.31	.14	.185

Right rear	19th-130th	do	7	62	7	37	0	0	0	0	0	0	.08	.067	.074
	132d-203d	Severe machine	11	206	45	111	5.10	0	1.15	.25	0	.02	.095	.07	.08
	217'h-245th	do	6	2,015	185	582	7.80	2.00	4.08	0	0	0	.11	.08	.09
	249th-404th	Hand	8	273	15	100	7.30	0	1.70	.20	0	.03	.09	.08	.09
Left front	19th-130th	do	7	1,650	296	809	.10	0	.01	0	0	0	.12	.07	.103
	132d-245th	Severe machine	17	2,280	289	1,258	9.80	0	2.63	8.50	0	.54	.14	.09	.103
	249th-404th	Hand	8	571	200	377	15.00	0	5.86	2.00	0	.03	.11	.10	.102
Left rear	19th-130th	do	7	104	7	45	0	0	0	0	0	0	.08	.07	.075
	132d-139th	Severe machine	3	45	15	25	0	0	0	0	0	0	.08	.08	.08
	146th-217th	do	9	3,393	173	1,376	4.20	0	1.30	.10	0	.01	.11	.08	.09
	224th-245th	do	5	40,000	398	22,636	20.00	0	9.00	34.00	0	8.50	.20	.12	.15
	249th-256th	Hand	2	40,000	22,750	31,375	40.00	5.50	22.75	0	0	0	.20	.12	.16
	285th-404th	do	6	345	20	219	1.60	0	.65	.70	0	.17	.09	.08	.085

The results showed that severe-machine milking apparently caused injury to the udder, predisposing it to infection and to mastitic conditions corresponding with those that occurred with routine-machine milking. The observation that more rapid or more serious injury did not occur with the 20-minute milking time than with the shorter milking time of routine-machine milking may be explained in part by the fact that seven of the nine cows on the severe-machine method had been milked by hand for 2 months or longer just prior to the severe-machine period; moreover, the seven functioning quarters of the two other cows (N–222 and N–424) had shown relatively high resistance against milking-machine injury during their previous lactations on routine-machine milking. These results, together with those obtained with cows milked by the routine-machine method, indicated that the amount of vacuum used was more important than the length of time the machine was left working on the udder, as a primary cause of udder injury.

CHARACTERISTICS OF THE MILK OF THE COWS ON MILD-MACHINE MILKING

Since it was recognized that a vacuum existed constantly on the tip of the teat and on the lower end of the teat canal during the operation of the milking machine, and since it had been determined that the withdrawal of milk took place almost as rapidly when the machine was exerting 12 inches of vacuum as when it was exerting 16 inches, it seemed reasonable to suppose that a reduction of vacuum to 12 inches would prevent much of the injurious effect.

Therefore, in August 1936, three cows (N 216, N–310, and N–424) were changed from routine-machine to mild-machine milking, and in November 1936 cow N 234 on severe-machine milking and N–219 on hand milking were changed to mild-machine milking. Cows N–216 and N–310 had been affected severely with mastitis in one quarter each on routine-machine milking but during this period on mild-machine milking the milk of all their quarters was free of infection. Cow N–424 had had mastitis and lost the use of one quarter during the first 3 months of the lactation while on routine-machine milking, but after the change to mild-machine milking the milk of the three functioning quarters was free of symptoms. Cow N–234 had previously had severe mastitis and lost the use of two quarters while on routine-machine milking, and during the succeeding lactation on severe-machine milking the two functioning quarters had been severely mastitic. After the change to mild-machine milking, the symptoms in the milk of the two functioning quarters improved immediately. Cow N–219 had previously had mastitis in all four quarters while on routine-machine milking. However, the milk from all her quarters was free of symptoms during the first 3 months of this lactation on hand milking and remained free of symptoms during this period on mild-machine milking.

Following the favorable response obtained with the mild-machine method on the five cows discussed above, seven additional cows were put on the mild-machine method during 1937. Two of the cows were more than 5 years old (cow N–309 had been free of mastitis and cow N–419 had been affected severely with mastitis on routine-machine

milking), and two (N–428 and N–429) were first-calf heifers. These four cows were changed from hand milking to mild-machine milking toward the end of this lactation, and all four cows were milked again by the mild-machine method during the succeeding lactation. A summary of the characteristics of the milk from the individual quarters of these four cows during this series of two lactations is presented in table 5.

The results show that the milk from all the quarters was practically normal during the period of 10 months or longer of this study in the preliminary lactation on hand milking. Among 156 samples tested, only 3 contained more than 500,000 leucocytes per milliliter and only 8 contained *Streptococcus agalactiae* or other causative organisms; these symptoms were present in samples from cows N–419 and N–429, and they disappeared during the same period on hand milking. During the late part of the first lactation shown in table 5 for the four cows on mild-machine milking, slight abnormalities of the milk occurred in 11 of the 16 quarters, characterized by increases in the number of leucocytes and slight increases in the percentage of chlorides. However, with the exception of the right rear quarter of cow N–429, the leucocyte counts of the milk from these 11 quarters rarely exceeded 1 million, and the high leucocyte count was not correlated with infection in any of these quarters. Streptococci were present in 1 or 2 scattered samples from each of only 4 quarters.

During the succeeding lactation on mild-machine milking exclusively, the milk of the four cows remained practically normal for the first 5 to 10 months; the leucocyte counts rarely exceeded 500,000, and the occasional infections that occurred were only temporary and the organisms were present in small numbers. However, toward the end of the lactation, the milk from most of the quarters showed definite increases in the number of leucocytes and in the percentage of chlorides, and 2 of the 16 quarters became rather severely infected. The left front quarter of cow N–419 became infected with *Streptococcus agalactiae* during the late part of the lactation, and minor symptoms developed in the right front quarter. The infection in the left front quarter became rather severe by the time she was dried off. The left front quarter of cow N–429 became severely infected with *S. agalactiae* during the late part of the lactation. The two other cows became mildly infected—N–309 with *S. agalactiae* in the left front quarter, and N–428 with *S. agalactiae* in the right front quarter and both *S. agalactiae* and *Pseudomonas aeruginosa* in the left rear quarter.

In addition, the leucocyte counts exceeded 1 million per milliliter and the percentage of chlorides exceeded 0.11 in the milk from 4 of the 16 quarters. The milk from these quarters was tested by special bacteriological procedures, referred to earlier, but organisms that might have been the cause of the symptoms could not be found.

The milk of two additional first calf heifers (N–116 and N–240) was tested while they were on mild-machine milking during a complete lactation. The data are presented in table 6. The percentage of chlorides in their milk was somewhat higher than normal, but this symptom was not accompanied by an established infection and there was no other indication of injury to their udders.

TABLE 5.—*Characteristics of the milk of 4 cows milked by hand from the beginning of one lactation, changed to mild-machine milking during the same lactation, and continued on mild-machine milking during the next lactation*

Cow, calving date, and quarter	Days in lactation period covered by samples	Method of milking	Number of udder-quarter samples tested	Leucocytes (thousands per milliliter)			S. *agalactiae* (thousands per milliliter)			Other streptococci (thousands per milliliter)			Chlorides (percent)		
				Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Cow N-309:															
Apr. 30, 1936; right front	186th-284th	Hand	4	213	60	148	0	0	0	0	0	0	0.085	0.07	0.076
	287th-376th	Mild-machine	9	821	96	324	0	0	0	0	0	0	.10	.08	.09
Aug. 23, 1937; right front	31st-142d	do	5	525	80	241	0.10	0	0.02	0	0	0	.09	.08	.087
	164th-337th	do	7	1,613	706	1,225	0	0	0	0	0	0	.12	.10	.11
Apr. 30, 1936; right rear	186th-284th	Hand	4	197	105	135	0	0	0	0	0	0	.077	.07	.072
	287th-376th	Mild-machine	9	885	261	510	0	0	0	0	0	0	.09	.08	.082
Aug. 23, 1937; right rear	31st-142d	do	5	197	7	122	.10	0	3.02	0	0	0	.08	.07	.08
	164th-337th	do	7	1,390	249	840	0	0	0	0	0	0	.117	.09	.10
Apr. 30, 1936; left front	186th-284th	Hand	4	266	95	141	0	0	0	0	0	0	.088	.07	.075
	287th-376th	Mild-machine	9	798	190	420	1.60	0	.18	0	0	0	.10	.07	.088
Aug. 23, 1937; left front	31st-142d	do	5	677	126	275	.20	0	.05	0	0	0	.085	.08	.082
	164th-337th	do	7	2,423	537	1,202	7.70	0	1.28	0	0	0	.118	.099	.105
Apr. 30, 1936; left rear	186th-284th	Hand	4	141	24	77	0	0	0	0	0	0	.083	.06	.073
	287th-376th	Mild-machine	9	358	90	178	0	0	0	0	0	0	.09	.07	.08
Aug. 23, 1937; left rear	31st-142d	do	5	221	16	99	0	0	0	0	0	0	.08	.07	.074
	164th-337th	do	7	1,228	174	668	0	0	0	0	0	0	.119	.08	.095
Cow N-419:															
Apr. 7, 1936; right front	20th-309th	Hand	16	348	16	84	0	0	0	0	0	0	.076	.05	.066
	310th-361th	Mild-machine	6	387	93	193	0	0	0	0	0	0	.07	.06	.066
Aug. 27, 1937; right front	26th-248th	do	8	416	57	177	.10	0	.01	.10	0	.01	.086	.06	.07
	298th-396th	do	3	1,170	780	1,027	0	0	0	0	0	0	.112	.08	.10
Apr. 7, 1936; right rear	20th-309th	Hand	16	190	8	62	.40	0	.05	0	0	0	.076	.05	.065
	310th-361th	Mild-machine	6	327	76	102	0	0	0	.10	0	.02	.07	.05	.062
Aug. 27, 1937; right rear	26th-248th	do	8	182	40	101	.20	0	.06	7.60	0	1.20	.066	.06	.062
	298th-396th	do	3	740	425	618	0	0	0	0	0	0	.095	3 .065	.083
Apr. 7, 1936; left front	20th-309th	Hand	16	330	7	87	.50	0	.01	0	0	0	.085	.06	.07
	310th-361th	Mild-machine	6	369	142	215	0	0	0	.05	0	.01	.07	.05	.066
Aug. 27, 1937; left front	26th-248th	do	8	185	88	130	6.00	0	.87	0	0	0	.084	.06	.07
	298th-396th	do	3	21,600	1,440	8,200	1.50	0	.75	6	0	0	.122	.113	.117
Apr. 7, 1936; left rear	20th-309th	Hand	16	116	7	29	3.20	0	.20	0	0	0	.078	.05	.055
	310th-364th	Mild-machine	6	103	29	56	0	0	0	0	0	0	.06	.06	.06
Aug. 27, 1937; left rear	26th-396th	do	11	459	7	123	.10	0	.02	.20	0	.05	.094	.06	.069

Cow N-428:														
Apr. 5, 1936; right front.	23d-296th	Hand	4	320	33	150	0	0	0	0	0	0	.07	.06	.063
	303d-380th	Mild-machine	7	864	118	425	0	0	0	0	0	0	.08	.06	.073
Aug. 28, 1937; right front.	25th-306th	do	13	642	32	193	0	0	0	.40	0	.05	.09	.065	.079
	338th	do	1	1,328			8.40			0			.092		
Apr. 5, 1936; right rear	23d-296th	Hand	4	63	8	59	0	0	0	0	0	0	.088	.05	.072
	300th-380th	Mild-machine	8	460	22	102	0	0	0	0	0	0	.07	.06	.066
Aug. 28, 1937; right rear.	25th-338th	do	14	774	14	100	0	0	0	.20	0	.02	.088	.06	.075
Apr. 5, 1936; left front.	23d-296th	Hand	4	285	102	206	0	0	0	0	0	0	.08	.054	.07
	300th-380th	Mild-machine	8	1,229	273	713	.05	0	.01	0	0	0	.08	.07	.076
Aug. 28, 1937; left front.	25th-338th	do	14	774	45	298	.01	0	.01	.40	0	.04	.092	.06	.079
Apr. 5, 1936; left rear	23d-296th	Hand	4	95	8	88	0	0	0	0	0	0	.072	.05	.063
	300th-380th	Mild-machine	8	102	15	56	0	0	0	0	0	0	.07	.06	.055
Aug. 28, 1937; left rear.	25th-101st	do	5	115	20	62	0	0	0	0	0	0	.07	.06	.065
	130th-338th	do	9	20,250	1,076	6,074	.69	0	.14	[1] 10.00	0	1.25	.17	.088	.103
Cow N-429:															
Mar. 15, 1936; right front.	16th-348th	Hand	15	225	8	43	0	0	0	0	0	0	.089	.06	.07
	352d-402d	Mild-machine	6	1,755	58	443	0	0	0	0	0	0	.08	.07	.073
Sept. 1, 1937; right front.	29th-384th	do	14	441	24	151	0	0	0	.20	0	.01	.08	.06	.07
Mar. 15, 1936; right rear.	16th-348th	Hand	15	1,137	25	320	8.70	0	.76	0	0	0	.083	.06	.073
	352d-402d	Mild-machine	6	14,000	162	3,678	0	0	0	0	0	0	.09	.07	.082
Sept. 1, 1937; right rear	29th-384th	do	14	150	7	68	0	0	0	0	0	0	.07	.06	.066
Mar. 15, 1936; left front.	16th-348th	Hand	15	1,548	8	226	0	0	0	0	0	0	.093	.06	.075
	352d-402d	Mild-machine	6	2,200	223	715	0	0	0	0	0	0	.08	.07	.077
Sept. 1, 1937; left front	29th-259th	do	10	489	50	146	.10	0	.01	0	0	0	.08	.06	.068
	296th-384th	do	4	85,000	133	27,229	4,000	.20	1,152	0	0	0	.23	.065	.128
Mar. 15, 1936; left rear.	16th-348th	Hand	15	216	7	50	0	0	0	0	0	0	.086	.06	.07
	352d-402d	Mild-machine	6	152	52	83	0	0	0	0	0	0	.08	.07	.072
Sept. 1, 1937; left rear	29th-384th	do	14	921	48	102	5.60	0	.36	.10	0	.01	.08	.06	.072

[1] *Pseudomonas aeruginosa* infection from 298th to 306th day in this quarter.

TABLE 6.—*Characteristics of the milk of 2 first-calf heifers on mild-machine milking during the first lactation*

Cow, calving date, and quarter	Days in lactation period covered by samples	Number of udder-quarter samples tested	Leucocytes (thousands per milliliter)			*S. agalactiae* (thousands per milliliter)			Other streptococci (thousands per milliliter)			Chlorides (percent)		
			Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Cow N–116, calved July 16, 1937:														
Right front	4th–340th	8	272	15	97	0	0	0	0.40	0	0.06	0.116	0.10	0.108
Right rear	4th–340th	8	96	7	39	.05	0	.01	.20	0	.03	.11	.092	.103
Left front	4th–340th	8	428	7	104	.00	0	0	0	0	0	.13	.09	.10
Left rear	4th–340th	8	293	15	60	.10	0	.01	.10	0	.03	.13	.09	.102
Cow N–240, calved Aug. 5, 1937:														
Right front	103d–418th	10	772	270	532	.20	0	.02	0	0	0	.14	.10	.117
Right rear	103d–418th	10	190	8	60	.20	0	.02	0	0	0	.10	.08	.09
Left front	103d–418th	10	95	7	55	.00	0	0	0	0	0	.105	.085	.098
Left rear	103d–418th	10	74	14	37	0	0	0	0	0	0	.107	.087	.096

The twelfth cow in this group (N–426) had been milked by hand and was free of mastitis during her first lactation. She was milked by the mild-machine method during her second lactation, and the characteristics of her milk remained normal.

These results indicate that machine milking with reduced vacuum for a short period of operation (12 inches of mercury for about 5 minutes) generally resulted in somewhat higher leucocyte counts and higher chloride values than hand milking; but that, although infective organisms were present occasionally in at least small numbers in the milk of most of the cows studied, any slight injury that may have resulted from the relatively low vacuum was not sufficient to aggravate an infection seriously.

CHARACTERISTICS OF THE MILK OF THE COWS ON HAND MILKING

Among 25 cows whose milk was studied in detail during more than 40 lactations on different methods of milking, 13 were studied while they were being milked by hand and by machine during the same lactation (fig. 2, footnote 1). Study of their milk provided direct comparisons between the effects of hand milking and those of machine milking, and during the periods on hand milking these cows served directly as controls in the study of the effects of various methods of machine milking during the same lactations. Additional controls were provided and additional information concerning hand milking was obtained from the study of 4 of these 13 cows and 8 others (fig. 2, footnote 2) for part or all of a complete lactation during a period of 30 months.

It was noted from the study of the characteristics of the milk that the mastitic conditions of cow N–114 (table 3) and cows N–106, N–238, and N–239 (table 4) were alleviated greatly after a change to hand milking during a lactation. In later studies, similar improvement was noted in the mastitic conditions of cows N–216 and N–106 while they were milked by hand. Detailed data on the milk of these two cows showing marked and progressive improvement on hand milking, are presented in table 7.

In these two cows, as in others that improved on hand milking, complete recovery did not occur usually until after the cows became dry. This tendency to recover from mastitis during the dry or intervening period between lactations, after development of mastitis on machine milking, was observed in at least 14 of the 25 cows. Of 13 cows that were milked by hand during a part or all of a lactation after a period on machine milking, 10 remained practically free of infection and of other symptoms during the period on hand milking, after recovering. A summary of the detailed data on the characteristics of the milk of 2 of these cows (N–227 and N–114) during their second lactations and on hand milking, is presented in tables 2 and 3, respectively. Detailed data on the milk of the four quarters of another of these cows (N–419) are presented in table 8. The relative freedom from abnormality shown in these data was typical of the milk of the younger cows on hand milking after they had recovered from the disease.

TABLE 7.—*Effects of hand milking on bacteriological and chemical characteristics of the udder-quarter milk of cow N–216 following a mastitic condition on severe-machine milking, and of cow N–106, which had had mastitis on severe-machine milking earlier and was severely mastitic at the beginning of the lactation*

Sampling date	Right front quarter				Right rear quarter			
	Strip-cup test data [1]	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)	Strip-cup test data [1]	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)
Cow N–216, calved June 12, 1937:								
Severe-machine milking June 14, 1937–July 17, 1937—								
June 22	1	20, 592	500	0. 13	0	348	4. 8	0. 10
June 28	2	12, 609	755	. 13	0	158	. 9	. 09
June 30	-------	16, 445	510	. 12	0	56	3. 0	. 08
July 6	1	7, 744	1, 785	. 12	0	80	3. 5	. 095
July 8	3	22, 000	655	. 14	0	46	1. 0	. 09
July 14	4	10, 000	840	. 12	0	126	6. 8	. 10
Hand milking July 18, 1937–July 24, 1938—								
July 22	2	2, 960	----------	. 11	0	1, 825	----------	. 08
July 27	0	720	2. 0	----------	0	700	5. 3	----------
Aug. 4	0	12, 518	18. 0	. 12	0	24	1. 3	. 09
Aug. 10	0	395	8. 7	. 12	0	237	1. 6	. 10
Aug. 16	0	316	1. 7	. 11	0	148	54. 0	. 10
Sept. 14	0	739	2. 5	. 11	0	245	8. 8	. 09
Cow N–106, calved Apr. 25, 1938:								
Hand milking—								
Apr. 28	-------	7, 579	6, 000. 0	. 16	-------	12, 155	3, 000. 0	. 13
May 2		6, 900	886. 0	. 134	0	498	90. 0	. 093
May 9	0	4, 263	8. 5	. 11	0	109	0. 4	. 097
May 16	0	2, 465	39. 0	. 103	0	63	5. 5	. 094
June 27	0	3, 558	45. 0	. 106	0	15	1. 6	. 079
Sept. 15	0	3, 052	70. 0	. 097	0	56	17. 0	. 084

Sampling date	Left front quarter				Left rear quarter			
	Strip-cup test data [1]	Leucocytes (thousands per milliliter)	*S agalactiae* (thousands per milliliter)	Chlorides (percent)	Strip-cup test data [1]	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)
Cow N–216, calved June 12, 1937:								
Severe-machine milking June 14, 1937–July 17, 1937—								
June 22	0	154	8.8	0.07	0	687	6	0.08
June 28	0	8,951	48	.09	0	6,700	104	.09
June 30	1	11,672	245	.09	1	4,059	2,500	.08
July 6	2	17,380	10,000	.135	1	20,540	20,000	.11
July 8	3	30,415	7,450	.19	3	30,000	12,500	.09
July 14	4	19,000	3,600	.16	4	12,000	48,100	.10
Hand milking July 18, 1937–July 24, 1938—								
July 22	2	10,585	----------	.11	2	10,001	----------	.11
July 27	0	1,358	1	----------	0	3,718	31.0	----------
Aug. 4	0	286	1	.10	0	3,276	17.0	.09
Aug. 10	0	173	2	.10	0	2,045	4.9	.09
Aug. 16	0	56	3.7	.10	0	2,664	8.7	.09
Sept. 14	0	343	0	.09	0	2,530	10.0	.08
Cow N–106, calved Apr. 25, 1938:								
Hand milking—								
Apr. 28	----------	11,797	8,000.0	.14	----------	16,588	5,000.	.177
May 2	0	13,286	53.0	.115	0	2,044	123.0	.11
May 9	0	180	0.2	.093	0	481	0	.12
May 16	0	91	1.0	.082	0	505	.5	.111
June 27	0	29	3.9	.076	0	30	1.4	.088
Sept. 15	0	7	75.0	.075	0	44	6.6	.08

[1] The figure 0 indicates no clots; 1, a few small clots; 4, numerous large and small clots; and 2 and 3, intermediate conditions.

TABLE 8.—*Complete results of the bacteriological and chemical tests of the udder-quarter samples from a normal cow* [1] *on hand milking* [2]

Sampling date	Right front quarter			Right rear quarter			Left front quarter			Left rear quarter		
	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)	Leucocytes (thousands per milliliter)	*S. agalactiae* (thousands per milliliter)	Chlorides (percent)
1936												
Apr. 27	20	0	0.07	58	0	0.07	66	0	0.07	26	0	0.08
Apr. 29	17	0	.08	35	.2	.08	31	0	.07	9	0	.07
May 13	47	0	.06	72	0	.06	39	0	.06	8	0	.06
May 27	30	0	.06	39	0	.06	7	0	.06	7	0	.06
June 8	23	0	.06	26	0	.06	56	0	.07	19	0	.06
June 22	21	0	.07	28	0	.07	73	0	.07	7	0	.07
July 8	30	0	.06	18	.3	.06	31	2	.06	62	3.2	.06
July 22	121	0	.07	64	0	.07	192	.05	.08	116	0	.07
Aug. 10	54	-------	.07	8	-------	.07	23	-------	.07	7	-------	.06
Aug. 26	25	0	.07	25	0	.07	26	0	.08	9	0	.07
Sept. 9	84	0	.06	34	0	.06	34	0	.07	85	0	.06
Sept. 22	55	0	.07	25	.4	.06	152	0	.07	57	0	.06
Nov. 3	55	0	.07	150	0	.06	20	.05	.07	15	0	.06
1937												
Feb. 4	318	-------	.05	190	-------	.05	178	-------	.06	62	-------	.05
Feb. 8	95	0	.06	73	0	.06	130	0	.06	15	0	.06
Feb. 10	348	0	.06	150	.1	.06	330	0	.06	29	0	.05
Feb. 11	190	0	------	188	0	------	132	0	------	103	0	------

[1] Cow N–419; calved Apr. 7, 1936, dry May 1, 1937; previously on routine-machine milking for 539 days, mastitis + to +++, still mastitic when previous lactation ended.

[2] Strip-cup results on all samples were negative.

The remaining 3 of these 13 cows (N–310, N–402, and N–404), which were milked by hand for a complete lactation after they had been severely affected with mastitis in one or more quarters while on routine-machine milking, were the only animals that became severely affected with streptococcal mastitis on hand milking. These 3 cows showed symptoms of mastitis, and each lost one quarter early in the hand-milking lactation. One of them (N–310) was 5 years old, and the others (N–402 and N–404) were 10 and 8 years old, respectively. Cows N–310 and N–404 had been on rations rather low in vitamin A for long periods; and cow N–402, several years previously, had been fed for more than 3 years on a ration extremely low in vitamin A. In spite of this unfavorable background, cow N–310 did not become mastitic in the quarters that continued to function until the last 2 weeks of the lactation. Similarly, the functioning quarters of cow N–402 did not become severely mastitic until after the sixth month; and the milk of cow N–404, although infected badly with *Streptococcus agalactiae*, exhibited a mildly chronic condition only after the sixth month, and this condition continued until the end of the lactation.

A summary of the frequency of the presence of mastitic symptoms in the quarters of the 13 cows on hand milking after partial or complete recovery from mastitis incurred during their previous lactations on machine milking, showing relative freedom from mastitic symptoms on hand milking, is presented in table 9.

The outstanding abnormality of the milk of 5 of the 10 cows that remained relatively free of infection on hand milking was that the percentage of chlorides was higher than normal, which indicated permanent injury to the secretory tissue as a result of their previous mastitic condition on machine milking. The frequency of symptoms of mastitis in the milk of cows N–310, N–402, and N–404 present a marked contrast to that of the 10 other cows, which were younger animals and which had been on normal diets and had largely recovered from their previous mastitic condition before this period on hand milking.

Six heifers were milked by hand for the first part or all of their first lactations. Two of these (N–428 and N–429) were milked by hand for 10 and 12 months, respectively, and were then changed to mild-machine milking during the same lactation. The comparative effects of hand and mild-machine milking on the milk of these two cows are shown in table 5 and described on page 23. Another cow (N–431) was changed to severe-machine milking after 9 months on hand milking during her first lactation. Three others (N–426, N–427, and N–432) were milked by hand during all of their first lactations. The results of the studies of the milk of the individual quarters of these six cows, summarized in table 10, show that in five of the six cows there was relatively little evidence of symptoms during the hand-milking period.

TABLE 9.—*Frequency distribution of mastitic symptoms in udder-quarter milk of 13 cows on hand milking after partly or completely recovering from mastitis contracted on machine milking*

Cow No.	Days in lactation period covered by samples	Number of samples	*S. agalactiae*: Number of samples containing—		Chlorides: Number of samples containing—			Leucocytes: Number of samples containing—		
			Between 100 and 10,000 per milliliter	More than 10,000 per milliliter	Between 0.09 and 0.11 percent	Between 0.11 and 0.14 percent	More than 0.14 percent	Between 500,000 and 1,500,000 per milliliter	Between 1,500,000 and 5,000,000 per milliliter	More than 5,000,000 per milliliter
N–106 [1]	4th–144th	32	4	0	7	3	1	6	1	1
N–111 [1]	9th–268th	12	4	0	1	7	0	0	1	0
N–114 [1]	9th–415th	64	0	0	8	24	0	3	0	0
N–219	73d	4	0	0	3	0	0	0	0	0
N–227 [1]	3d–281st	40	3	0	12	27	1	2	1	0
N–234	16th–48th	6	0	0	2	0	0	1	0	0
N–238 [1]	3d–164th	32	2	1	10	0	0	0	0	0
N–309	187th–285th	16	1	0	3	0	0	0	0	0
N–415	17th–73d	10	0	0	0	0	0	0	0	0
N–419	21st–310th	64	4	0	0	0	0	0	0	0
N–310 [2]	15th–365th	28	8	10	7	4	3	5	3	4
N–402 [2]	21st–527th	35	3	10	8	5	10	8	5	8
N–404 [2]	10th–485th	32	7	19	7	0	0	7	20	2

[1] Percentage of chlorides higher than in milk of normal cows, indicating permanent injury to secretory tissue as a result of previous mastitis on machine milking.

[2] Relatively old cows; had been on deficient rations.

TABLE 10.—*Bacteriological and chemical characteristics of the milk of 6 heifers during the period on hand milking from the beginning of the first lactation*

Cow, date of calving, and quarter	Days in lactation period covered by samples	Number of udder-quarter samples tested	Leucocytes (thousands per milliliter)			*S. agalactiae* or other infective organisms (thousands per milliliter)			Chlorides (percent)		
			Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Cow N–426, calved May 2, 1936:											
Right front	187th–340th	3	1,000	108	432	0.05	0	0.03	0.09	0.08	0.083
Right rear	187th–340th	3	792	58	314	0	0	0	.083	.08	.082
Left front	187th–340th	3	1,680	53	611	0	0	0	.09	.07	.08
Left rear	187th–340th	3	1,260	43	498	0	0	0	.08	.07	.08
Cow N–427, calved Aug. 14, 1936:											
Right front	89th–367th	12	4,160	245	1,576	[1] 91.00	1.00	26.00	.125	.05	.083
Right rear	89th–367th	12	853	7	165	0	0	0	.092	.04	.059
Left front	89th–367th	12	592	7	147	0	0	0	.069	.04	.056
Left rear	89th–367th	12	695	7	146	0	0	0	.073	.04	.054
Cow N–428, calved May 5, 1936:											
Right front	24th–297th	4	320	33	156	0	0	0	.07	.06	.063
Right rear	24th–297th	4	63	8	44	0	0	0	.088	.05	.072
Left front	24th–297th	4	285	102	206	0	0	0	.08	.054	.07
Left rear	24th–297th	4	95	8	67	0	0	0	.072	.05	.063
Cow N–429, calved Mar. 15, 1936:											
Right front	16th–348th	15	225	8	43	0	0	0	.09	.06	.07
Right rear	16th–348th	15	1,137	25	320	8.70	0	.72	.083	.063	.073
Left front	16th–348th	15	1,548	8	226	0	0	0	.093	.06	.075
Left rear	16th–348th	15	216	7	50	0	0	0	.086	.06	.07

[1] Infection with *Staphylococcus aureus*.

TABLE 10.—*Bacteriological and chemical characteristics of the milk of 6 heifers during the period on hand milking from the beginning of the first lactation*—Continued

Cow, date of calving, and quarter	Days in lactation period covered by samples	Number of udder-quarter samples tested	Leucocytes (thousands per milliliter)			*S. agalactiae* or other infective organisms (thousands per milliliter)			Chlorides (percent)		
			Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Cow N–431, calved Aug. 1, 1936:											
Right front	101st–255th	5	103	6	34	[2] 0.05	0	0.01	0.07	0.06	0.065
Right rear	101st–255th	5	37	8	21	.05	0	.01	.07	.06	.066
Left front	101st–255th	5	28	7	18	0	0	0	.07	.06	.063
Left rear	101st–255th	5	29	7	14	0	0	0	.07	.06	.065
Cow N–432, calved Jan. 12, 1937:											
Right front	80th–365th	4	1,043	15	312	0	0	0	.08	.065	.07
Right rear	80th–365th	4	356	7	114	0	0	0	.07	.06	.067
Left front	80th–365th	4	1,428	22	505	0	0	0	.09	.066	.08
Left rear	80th–365th	4	158	15	89	.10	0	.02	.07	.07	.07

[2] Temporary infection with streptococci other than *S. agalactiae*, without other symptoms.

Cow N–427 (table 10) was the only animal in this study in which a sustained infection developed during the period on hand milking that could not be accounted for by any known conditions of the experiments. The causative agent was *Staphylococcus aureus*. It occurred in the right front quarter only, after the second month of the lactation, and persisted until the end of the lactation. The milk contained blood at the beginning of the lactation, and it is likely that the quarter had been injured. With this exception, only 7 of the 165 udder-quarter samples from these six cows contained streptococci or other causative organisms, and only 15 had leucocyte counts greater than 500,000 per milliliter. Likewise, among these 165 samples, the percentage of chlorides exceeded 0.09 in only 4 samples, and the average percentage for all the quarters was less than 0.084. This value is considerably lower than the chloride values of most of the samples from the cows on hand milking that had had mastitis previously while on machine milking (summarized in table 9), and it is markedly lower than the values of the samples from cows on machine milking, even among the quarters that did not show other symptoms of mastitis.

COMPARATIVE RELATIONSHIPS OF DIFFERENT METHODS OF MILKING TO THE SYMPTOMS OF INJURY AND TO THE INCIDENCE AND SEVERITY OF MASTITIS

The comparative effects of the different methods of milking on the incidence and severity of mastitis in the herd were determined directly when cows were changed from machine to hand milking, or from hand to machine milking and in some cases back to hand milking, during one lactation. These effects were demonstrated by the almost immediate changes that occurred in the severity of the infections and in the characteristics of the milk of cow N–114 (table 3) in the studies on routine-machine milking, of cows N–238, N–239, and N–106 (table 4), and cow N–216 (table 7) on severe-machine milking, and of cows N–309, N–419, N–128, and N–429 (table 5) on mild-machine milking. Additional data obtained in the studies of the milk of cows N–227 (table 2), N–114 (table 3) and N–238 (table 9), that were milked exclusively by hand during the succeeding lactation after becoming severely mastitic on machine milking at 16 inches of vacuum, illustrate further the marked contrast between the effects of machine milking at high vacuum and those of hand milking. These results indicate that hand milking—and also mild-machine milking—had less tendency to injure the udder and increase the susceptibility to mastitic infection than did routine- or severe-machine milking.

However, the cows were found to differ in their resistance to injury from machine milking, even when the machine was operated at high vacuum. There were four cows that were relatively resistant to injury by milking at high vacuum, namely, N–111 on routine-machine milking and N–222, N–424, and N–431 on severe-machine milking. Cow N–111 was a first-calf heifer, and, although the milk from both front quarters contained *Streptococcus agalactiae* regularly after the third month of the lactation, neither of these quarters became severely mastitic. Meanwhile, both rear quarters remained free of infection

and showed no symptoms of mastitis. All her quarters were free of infection during the succeeding lactation on hand milking. Cows N–222 and N–424 (p. 19) were affected only mildly by machine milking, even though both were milked by the routine- and severe-machine methods for two successive lactations. The udder-quarter samples from these two cows frequently contained various kinds of streptococci, but *S. agalactiae* was found only occasionally. Cow N–431 (p. 19), a first-calf heifer, was milked by hand for more than 8 months during the first lactation, and then by the severe-machine method during the remainder of that lactation and during the succeeding lactation. Injurious effects of severe-machine milking did not appear until after the ninth month of the second lactation. During the tenth month, the milk from each of three quarters contained more than 10,000 *S. agalactiae* per milliliter, and the left rear quarter was infected also with *Pseudomonas aeruginosa*. At the same time, other symptoms of mastitis occurred in the infected quarters.

Variations in resistance to injury and to infection on the different methods of milking were observed among the individual quarters of each cow, particularly of the cows milked by machine at 16 inches of vacuum. Of 12 cows studied thus that developed severe mastitis and on which the usual data were obtained on the milk of four quarters, severe mastitis occurred in only one, two, or three of the quarters among 11 animals, and the remaining quarter or quarters either were unaffected or were affected only mildly. The one exception was cow N–114, which was affected severely in all quarters on routine-machine milking (table 3 and fig. 4).

Data showing the incidence and relative severity of mastitis in the individual quarters of each of the 25 cows studied during this investigation under different methods of milking, with the mastitic conditions evaluated according to the criteria described above, are presented in table 11, together with historical information concerning all the cows in the investigation.

It will be observed (table 11) that the largest proportion of cases of severe mastitis (+ + +) occurred in the right front quarters. Of the severe cases that occurred on severe-machine milking, 37.5 percent were in the right front, 17.5 percent in the right rear, 27.5 percent in the left front, and 17.5 percent in the left rear quarters. The only quarter that developed severe mastitis (+ + +) on mild-machine milking was the left front quarter of cow N–429. The evidence in these investigations points in most cases directly to udder injury caused by the action of the milking machine as being an important factor in the occurrence of mastitis, and it is apparent that such effects of injury were more prevalent and more severe in the front than in the rear quarters. These studies do not offer any explanation as to whether or not the front quarters were more vulnerable to injury by the milking machine because of differences in the sizes and lengths of the teats, which cause the teat cups to fit improperly; because the front quarters usually produce less milk and the machine works on them for a longer period while they are empty; or because the front teats are more subject to injury during the movements of the cow.

TABLE 11.—*Historical information on 25 cows, with details of methods of milking and of the incidence of mastitis for the period of the experiments*

Cow No., date of birth, and calving date	Method of milking, and date	Degree of mastitis in each quarter			
		Right front	Right rear	Left front	Left rear
N-106, born Jan. 23, 1930:					
Calved Apr. 29, 1935 [1]	Routine machine, Apr. 29, 1935, to Apr. 22, 1936	+++	+++	0	+++
	Hand, Apr. 23, 1936, to July 31, 1936	0	0	0	++
	Hand, Dec. 4, 1936, to Apr. 12, 1937	0	0	0	0
Calved Dec. 4, 1936	Severe machine, Apr. 13, 1937, to Aug. 5, 1937	+++	+	++	+++
	Hand, Aug. 6, 1937, to Feb. 1, 1938	++	+	+	+
Calved Apr. 25, 1938	Hand, Apr. 25, 1938 [2]	+ + to +++	+ to ++	+ to ++	+ to ++
N-111, born Aug. 2, 1932:					
Calved July 29, 1935	Routine machine, July 29, 1935, to Aug. 14, 1936	++	0	+	+
Calved Mar. 27, 1937	Hand, Mar. 27, 1937, to Jan. 21, 1938	0	0	0	0
N-114, born Feb. 9, 1933:					
Calved July 31, 1935	Routine machine, July 31, 1935, to Apr. 20, 1936	+++	+ ++	+++	+++
	Hand, Apr. 21, 1936, to Aug. 1, 1936	+	+	++	++
Calved Nov. 3, 1936	Hand, Nov. 3, 1936, to Jan. 1, 1938	0	0	0	+
N-116, born Oct. 9, 1934: Calved July 16, 1937.	Mild machine, July 19, 1937, to Aug. 1, 1938	0	0	0	0
N-216, born Jan. 26, 1929:					
Calved (date unknown)	Hand, dates unknown	0	0	0	0
Do	Routine machine, dates unknown	+++	0	0	0
Calved July 25, 1935	Routine machine, July 25, 1935, to Aug. 10, 1936	+	0	0	0
	Mild machine, Aug. 11, 1936, to Feb. 1, 1937	0	0	0	0
Calved June 12, 1937	Severe machine, June 14, 1937, to July 17, 1937	+++	+	+++	+++
	Hand, July 18, 1937, to July 24, 1938	++	+	+	+ to 0

See footnotes at end of table.

TABLE 11.—*Historical information on 25 cows, with details of methods of milking and of the incidence of mastitis for the period of the experiments*—Continued

Cow No., date of birth, and calving date	Method of milking, and date	Degree of mastitis in each quarter			
		Right front	Right rear	Left front	Left rear
N-219, born Jan. 9, 1931:					
Calved Oct. 7, 1934	Routine machine, Oct. 9, 1934, to Dec. 31, 1935	+++	++	+++	++
Calved Aug. 30, 1936	Hand, Aug. 30, 1936, to Nov. 14, 1936	0	0	0	0
	Mild machine, Nov. 15, 1936, to Sept. 9, 1937	0	0	0	0
Calved July 19, 1938	Mild machine, July 19, 1938 [2]	0	0	0	0
N-222, born Jan. 17, 1931:					
Calved Feb. 12, 1935	Routine machine, Feb. 15, 1935, to Mar. 15, 1936	++	0	++	+
Calved May 26, 1937	Severe machine, May 28, 1937, to June 1, 1938	+	++ to +	+	++
N-227, born Mar. 8, 1931:					
Calved Feb. 16, 1935	Routing machine, Feb. 19, 1935, to Feb. 28, 1936	+++	+++	+	+
Calved July 10, 1937 [2]	Hand, July 10, 1937	0	0	0	0
N-234, born Dec. 15, 1932:					
Calved 1935 (exact date unknown).	Routine machine, approximately 1 year	++	++	++++	++++
	Hand, Apr. 29, 1936 to June 16, 1936	0	0	[3]	[3]
Calved Apr. 29, 1936	Severe machine, June 17, 1936 to Oct. 30, 1936	+++	+++	[3]	[3]
	Mild machine, Oct. 31, 1936, to Dec. 10, 1936	++	++	[3]	[3]
N-238, born Mar. 8, 1934:					
	Hand, Aug. 28, 1936 to Nov. 14, 1936	0	0	0	0
Calved Aug. 28, 1936	Severe machine, Nov. 15, 1936 to Sept. 15, 1937	+++	++	+++	+
	Hand, Sept. 16, 1937 to Jan. 7, 1938	+	0	+	0
Calved Apr. 5, 1938	Hand, Apr. 5, 1938 [2]	0	0	0	0
N-239, born Apr. 8, 1934: Calved Dec. 7, 1936	Hand, Dec. 7, 1936, to Jan. 29, 1937	0	0	0	0
	Severe machine, Jan. 30, 1937 to July 28, 1937	+++	+	+++	+
	Hand, July 29, 1937, to Mar. 1, 1938	++ to +	0	++ to +	0

N-240, born June 27, 1934: Calved Aug. 5, 1937.	Mild machine, Aug. 8, 1937 [2]	+		0		0		0
N-309, born Dec. 16, 1931:								
Calved 1934	Routine machine, approximately 1 year		0		0	+	+	
Calved April 30, 1936	Hand, Apr. 30, 1936 to Feb. 10, 1937		0		0	0		0
	Mild machine, Feb. 11, 1937, to June 1, 1937		0		0	0		0
Calved Aug. 23, 1937	Mild machine, Aug. 27, 1937 to Sept. 2, 1938	0 to +		0 to +		0 to ++	0 to +	
N-310, born Apr. 5, 1932:								
Calved Nov. 12, 1935	Routine machine, Nov. 15, 1935 to Aug. 10, 1936		0	+++		0		0
	Mild machine, Aug. 11, 1936 to Oct. 27, 1936		0		0	+	+	
Calved Mar. 1, 1937	Hand, Mar. 1, 1937 to Mar. 7, 1938	[4] + to ++++		[5] 0 to +++		[5] 0 to +++	[5] ++	
Calved June 19, 1938	Hand, June 19, 1938 [2]		[3]		0	+++	++	
N-402, born May 2, 1926:								
Calved Jan. 19, 1935 [1]	Routine machine, Jan. 22, 1935, to June 15, 1936	++++		+		+++	++	
Calved Oct. 22, 1936	Hand, Oct. 22, 1936, to April. 1, 1938	[6] +++ to ++++		++		+++	++	
N-404, born Jan. 7, 1928:								
Calved May 29, 1935 [1]	Routine machine, June 1, 1935, to Aug. 14, 1936	+++		0		++++	+++	
Calved Nov. 15, 1936	Hand, Nov. 15, 1936 to Mar. 15, 1938	++		++		++ to ++++	++	
N-415, born Dec. 16, 1930:								
Calved Dec. 21, 1934	Routine machine, Dec. 21, 1934, to May 4, 1935	++++		+++		+++	++++	
Calved Mar. 28, 1936	Hand, Mar. 28, 1936, to June 16, 1936	[3](		0		0	[3]	
	Severe machine, June 17, 1936 to Oct. 5, 1936	[3]		+++		+++	[3]	
Calved Aug. 10, 1937	Hand, Aug. 10, 1937 to Sept. 15, 1938	[3]		+ to 0		0 to +	[3]	
N-419, born Apr. 2, 1931:								
Calved Apr. 9, 1934	Routine machine, Apr. 9, 1934 to Sept. 30, 1935	+++		+		++	++	
Calved Apr. 7, 1936	Hand, Apr. 7, 1936 to Feb. 11, 1937		0		0	0		0
	Mild machine, Feb. 11, 1937 to May 1, 1937		0		0	0		0
Calved Aug. 27, 1937	Mild machine, Aug. 29, 1937 to Nov. 21, 1938	+			0	0 to ++		0
N-424, Born Dec. 6, 1932:								
Calved Jan. 11, 1936	Routine machine, Jan. 14, 1936, to Aug. 10, 1936	++++		0		0		0
	Mild machine, Aug. 11, 1936 to Feb. 11, 1937	[3]		0		0		0
Calved May 24, 1937	Severe machine, May 26, 1937, to June 1, 1938	[3]		+		+	+	
N-426, born July 21, 1933:								
Calved May 2, 1936	Hand, May 2, 1936 to July 1, 1937		0		0	0		0
Calved Oct. 6, 1937	Severe machine, Oct. 9, 1937 to Oct. 30, 1937		0		0	0		0
	Mild machine, Oct. 31, 1937, to Nov. 21, 1938		0		0	0		0

See footnotes at end of table.

TABLE 11.—*Historical information on 25 cows, with details of methods of milking and of the incidence of mastitis for the period of the experiments*—Continued

Cow No., date of birth, and calving date	Method of milking, and date	Degree of mastitis in each quarter			
		Right front	Right rear	Left front	Left rear
N-427, born Oct. 22, 1933: Calved Aug. 14, 1936.	Hand, Aug. 14, 1936, to Sept. 1, 1937	[7] ++	0	0	0
N-428, born Oct. 27, 1933: Calved May 5, 1936	Hand, May 5, 1936 to Feb. 27, 1937	0	0	0	0
	Mild machine, Feb. 28, 1937 to June 1, 1937	0	0	0	0
Calved Aug. 28, 1937	Mild machine, Aug. 31, 1937 to Sept. 1, 1938	+	0	0	[5] ++
N-429, born Nov. 1, 1933: Calved Mar. 15, 1936	Hand, Mar. 15, 1936 to Feb. 27, 1937	0	0	0	0
	Mild machine, Feb. 28, 1937 to Apr. 21, 1937	0	+	0	0
Calved Sept. 1, 1937	Mild machine, Sept. 3, 1937, to Nov. 1, 1938	0	0	[9] 0 to +++	0
N-431, born Apr. 29, 1934: Calved, Aug. 1, 1936	Hand, Aug. 1, 1936 to Apr. 12, 1937	0	0	0	0
	Severe machine, Apr. 13, 1937, to Aug. 1, 1937	0	0	0	0
Calved Oct. 27, 1937	Severe machine, Oct. 31, 1937, to Dec. 1, 1938	+	0	+	+
N-432, born Nov. 6 1934: Calved Jan. 12, 1937.	Hand, Jan. 12, 1937, to Feb. 1, 1938	0	0	0	0

[1] Intervening lactation omitted.
[2] Still milking Dec. 31, 1938.
[3] Nonfunctioning quarter.
[4] Severe symptoms did not appear until Nov. 1937; quarter went dry Nov. 17, 1937.
[5] Severe symptoms did not appear until Feb. 1938.
[6] Quarter still abnormal; it went dry Mar. 1937.
[7] Staphylococcus infection.
[8] Pseudomonas infection.
[9] Acute condition, possible injury.

In spite of the variations in the severity of mastitis found among the cows and the quarters of each cow, it is evident from the detailed data presented earlier on the chemical and bacteriological characteristics of the milk that in these studies both the incidence and severity of mastitis were much greater under conditions of machine milking at a vacuum of 16 inches than at reduced vacuum, and that hand milking resulted generally in the smallest changes in the composition of the milk and the least aggravation of udder infections. These conclusions are brought out more clearly and the effects of machine milking at 16 inches of vacuum on the severity of mastitis are emphasized further by the data in figure 3, which show the relationships of the different methods of milking to the severity of mastitis in individual quarters. These data represent results obtained during extended periods of complete lactations for 21 cows on which the

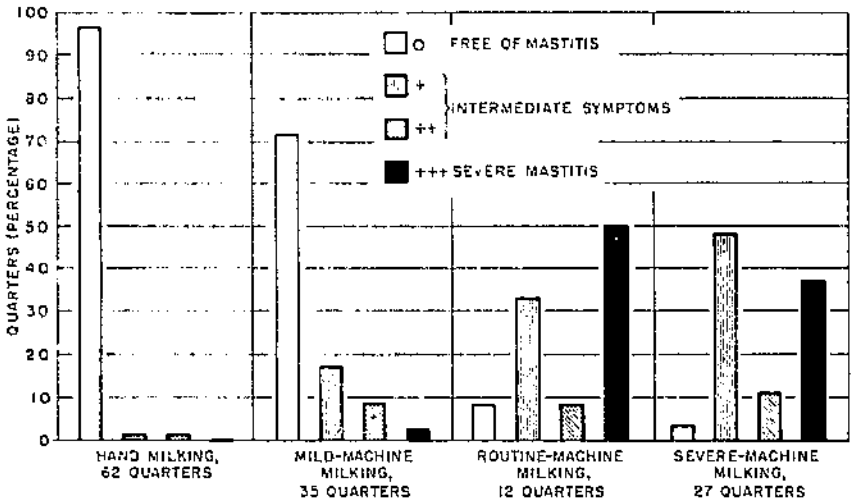


FIGURE 3.—Incidence and severity of mastitis among 21 cows that were on specified methods of milking for relatively long periods.

same method of milking was used for a long period and no frequent changes were made that might tend to distort the effects of the method in use at the time. The data show that the percentage of quarters that were free of symptoms was largest on hand milking, slightly less on mild-machine milking, and less than 10 percent on routine- and on severe-machine milking. The percentage of quarters that were mildly mastitic (+) increased on machine milking uniformly with the increase in the amount of vacuum and the length of time the vacuum was applied. Likewise, the proportion of quarters that developed severe mastitis (+++) on hand milking was zero, on mild-machine milking less than 3 percent, on routine-machine milking 50 percent, and on severe-machine milking 37 percent.

EFFECTS ON DIFFERENT METHODS OF MILKING AND OF MASTITIS ON THE YIELD OF MILK

Complete records of milk yields show that the method of milking had a significant effect on milk production in the cows that became mastitic. In determining the effect of the method of milking on milk yield, it is desirable to compare results only on cows that were kept on the particular method of milking for a large part or preferably all of a lactation.

Effects on the Yield of Milk

There were eight cows that completed two lactations each in which, during the major part of the first lactation, they were put on routine- or severe-machine milking and became mastitic; during the second lactation, six of these cows were on hand milking exclusively for the entire lactation, the seventh cow was on hand milking for 11 months and on mild-machine milking for 1 month, and the eighth cow was on hand milking for 2½ months and on mild-machine milking for 9½ months. All of the eight cows recovered either partly or completely during the second period. The yields of the eight cows for these two lactations are shown in table 12.

The periods during which the different methods of milking were used with these cows are shown in table 12 and also are given in detail in table 11. Routine-machine milking or severe-machine milking was the predominant method in the first experimental lactation, and hand milking was the predominant method in the second experimental lactation, except for cow N–219, in whose case mild-machine milking predominated.

In every case the yield of milk was greater and the decrease from the first to the twelfth month was less when the cows were milked chiefly by hand. The increases in yield in the second lactations varied from 1 percent to 160 percent, and the average increase was 60 percent.

Cow N–114 was a first-calf heifer when on routine-machine milking, and some increase in yield would be expected normally in the second lactation on hand milking. But her greater maturity when on hand milking fails to explain either the very great difference in yield or the greater persistence of yield. In the cases of the seven other cows, advances in age explain even less adequately the greater yield and persistence in the second lactation. There seems to be no explanation for these differences in yield and persistence except the injury and bacterial growth that developed on routine- and severe-machine milking and the tendency to recover from these conditions on hand milking, and also, in the case of cow N–219, on mild-machine milking.

It should be pointed out that in cows N–310, N–402, and N–404, the yields for the second lactations (hand milking) were obtained from only three functioning quarters in each case, since each of these cows had lost the use of one quarter because of mastitis during the earlier period on machine milking. In cow N–415, the yield for the second lactation was obtained from only two functioning quarters, and yet it was practically twice as much as during the earlier period when she contracted mastitis on machine milking. Thus, the in-

creases in yields in the second lactations of these cows are even more striking than is apparent from the data.

In addition to the eight cows whose yields of milk were compared for whole lactation periods (table 12), there were three other cows (N–106, N–238, and N–239) whose yields were studied while they were changed from severe-machine milking to hand milking within a single lactation period. In these cows, also, there was a slight tendency toward improvement in milk yield when the change to hand milking was made.

TABLE 12.—*Milk yields, in relation to the incidence and severity of mastitis, of 8 cows that were mainly on routine-machine milking for 1 complete lactation and then mainly on hand milking for a subsequent lactation* [1]

Cow, and calving dates	Method of milking and months on each method	Incidence and severity of mastitis [2]	Total yield	Yield in twelfth month as compared with that of first month
Cow N–114:			*Pounds*	*Percent*
July 31, 1935	Routine machine (7 months) and hand (5 months).	+ + +	6,206	10.0
Nov. 3, 1936	Hand (12 months)	+	16,142	47.7
Cow N–227:				
Feb. 16, 1935	Routine machine (12 months)	+ + +	11,039	7.2
July 10, 1937	Hand (12 months)	0	10,432	66.8
Cow N–310:				
Nov. 12, 1935	Routine machine (9 months) and mild machine (2½ months).	+ + +	5,362	0
Mar. 1, 1937	Hand (12 months)	+ + + +	[3] 5,448	39.5
Cow N–402:				
Jan. 19, 1935	Routine machine (12 months)	+ + + +	4,088	24.3
Oct. 22, 1936	Hand (12 months)	+ + + +	[3] 5,104	50.4
Cow N–404:				
May 29, 1935	Routine machine (12 months)	+ + + +	6,706	46.3
Nov. 15, 1936	Hand (12 months)	+ + + +	[3] 8,392	49.3
Cow N–415:				
Mar. 28, 1936	Hand (3½ months) and severe machine (3½ months).	+ + +	1,785	0
Aug. 10, 1937	Hand (12 months)	+	[4] 3,552	34.2
Cow N–419:				
Apr. 9, 1934	Routine machine (12 months)	+ + +	5,320	28.3
Apr. 7, 1936	Hand (11 months) and mild machine (1 month).	0	7,672	46.9
Cow N–219:				
Oct. 7, 1934	Routine machine (12 months)	+ + +	11,079	26.5
Aug. 30, 1936	Hand (2½ months) and mild machine (9½ months).	0	16,842	66.0

[1] Figures are for 12-month lactation periods, except for cows N–310 and N–415, whose yields were reduced to zero by mastitis before the end of the earlier lactation period.

[2] 0, no mastitis; increasing number of plus signs indicates increasing severity.

[3] Only 3 fully functioning quarters, since 1 quarter went dry early in the lactation because of mastitis in the previous lactation.

[4] Only 2 functioning quarters because of previous mastitis.

The yields of four cows that were milked by hand for most of one lactation and by the mild-machine method for a shorter period, and by the mild-machine method exclusively during all of the next lactation, are shown in table 13. Both the yield and the persistence of yield tended to be greater, on the average, in the first lactation than in the second. However, the persistence of yield in one cow (N–429) was greater on mild-machine milking than on hand milking, and cows N–419 and N–429 both gave slightly more milk on mild-machine milking. These results tend to corroborate the results of data given earlier, namely, that mild-machine milking is much less injurious than either routine- or severe-machine milking.

TABLE 13.—*Milk yields, in relation to the incidence and severity of mastitis, of four cows that were mainly on hand milking during one lactation period and then on mild machine milking during a subsequent lactation* [1]

Cow, and calving dates	Method of milking and months on each method	Incidence and severity of mastitis [2]	Total yield	Yield in twelfth month as compared with that of first month
Cow N–309:			*Pounds*	*Percent*
Apr. 30, 1936	Hand (10½ months) and mild machine (1½ months).	0	6, 162	40. 8
Aug. 23, 1937	Mild machine (12 months)	++	4, 227	13. 7
Cow N–419:				
Apr. 7, 1936	Hand (10 months) and mild machine (2 months).	0	7, 672	46. 9
Aug. 26, 1937	Mild machine (12 months)	++	7, 852	33. 8
Cow N–428:				
May 5, 1936	Hand (10 months) and mild machine (2 months).	[3] 0	8, 007	54. 9
Aug. 28, 1937	Mild machine (12 months)	++	6, 151	53. 1
Cow N–429:				
Mar. 15, 1936	Hand (11 months) and mild machine (1 month).	0 to +	8, 917	50. 5
Sept. 1, 1937	Mild machine (12 months)	0 to +++	9, 285	64. 3

[1] Cows were generally normal at end of first lactation on hand and mild-machine milking, but gradually developed symptoms of mastitis in the subsequent lactation on mild-machine milking.

[2] 0, no mastitis; increasing number of plus signs indicates increasing severity.

[3] High leucocyte counts but no other symptoms on mild-machine milking.

CHANGES IN THE MILK THAT ACCOMPANIED THE RECOVERY IN YIELD WHEN COWS WERE CHANGED FROM MACHINE MILKING TO HAND MILKING

Records of bacteriological and chemical tests of numerous udder-quarter samples of the milk of two of the cows (N–114 and N–227) whose milk records are shown in table 12, were obtained during both lactation periods. These data on cow N–227 are presented in table

2 for the earlier mastitic period on routine-machine milking and the later period on hand milking, and corresponding data on cow N–114 are presented in table 3. These records show that marked reductions in the number of leucocytes and streptococci and in the percentage of chlorides accompanied the greatly increased yields on hand milking.

Similar bacteriological and chemical records on the milk of the four cows changed from hand to mild-machine milking (yields shown in table 13) are presented in table 5. The small reduction in milk yield of two of these cows and the small increase in yield of the two others on mild-machine milking indicate that there was little or no effect on milk yield accompanying the symptoms of mastitis that developed—which were relatively slight and which did not occur until near the end of the second of the two lactations.

Figure 4 shows graphically the milk yield and the average chloride value of the milk of cow N–114 for the two lactations referred to in table 12. She developed a severe case of mastitis while on routine-machine

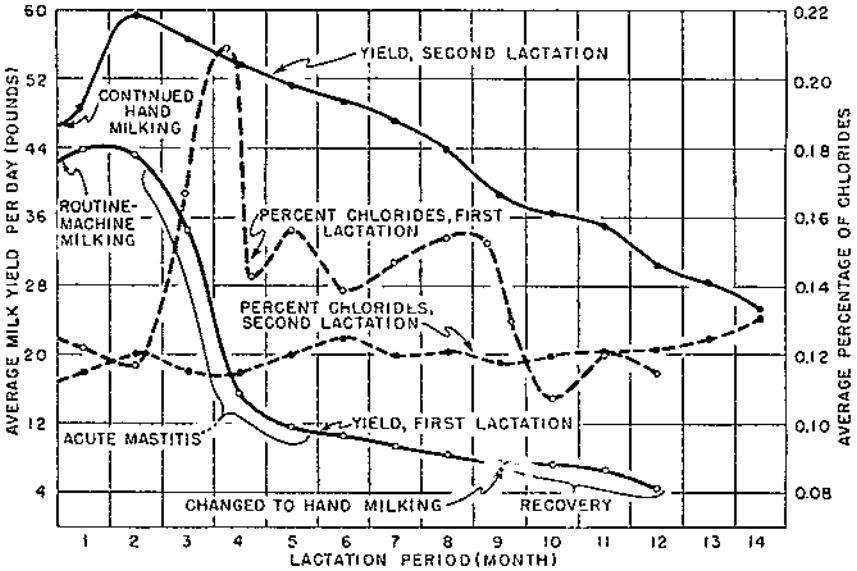


FIGURE 4.—Average yield of milk and percentage of chlorides in the milk of cow N–114 during two successive lactations, showing recovery from mastitis on hand milking.

milking during her first lactation. The acute, infective stage of the disease began during the third month and persisted in all quarters until the end of the fourth month. The milk from all quarters contained millions of *Streptococcus agalactiae* per milliliter and tens of millions of leucocytes; and the percentage of chlorides was higher than 0.17 in all quarters and as high as 0.24 in one quarter. During this period the milk yield decreased very abruptly to only 15 percent of the original yield.

Mastitic conditions remained severe in three of the four quarters until the cow was changed to hand milking in the ninth month. In

only one quarter did the characteristics of the milk improve during this time; this improvement occurred during the fifth month. During this period of a more or less chronic condition on machine milking, the rate of decrease in yield was arrested somewhat, but there was no recovery in yield.

Immediately after the cow was put on hand milking there was a definite improvement in the mastitic characteristics of the milk from the three quarters in which the symptoms had been most severe. The milk from the one quarter that improved during the fifth month showed some slight, further improvement, particularly in chloride values. The recovery in all four quarters progressed irregularly, but the milk from the three quarters mentioned above continued to contain several thousand streptococci per milliliter until the end of the lactation.

At the beginning of the second lactation this cow had recovered practically completely from her pathological condition. Throughout the second lactation, when she was on hand milking exclusively, the milk yield was normal and well sustained. No mastitis streptococci or other causal organisms were found in the samples of her milk. The only significant abnormality was a high chloride content, which increased to an average of slightly more than 0.13 percent during the last month of the lactation.

The chloride values shown in figure 4 illustrate in general the high range in the percentage of chlorides that was found in abnormal milk, the remarkable fluctuation that occurred in the percentage of chlorides as the acuteness of the mastitic condition changed, and the uniformity of chloride values in the milk of cows when their milk was normal in other respects. Our results are in accord with those of Davies (*6*), in which it was pointed out that mastitis is accompanied by a considerable increase in the percentage of chlorides in the milk, and also that the chloride values tend to increase slightly during the late part of a normal lactation.

DISCUSSION

The principal mastitis-causative organism found was *Streptococcus agalactiae*. All the cows that were studied during the detailed experiments that were begun in 1936 were exposed to this organism, and it was found in the milk of all the cows at one time or another. Likewise, this organism exclusively was responsible for nearly all the mastitic infections that occurred in the cows during most of 1935, 1936, and 1937. However, during part of 1937 and all of 1938, when the experimental tests were terminated, streptococci other than *S. agalactiae*, pseudomonades, and staphylococci were the significant causative organisms in the infections in a number of cows.

In spite of the fact that no attempt was made at that time to rid the herd of *Streptococcus agalactiae* by therapeutic treatments or by disposal of infected animals, the prevalence of this organism diminished greatly in the milk of most of the cows during the last 15 months of this study, and the number of serious cases of mastitis was reduced greatly. Although it is difficult to explain definitely the reduction of *S. agalactiae* infections and the general improvement of mastitic conditions in the herd during the last part of this study, it is apparent that the substitution of hand milking and machine milking at a

reduced vacuum for machine milking at 16 inches of vacuum alleviated greatly the mastitic condition of the cows that were infected seriously. Furthermore, it will be noted (fig. 2) that routine-machine milking was discontinued in August 1936, and that, with the exception of its use on 3 cows, severe-machine milking was discontinued in September 1937. Thus all but 3 in this herd of more than 40 cows, that freshened after September 1937, were milked either by hand or by the mild-machine method. Since it was shown that milking by hand—and similarly milking by machine at 12 inches of vacuum—produced only slight or no aggravation of the infected gland, it is not surprising that the mastitic conditions improved and that the chances of exposure to *S. agalactiae* were reduced greatly during the last 15 months of the experiments.

Streptococci other than *Streptococcus agalactiae*, consisting of *S. uberis*, species producing alpha hemolysis, and *S. fecalis*, were the initially causative agents in several of the cows on severe- and mild-machine milking, and were present prominently with *S. agalactiae* in the milk of cows N–106, N–222, N–238, N–424, and N–431 on severe-machine milking. They were the predominant infecting organisms in cows N–424 and N–431 toward the end of their lactations on severe-machine milking. It was found also that the predominant organism causing mastitis in cows N–106 and N–238 formed colonies that appeared visually to differ from the usual colony of *S. agalactiae*. However, physiological studies of the isolations from these atypical colonies showed them to be indistinguishable from *S. agalactiae*.

Other forms of bacteria were the causes of infection in the quarters of a few of the cows. *Pseudomonas aeruginosa* was the cause in the right front and right rear quarters of cow N–222 and in the left rear quarter of cow N–431 on severe-machine milking, and it was the cause in the left rear quarter of cow N–428 on mild-machine milking. *Staphylococcus aureus* was the cause in the right front quarter of cow N–427 on hand milking. She was the only heifer that developed a sustained infection on hand milking, and this infection disappeared during the dry period. Also, at the beginning of the second lactation, this cow was infected with *Staph. aureus* in the right rear quarter and with pseudomonades in the left rear quarter.

The colon-aerogenes group of bacteria was not found as a cause of infection in any of the quarters of the cows studied. The fact that these organisms, which are found commonly in manure and dirt, occurred in only one udder-quarter sample of milk among more than 2,000 that were studied in detail indicates that the precautions taken to prevent contamination of samples were followed vigilantly and were effective.

With the exception of the mixed streptococcal infections that occurred in the milk of several of the cows on severe-machine milking and the pseudomonadal infections in two other cows on severe-machine milking, no correlation was found in these studies between methods of milking and types of infection.

There was a definite relationship between the methods of milking and the frequency of occurrence of *Streptococcus agalactiae* in the milk. It was found in 56 percent of the samples from cows on routine-machine milking, in 35 percent of those from cows on severe-machine milking, in 10 percent of those from cows on mild-machine milking,

and in 7 percent of those from cows on hand milking. Likewise, there was a tendency among the cows on routine- and severe-machine milking for the number of *S. agalactiae* to increase in each successive sample tested and for the mastitic condition to become progressively worse until the number of streptococci reached a maximum. Subsequently, the infection and the mastitic condition became more or less chronic, but the pH of the milk continued to increase. In quarters showing a mild infection (+), the maximum number of streptococci generally reached several thousand per milliliter of milk. In the milk of many of the quarters that became severely affected (+++), the number of streptococci reached several million. On the other hand, in the milk of most of the cows on mild-machine milking and on hand milking, these streptococci occurred only occasionally, and there were rarely more than a few thousand per milliliter.

Among the 20 cows that were milked at some time by hand, all but 3 remained free of symptoms of streptococcal mastitis during the periods on hand milking, except for small numbers of *S. agalactiae* that were found occasionally. The three exceptions (N–310, N–402, and N–404) were cows in which streptococcal infections had persisted from infections incurred in previous lactations on routine-machine milking. It may be significant that these three exceptional cases, in which severe streptococcal mastitis occurred on hand milking, were old cows that had been on deficient rations for several years—rations that were particularly low in vitamin A.

As might be expected, the presence and increase in the number of causative organisms in developing infections usually preceded and less frequently accompanied an increase in the number of leucocytes and in the percentage of chlorides in the milk. An increase in the pH value of the milk to a value higher than 6.8 usually occurred after the peak of the infection or after the appearance of the maximum number of streptococci. However, in some cases there was a marked decrease rather than an increase in the pH value during the onset of acute mastitis. It is obvious, therefore, that the pH of the milk, whether determined by the brom-thymol-blue test or potentiometrically, is the least dependable of these criteria of symptoms in the early diagnosis of mastitis.

The milk of a number of cows contained an excessively high percentage of chlorides without the presence of infective organisms or other symptoms of mastitis. This occurred either among cows that had recovered from an infection incurred while they were on machine milking or among cows whose mammary tissues may have been injured slightly by machine milking but in which invasion of microorganisms had not occurred. It is apparent, therefore, that an abnormally high percentage of chlorides in milk can be due under some conditions to factors not related directly to infection and that the chloride test has less significance in the detection of infectious mastitis than either the leucocyte count or the presence of causative organisms.

Except under temporary conditions, numbers of leucocytes greater than 500,000 per milliliter were associated with the presence of an infection in most mastitic cases. On the other hand, the presence of causative organisms such as *Streptococcus agalactiae*—was not in

all instances indicative of an established infection. It was found in numbers greater than 1,000 per milliliter in the milk of some of the cows several weeks before other symptoms of mastitis appeared. In other cases it was present frequently in the milk in numbers greater than 1,000 per milliliter without the development of other abnormalities. These observations indicate that the time and conditions required for the establishment of foci of infection vary in different quarters and in different animals. The failure of *S. agalactiae*, when present, to increase progressively in numbers or to become established under such favorable conditions of nutriment and temperature as exists in the bovine udder may be explained either by the presence of inhibiting factors in the milk and in the blood of mammary tissue or by a lack of virulence of the organism present. It has been well established that milk exhibits a bactericidal property (*7*, *4*, *1*), and the presence of such a property in bovine blood serum has been reported (*1*).

The increased prevalence of mastitis and of severity of infection that occurred among the cows milked by machine at 16 inches of vacuum, as compared with the relative freedom from mastitis among the cows milked by hand or by machine at 12 inches of vacuum, indicates that there occurred either an injury, such as a physical impairment of the glandular tissue which permitted relatively easy invasion by bacteria into the secretory tissues, or a decrease in the resistance of the secretory tissue which caused a break-down of the protective mechanism, after which the invading organisms were able to multiply and cause infectious mastitis.

The causes of mastitis in general and of specific udder infections are subject to differences of opinion and are not completely understood. It is not the intent of this report, therefore, to indict machine milking as the cause of all mastitis in machine-milked herds. However, the views widely prevalent that mastitis is essentially a contagious disease and that the chief problems are those of eliminating *Streptococcus agalactiae* or of preventing its spread are inadequate, in the light of these results, as a basis for control of the disease. Injuries to the teats and udders undoubtedly play a significant role in the invasion by bacteria and in increased susceptibility to infection, and to that extent the use of the milking machine at 16 inches or more of vacuum is apparently a factor in provoking susbequent infection in a large proportion of cows that are milked under conditions similar to those described here.

SUMMARY

In a herd of cows that had been on routine-machine milking for several years and among which the incidence of mastitis had become very high, experiments were conducted to determine the effect of different methods of milking on the incidence of mastitis, as determined by the biological and chemical changes of the milk, and on the yield of milk.

Routine tests were made at frequent intervals throughout each lactation on udder-quarter samples of foremilk from all the cows included in this study. The tests included determination of the number of leucocytes and of *Streptococcus agalactiae* and other causal, in-

fective bacteria, and determination of the percentage of chlorides. However, strip-cup tests and other corroborative tests were used as an aid in the diagnoses.

Twenty-five cows were studied periodically on four different methods of milking, namely, routine-machine milking, severe-machine milking, mild-machine milking, and hand milking.

The incidence of mastitis, the decrease in milk yield resulting therefrom, and the accompanying changes in characteristics of the milk were in general proportional to the amount of vacuum in the machine and the length of time it was left working on the udder.

Considerable improvement resulted when cows with mastitis were changed from routine- or severe- to mild-machine milking; and particularly marked improvement or almost complete recovery resulted in most of the cows when they were changed to hand milking. When previously mastitic cows on good rations milked by the routine- or the severe-machine method were changed to mild-machine or hand milking- particularly the latter—the milk yield tended to return to the normal level; the number of leucocytes in the milk decreased markedly; the mastitis streptococci decreased in number but usually did not disappear immediately nor sometimes entirely; and the percentage of chlorides decreased to a level almost, but not quite, as low as that found in the milk of the same cows before they had mastitis. On apparent recovery, there usually remained some evidence of changes in the milk which might indicate remaining injury or induration of secretory tissue.

An abnormally high percentage of chlorides was usually present in the udder-quarter milk of normal cows on routine- or severe-machine milking even though the quarter never became mastitic. Likewise, this was a characteristic of the milk from cows which had recovered from severe mastitis in a previous lactation.

Numerous cases of mastitis were observed in which *Streptococcus agalactiae* either was absent from the milk or did not appear in significant numbers even though other indications of injury had become very evident. On the other hand, the milk from apparently normal cows frequently contained several thousand of this organism per milliliter without showing any other evidence of udder injury.

This report emphasizes the significance of the degree of udder injury caused by different methods of milking, evaluated by determining the changes occurring in the characteristics of the milk, and the effect of mastitis in decreasing milk yield and in causing the complete loss of the secretory function in individual quarters of the udder.

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