THE VARIABLES AFFECTING THE MILKING TIME IN MICHIGAN DHIA HERDS

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Robert Charles Knisely

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THE VARIABLES AFFECTING THE MILKING TIME

IN MICHIGAN DHIA HERDS

by

ROBERT CHARLES KNISELY

AN ABSTRACT

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

MASTER OF SCIENCE

Department of Dairy

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Approved______________________________

ABSTRACT ROBERT CHARLES KNISELY

The milking of cows is one of the most important and one of the most time consuming jobs in the operation of a dairy farm. Data for 737 Michigan DHIA herds were studied to determine what factors affected the rate of milking in these herds. In order to do this it was necessary to determine what criterion should be used to measure the variability of the factors that might affect the rate of milking.

By the use of correlation analysis it was determined that cows milked per man hour should be the criterion used to measure the overall efficiency of the milking operation. The distribution of this factor in the population studied was found to be nearly normal. For specific comparisons, the use of some other criterion may be desirable.

Using the above mentioned criterion, it was determined that herd size, type of housing, use of pipeline milkers, and the relationship between the number of operators and number of milking machines had a significant effect on the rate of milking ($P > .05$). It was also determined that breed, level of production, and make of milking machine did not have a significant effect on the rate of milking ($P < .05$).

From the small number of herds using any one of seven different types of milking parlors, no evidence could be found that any one type of milking parlor was superior. Only one herringbone parlor was included in the study.

The effect of the presence of the DHIA supervisor on the rate of milking was very slight, increasing the milking time by less than five minutes per milking.

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INTRODUCTION

The milking of cows is one of the most important jobs in the operation of a dairy farm. It is also one of the most time consuming. If the efficiency of the milking operation could be improved, it would be possible to make a substantial saving in time and money.

Before this saving can be accomplished, it is first necessary to determine what variables affect the rate of milking, and to evaluate the criteria used in determining the effect of these variables on the milking rate.

This study was designed to first ascertain the criteria to be used, and then to determine the effect and variability of these factors on the milking time or rate of milking in Michigan DHIA herds.

THE REVIEW OF LITERATURE

Variables Affecting the Rate of Milking

The literature pertaining to the milking of cows may be conveniently divided into six main categories: the cow, the man, the machine, the layout of the milking area, the relationship between the number of operators and the number of milking machines, and the relationship between the man and the cow.

The Cow

Genetic differences

At least three workers have found differences in the milking rates for cows of various breeds. Beck (3) found that under standard milking conditions the time required to milk Holstein, Jersey, Ayrshire, and Guernsey cows during peak production ranged from 2 to 7 minutes, with an average time of 3.5 minutes per cow. Seventy-six per cent of the cows milked out in less than 4 minutes, and 39% milked out in less than 3 minutes.

Beck (3) found that Holsteins milked the fastest, followed by Jerseys, Ayrshires, and Guernsey. Stewart *et al*. (37) conducted a similar experiment, ranking four breeds in the following order: Holstein, Jersey, Brown Swiss, and Guernsey. Carrulo (10) conducted an experiment involving Holsteins and Guernseys and found that the flow rates were faster for the Holsteins. From these results it appears that the milking rates of the five dairy breeds can be ranked (from fastest to slowest), Holstein, Jersey, Ayrshire or Brown Swiss, and Guernsey.

Inherent rate of milking was reported by Smith (35) to be one of the major factors affecting the rate at which a cow can be milked. Beck *et al*. (3) found that there were significant differences between flow rates and milking times for daughters of different sires. Ipsen (25) stated that there were large differences among the milk flow rates of daughters of different sires used in the Danish sire testing stations.

The among cow variations, for the milk flow rates, were reported by Dodd (15) to be very much greater than the within cow variations. Dodd and Foote (17) studied a large number of animals and found significant correlations between milking rates of dams and daughters, and between rates of sibs. From these observations they concluded that milking rate was inherited.

Level of production

A relationship between milk yield and milking rate was found to exist by Clough and Dodd (12) and Harshbarger (22). They reported that high producing cows milked at a faster rate than low producers. Foote (20) found the correlation between milk yield and duration of milking to be 0.429. He reported that the correlation for low producers was slightly lower. Sandvik (34) found a similar correlation, but when a correction was made for the effect of milk yield, he stated that the correlation between milk yield and flow rate was near 0.00. Thus, he concluded that slow milking cows were not necessarily low producers.

The teat sphincter

The role of the teat sphincter and its relation to the milking of cows has been reviewed by Hupp (24). He stated that many workers attribute to the teat sphincter the major role in determining the rate of milk flow under a given set of conditions.

Baxter and associates (2) have shown that most of the variation in the rate of milk flow between cows could be eliminated by cannulating the teat orifice, thus eliminating the effect of the sphincter. The average

peak flow rates were 2.25 pounds per minute for the cannulated teats and 1.98 pounds per minute for the teats milked with the standard teat cup.

Stage of lactation

The effect of stage of lactation on flow rate and milking time has been studied by several workers. Dodd (15) stated that as the interval since calving increased, peak flow rate and machine rate decreased, while machine time increased independently of yield changes. He found that the flow rate decreased as the lactation progressed, the fastest rate of decline being for the higher producing cows.

Stewart and Schultz (37) found that both milking rate and total duration of milking decreased significantly with advanced lactation. The milking times reported were 4.5, 3.4, and 2.8 minutes per cow during early, middle and late lactation, respectively.

Beck (3) found that flow rate and milking time both decreased as the lactation progressed. Harshbarger (22) reported that flow rate decreased along the same trend as the decrease in production. Whittlestone (43) reported this same trend, but suggested that this was offset by the decrease in production. The time gained by reduced production was partly offset by an increase in the time necessary for milk flow to start. He also found that the amount of strippings remained quite constant. Thus, the average total milking time of 4.37 minutes per cow remained quite constant.

The Man

The man has control of most of the environmental factors in the milking operation. It is obvious that there are differences among men, and that

these differences could greatly affect the efficiency of the milking operation.

Physical factors

Man has little control over his physical make-up. Morris (28-29) listed three factors--physical fitness, weight and the degree of fatigue--as being important in the milking operation. He found that height of the platform was also an important factor in elevated parlors. He stated that the height of the platform should be between 30 and 36 inches, depending on the height of the operator. Morris (28) stated that the ratio of time taken by the slowest worker to that taken by the fastest was considered to be in the order of 2, or 2.5 to 1. This was for performance of a single task under similar conditions. Other sources of variability could only increase this ratio. Parsons (30) also mentioned physical ability as an important factor in the milking operation.

Management factors

Man has control of, or can alter, many things affecting the milking operation. Four factors that can be controlled by man were listed by Williams (44): considerable variation in the things farmers consider it necessary to do, convenience of arrangement, adequacy of equipment, and the extent to which the work has been planned. Holms (23) and Fellows (19) stressed the development of a routine by the operator as being an important factor in improving the efficiency of the milking operation. Rorholm (33) suggested that the operator could improve his working methods by use of a planned routine. Work methods was a factor reported by Cargill (9) to cause a variation in the hourly return for labor.

The Machine

Prior to the invention of the milking machine, the cow and the man were the most important factors in the milking operation. The milking machine has taken much of the work out of the milking operation and has enabled the man to milk cows at a faster rate. The three primary adjustments that can be made on the machine are the level of vacuum, the pulsation rate and the ratio of vacuum to release of vacuum.

Vacuum level

Several workers (2, 21, 27, 36, 37, 39, 41) have studied the effect of various vacuum levels on flow rates and milking times. They used vacuum levels ranging from 10 to 20 inches of negative pressure, expressed in inches of mercury. These workers found that flow rate increased at a decreasing rate as the vacuum level was increased. Peak flow rates reported by Stewart and Schultz (38) were 4.2, 5.2, and 5.8 pounds per minute at 10, 12.5, and 15 inches of vacuum, respectively.

In general, there tended to be more strippings left in the udder when the higher vacuum levels were used. This seemed to be caused by increased "teat cup crawl" at the higher vacuum levels. In general, these workers concluded that it does not seem to be practical to increase the vacuum level beyond that recommended by the manufacturer for a specific type or make of machine.

Pulsation rate and ratio

The effect of pulsation rates, ranging from 20 to 80 per minute, on the rate of milking has been studied by several workers. Clough and Dodd (12), Stewart and Schultz (38, 39) and Smith and Petersen (36) all found

that milking rate increased as the pulsation rate was increased. The greatest increase was from 20 to 50 pulsations per minute and a slight increase was noted up to 80 pulsations per minute. Whittlestone (44) found no effect due to a change in pulsation rate.

Smith and Petersen (36) studied the effect of changing the pulsation ratio (the time ratio of the length of the release of vacuum to the vacuum period). They found that an increase could be obtained by widening the pulsation ratio to as much as 1 to 3. These workers suggested that the pulsation rate and ratio recommended by the manufacturer be used for each machine.

Layout of the Milking Area

Several workers (1, 7, 8, 9, 11, 18, 19, 23) have found that the yearly labor requirements tend to be about 120 hours per cow for conventional housing and 85 hours per cow for loose housing. A large portion of this difference seemed to be due to variations in the labor requirements for the milking operation. The milking time tended to be less in the elevated milking parlors, the difference being about four cows per man hour with the same number of machines. An additional increase of up to 10 cows per hour has been reported for each additional machine handled (6).

Parsons (30) found that several North Carolina farmers reduced their labor requirements for milking cows by more than 50% after the installation of elevated parlors and cow to can milkers; and, as a result, several farmers increased the size of their herds. Cargill (9) found that barn arrangement was one of the major factors responsible for a variation in the average hourly return for labor on farms studied.

Workers at Michigan State University (6) recently completed a study of the milking operations in several types of parlors and found considerable differences in milking rate, ranging from an average of 25 to 47 cows per man hour for the various arrangements. These results agree favorably with earlier data reported by Whittlestone (45) in New Zeeland.

Man-Machine Relationship

Morris (28, 29) reported that the most important factor affecting the rate of milking of cows was the number of milking machines handled. But as the number of milking machines per man increased, the efficiency at which he handled each machine decreased, the number of cows per hour per set of cups also decreased, and the time that the teat cups were on the cow tended to increase. Cullity (13) also found the latter to be true.

Man-machine balance

The variation in man minutes per cow and cows milked per milking unit hour was reported, by Morris (28), to be greater between the different man-machine balances than between different layouts with the same balance. He also found that the results from stanchion barns did not differ significantly from those for parlors. This was partly due to the limiting effect of the man-machine ratio, perhaps until it reaches 1:3, and also partly to the small number of returns received to his questionnaires.

Morris (28) stated that these results showed quite conclusively the depressing effect of a second man on the output per man hour in milking.

Following is a table compiled by Morris showing the man minutes per cow and cows per unit hour for different man-machine balances.

Man-machine Balance	Man Minutes per Cow	Cows per Unit Hour
1:1	5.9	12.3
2:2	8.0	8.1
2:3	4.8	9.1
1:2	4.4	7.0
2:4	4.4	6.8
1:3	3.2	6.5

Morris stated that as the number of machines per man decreased, the extra time was spent for longer preparation with an increase in idle machine time.

Baker and Bailey (1) suggested that one man should not attempt to operate more than two milking machines. Brayshaw (5) reported that the simplest and most easily corrected loss occurred when two men operated three bucket milkers; but, if one man was given a third machine, the cow was likely to be kept waiting for the man.

Cargill (9) found that, in a milking parlor, the number of milking machines per operator affected the cows milked per machine hour and machine efficiency. He also found that individuals operating more than two machines had a below average machine efficiency and fewer than average cows milked per machine hour. Figures from two farms with identical arrangements and equipment showed that two men milked at the rate of 8.9 cows per man hour and 82% machine efficiency, whereas one man in the same place averaged 16.5 cows per man hour with 87% machine efficiency.

Man-Cow Relationship

It is a generally accepted opinion that the man-cow relationship is very important. It has been shown by Ely and Petersen (31) that fright causes an immediate cessation of milk flow. Also, several other factors that are controlled by the man are important in the stimulation of the cow and the control of the let down hormone.

Stimulation of the cow prior to milking

Roark *et al*. (31) studied the variations of milking rates in response to different stimuli and reported that mechanical milking is more efficient if milk let down is stimulated before the milking machine is attached. They found that milking time could be shortened by as much as 27%, and that the amount of strippings could be reduced when massage and fore milking were performed. Fore milking alone was more effective than massage alone, but better performance was achieved when both were used together.

Several workers (16, 26, 32) have varied the temperature of the wash water from 45^{o}F. to 132^{o}F., but no differences could be detected in milking rate or flow rate due to variation in the temperature of the water.

Smith (35) reported that technique was the most important factor affecting the rate of milking. Ward and Smith (40) conducted an experiment to determine whether there were any differences in production when cows were milked at 4, 8, 12, 16 and 20 minutes after the application of a conditioned stimulus, as compared to 2 minutes after application of the same stimulus. They found that there was a highly significant decrease in production when cows were milked 12 or more minutes after stimulation. Whittlestone (43) reported that placement of the teat cups was the main stimulus factor. He also reported (42) that vigorous machine stripping produced the same result in the cows as hand stripping, mainly the secretion of more let down hormone.

EXPERIMENTAL PROCEDURE

Collection of the data

The first step in obtaining the information for this study was to prepare a questionnaire (see page 13), and mail several copies to all DHIA supervisors. They were instructed to complete one questionnaire for each herd while visiting the farm for the January, 1958 test. The completed questionnaires were returned with the monthly barn sheets to the DHIA-IBM tabulating center at Michigan State University.

Seven-hundred and eighty questionnaires were returned, but only 737 were complete enough to be used. Forty-three had to be discarded because they were incomplete. These 737 herds represented approximately 70 per cent of all Michigan DHIA-IBM herds as of that date.

Preparation of the data

The information from the sheets was coded and transferred to IBM cards. These cards were then collated with the monthly herd summary cards (card number 4) in order to combine the production data with the data on the milking operation.

The next step was to make some basic calculations that were needed for the analysis of these data. The computational formulae for these calculations are as follows:

1. Man hours per milking =

$$\text{Number of operators} \times \frac{\text{Milking time (min)}}{60}$$

2. Machine hours per milking =

$$\text{Number of machines} \times \frac{\text{Milking time (min)}}{60}$$

3. Average daily production per cow milked =

$$\frac{\text{Total daily production for the herd}}{\text{Number of cows milked}}$$

4. Cows milked per man hour =

$$\frac{\text{Number of cows milked (per milking)}}{\text{Man hours (per milking)}}$$

5. Pounds of milk milked per man hour =

$$\frac{\text{Total daily production for the herd}}{\text{Number of milkings per day} \times \text{Man hours per milking}}$$

6. Cows milked per machine hour =

$$\frac{\text{Number of cows milked (per milking)}}{\text{Machine hours (per milking)}}$$

7. Pounds of milk milked per machine hour =

$$\frac{\text{Total daily production for the herd}}{\text{Number of milkings per day} \times \text{Machine hours per milking}}$$

After these calculations were completed, it was necessary to make additional calculations for the statistical analysis.

Questionnaire mailed to DHIA supervisors

HOUSING AND MILKING PRACTICES SURVEY DHIA-IBM

County Number ________ Herd Number ________ Tester Code Number ________

Breed ________ Number of Cows ______ Cows Milked ______ Cows Dry ____

What type of housing is used? Loose Housing ______ Stanchion Barn ______

How do the cows stand in the barn? Face In _______ Face Out ____________

If this is a loose housing housing barn, what type of milking parlor is used? One Row Side Opening ______ Two Row Side Opening ________________

Tandem Walk Through _______ U. Shaped ____________________________

L. Shaped _________________ Herring Bone _________________________

Other (specify) ____

Are the cows and the operator on the same level? Yes ______ No ________

Milking Practices

Make of machine ________________ No. of single units used _______________

Number of persons doing the milking _______________________________________

Is a pipeline used? Yes ______________ No ____________________

How long does it take to milk on test day? (One Milking) _________________

How long does it take to milk on any other day? (One Milking) ____________

Is the operator doing any other chores while milking? Yes ____ No ______

If yes, please explain briefly what else is being done. __________________

____

____

____

____

RESULTS AND DISCUSSION

The results of this study will be presented in the following order. First, the results of a survey of the 737 herds included in the study will be presented. From the results of this survey, four factors will be chosen as possible criteria to be used in further analysis of these data. From these four criteria, one will be selected to be used in determining the variability of several factors that may affect the rate of milking. The distribution of this factor in the population will then be shown. An analysis of these data will then be presented, using the above mentioned criterion.

A Survey of the Data

The first step in analyzing the data in this study, was to make a survey of several factors within the population. The means for these factors are shown in Table 1 (page 15).

The four factors selected from Table 1 to be used in measuring the efficiency of the milking operation are:

1. Cows milked per man hour.
2. Cows milked per machine hour.
3. Pounds of milk milked per man hour.
4. Pounds of milk milked per machine hour.

Table 1

THE MEANS FOR SEVERAL FACTORS RELATED TO THE MILKING OPERATION IN 737 MICHIGAN DHIA HERDS

	Mean	Standard Deviation of the Mean
Cows milked per man hour	14.4	0.2
Cows milked per man hour (on test day)	12.3	
Cows milked per machine hour	7.2	0.1
Milk milked per man hour (lbs)	233.1	4.1
Milk milked per machine hour (lbs)	115.9	1.6
Total cows (per herd)	27.2	
Cows milked (per herd)	22.9	0.4
Daily milk production (lbs per cow milked)	32.3	0.3
Men milking (per herd)	1.4	
Milking machines (per herd)	2.5	
Milking machines (per man)	1.9	
Cows milked per milking machine	9.1	

Selecting a Criterion of Efficiency

In order to determine which of the above four criteria should be used to determine the variability of factors affecting the rate of milking, two basic questions had to be answered. Cows are the producing unit, but milk is the saleable product; therefore, should the number of cows milked or pounds of milk milked be the basic unit used in making these comparisons?

Cows are milked by machines, but the machines are operated by men; therefore, should man hours or machines hours be used to measure the efficiency of the milking operation?

In order to answer these questions, correlations were made among the four criteria selected, level of production, and herd size. The results of this correlation analysis appear in Table 2 (page 17).

When pounds of milk milked per man hour and cows milked per man hour were correlated, the resulting coefficient was 0.87. This indicates that these factors are highly dependent on each other.

Cows milked per man hour, and cows milked per machine hour were correlated with level of production. The resulting coefficients were 0.05 and -0.01, respectively. Neither one was significantly different from 0.00 ($P < .05$). This indicates that the number of cows milked per man or machine hour is not dependent on level of production.

When pounds of milk milked per man hour and cows milked per machine hour were correlated with level of production, the resulting coefficients were 0.48 and 0.59, respectively. Both of these coefficients were significantly greater than 0.00 ($P > .01$). This indicates that the pounds of milk milked per man or machine hour is dependent on level of production.

These results indicate that cows milked per man or machine hour is a superior measure of overall efficiency because it is not dependent on level of production. Therefore, by using cows milked per man or machine hour as the efficiency criterion, the milking operation in herds of various production levels can be compared directly.

Man hours are much more expensive than machine hours in the milking operation. Thus, from an economic standpoint, comparisons of milking

<u>Table 2</u>

LINEAR CORRELATION COEFFICIENTS FOR SIX FACTORS

RELATED TO THE MILKING OPERATION

	Cows Milked Per Man Hour	Milk Milked Per Man Hour (lbs)	Cows Milked Per Machine Hour	Milk Milked Per Machine Hour (lbs)	Average Daily Production Per Cow Milked	Number of Cows Milked
Cows milked per man hour	1.0000	0.8656	0.4934	0.4146	0.0516	0.3738
Milk milked per man hour (lbs)		1.0000	0.4012	0.6366	0.4847	0.3594
Cows milked per machine hour			1.0000	0.7805	0.1446	-0.0080
Milk milked per machine hour (lbs)				1.0000	0.5921	0.1764
Average daily production per cow milked					1.0000	0.1576
Number of cows milked						1.0000

efficiency should be made on a man hour basis. The correlation analysis showed a positive relationship between measurements made on a man hour basis and those made on a machine hour basis, but these correlations were not large enough to warrant the use of machine hours as a measure of overall efficiency in the milking operation.

The previous determination, that cows milked should be the basic unit used and that man hours should be the factor used in measuring the efficiency of the milking operation, indicates that cows milked per man hour should be the criterion used to measure the overall efficiency of the milking operation. When making specific comparisons, such as comparing different makes of milking machines, the use of some other criterion may be desirable.

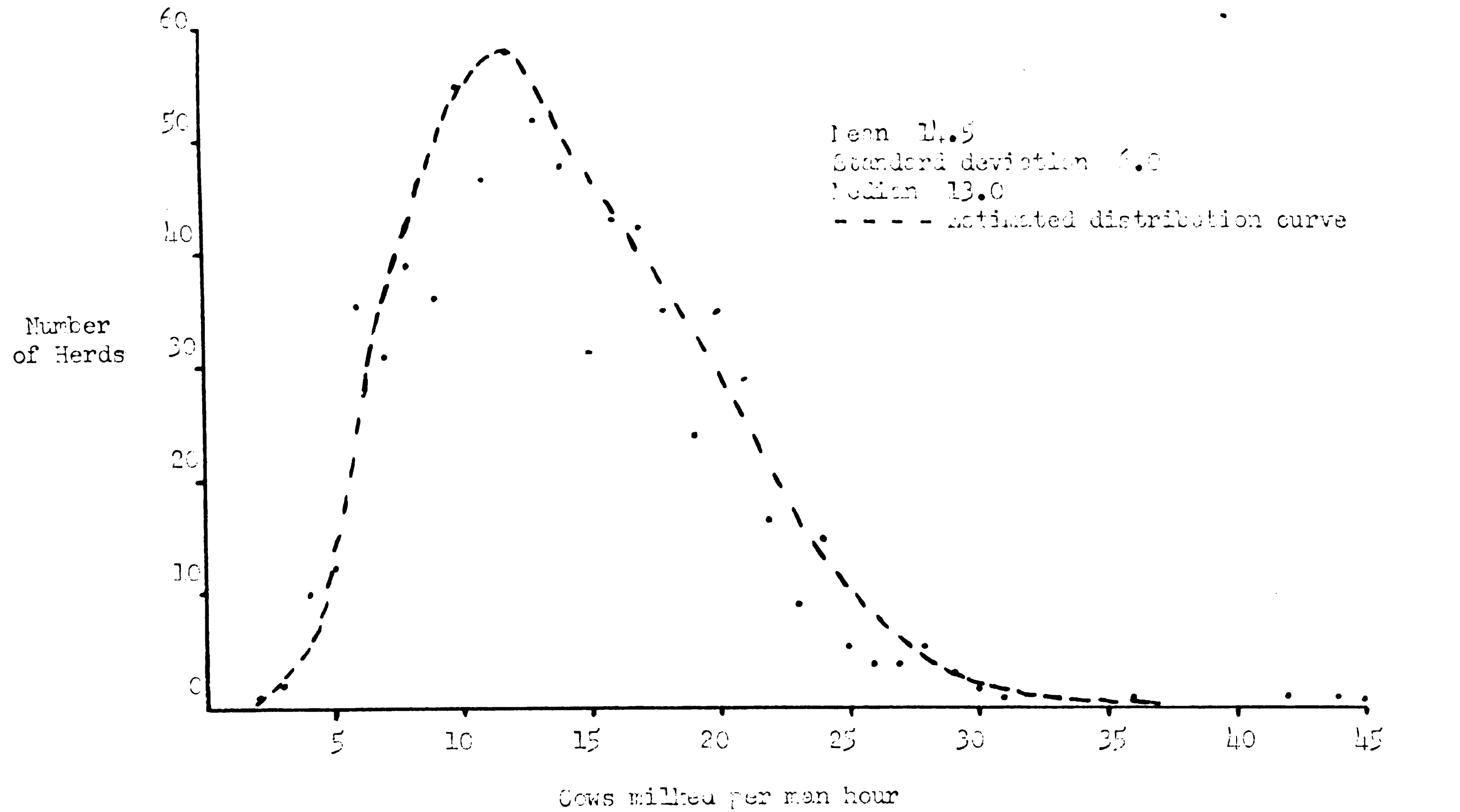
Distribution of the Herds

From the previous analysis it was determined that cows milked per man hour should be used to measure the variability of factors affecting the rate of milking. Before using this factor in the statistical analysis, a frequent distribution was made in order to determine the normality of the distribution within the population. The frequency distribution curve is shown in Figure 1.

The frequency distribution appears to be nearly normal. It is skewed slightly to the left, as would be expected, because the lower limit of the rate of milking is much closer to the mean than the upper limit.

Figure 1

The frequency distribution of cows milked per man hour in 737 DHIA herds.



Factors That May Affect the Rate of Milking

The factors, appearing in this study, that could affect the rate of milking in Michigan DHIA herds were: 1) breed, 2) level of production, 3) make of milking machine, 4) type of housing, 5) herd size, 6) type of milking parlor, 7) pipeline milkers, 8) the relationship between various numbers of operators and milking machines, and 9) the DHIA supervisor. The data obtained in this study were analyzed to determine the variability of these factors in relation to the milking operation.

The unequal sub-class numbers and non-homogeneity of variances made it impossible to accurately test for interactions among the above groups. Thus, each classification was analyzed separately and the means were tested for equality by the use of the Student's T-test, as outlined in Chapter 9 of Dixon and Massey (14).

Breed

All herds were classified into one of five breed groups. These were Guernsey, Holstein, Jersey, Mixed, and the 4% breeds. The latter group consisted of the Ayrshire, Brown Swiss, Red Dane and Milking Shorthorn breeds. This grouping was made due to the similarity of fat test of the milk and the small number of herds in any one of these breeds. The data for the five breed groups are shown in Table 3 (page 21).

The average number of cows milked per man hour was not significantly different for the various breed groups ($P < .05$). But the mean for the Holstein group was greater than that for the 4% group ($.05 < P < .01$). This may be due to some factor caused by combining the four breeds into one group. These results indicate that breed is not a factor determining the number of cows that are milked per man hour in Michigan DHIA herds.

Table 3

COWS MILKED PER HERD, LEVEL OF PRODUCTION, AND COWS MILKED PER MAN HOUR FOR HERDS OF FIVE BREED GROUPS

	Guernsey	Holstein	Jersey	Mixed	4% Breeds
Number of herds	87	501	33	80	36
Cows milked per herd	19.8	23.7	24.1	23.0	19.4
Production per cow per milking (lb.)	12.3	17.6	10.6	14.6	14.2
Cows milked per man hour	13.7	14.7	14.8	13.7	12.8
Standard deviation of mean (cows milked/man hour)	0.7	0.3	0.9	0.8	0.9

Level of production

The herds were divided into three groups based on level of production, the high, the middle, and the low group. The level of production for each group is shown in Table 4 (page 22), along with the average number of cows milked per man hour.

The average number of cows milked per man hour was not significantly different for the three groups ($P < .05$). This supports the results of the correlation analysis which showed no relationship between level of production and cows milked per man hour. These data indicate that level of production does not affect the number of cows milked per man hour in the average Michigan DHIA herd.

Table 4

COWS MILKED, LEVEL OF PRODUCTION, AND COWS MILKED PER MAN HOUR FOR HERDS OF THREE PRODUCTION LEVELS

	High Third	Middle Third	Low Third
Number of herds*	245	245	245
Milk production per cow per milking (lb.)	20.2	16.2	12.1
Cows milked per man hour	14.8	14.4	13.9
Standard deviation of mean (cows milked/man hour)	0.4	0.3	0.4

*Two herds were discarded at random in order to have an equal number of herds in each group.

Make of milking machine

Several makes of milking machines are used in Michigan DHIA herds. In order to determine whether the make of machine affects the efficiency of the milking operation, the various makes of machines were compared. A comparison was made, using cows per machine hour and pounds of milk milked per machine hour, as well as cows per man hour, in order to determine differences in machine efficiency.

Surge, DeLaval or Chore Boy machines were used in 86% of the herds in this study. Eight other makes of machines were used in 12% of the herds. In the remaining 2% a combination of two makes of machines were used, or a combination of machine and hand milking. Due to sampling error, adequate comparisons could not be made for any machine being used in less than 5% of the herds; thus only the first three mentioned machines were compared. These data are shown in Table 5 (page 23).

There were no significant differences ($P < .05$) between the three makes of machines for any of the three factors mentioned above. The means and their standard deviations are shown in Table 5. These data indicate that make of machine does not affect the efficiency of the milking operation ($P < .05$) in Michigan DHIA herds.

Table 5

COWS MILKED PER MAN HOUR, COWS MILKED PER MACHINE HOUR, AND POUNDS OF MILK MILKED PER MAN HOUR FOR THREE MAKES OF MILKING MACHINES

	Surge	DeLaval	Chore Boy
Number of herds	467	121	44
Cows milked per man hour $\pm S_{\bar{x}}$*	14.9 ± 0.7	13.9 ± 1.3	12.7 ± 1.9
Cows milked per machine hour $\pm S_{\bar{x}}$*	7.4 ± 0.3	7.2 ± 0.7	6.9 ± 1.0
Milk milked per machine hour (lbs.) $\pm S_{\bar{x}}$*	119.4 ± 5.5	117.0 ±10.6	117.3 ±17.7

* $S_{\bar{x}}$ = Standard deviation of the mean

Milking arrangement

The type of milking arrangement is largely determined by the type of housing, and is also affected to a certain extent by herd size. In general, cows housed in a stanchion barn are milked in stanchions. Cows housed in a loose housing barn are generally milked in a milking parlor, usually an elevated parlor. The data also show that where loose housing is used, herds tend to be larger. In some instances a combination of the two types of housing is used. This is referred to in this study as a switch barn. In this type of arrangement the cows are usually milked in shifts in the stanchions. Thus, type of housing will be used synonymously with type of milking arrangement for this portion of the study.

The data for the different types of housing are shown in Table 6. It should be noted that the levels of production for these groups are nearly equal.

The number of cows milked per man hour were significantly different ($P > .05$) for all three groups; however, the difference between stanchion and switch barns was not significant ($.05 < P < .01$).

Table 6

COWS MILKED PER HERD, LEVEL OF PRODUCTION, AND COWS MILKED PER MAN HOUR FOR HERDS IN THREE TYPES OF HOUSING

	Stanchion Barns	Loose Housing	Switch Barns
Number of herds	594	119	24
Cows milked per herd	21.1	31.9	23.5
Production per cow per milking (lb.)	16.2	16.4	16.2
Cows milked per man hour	13.7	17.5	16.1
Standard deviation of mean (cows milked/man hour)	0.2	0.7	1.0

Type of milking parlor

The number of loose housing herds using each type of parlor was relatively small, and the variances were quite large and unequal. Therefore, they were not compared by use of the T-test.

Ninety-five per cent confidence intervals were constructed around the means. A comparison was then made to determine the extent to which the intervals around the means overlapped. A considerable amount of overlapping was shown and no single type of parlor was shown to be more efficient than the others. The data for the different parlor types are shown in Table 7. Only one herringbone parlor was included in this study.

Table 7

COWS MILKED PER MAN HOUR FOR SEVEN TYPES OF MILKING PARLORS

Type of Parlor	Number of Herds	Cows Milked Per Man Hour	Standard Deviation of Mean (Cows)
One row side opening	40	16.7	0.8
Two row side opening	9	22.9	4.8
Tandem walk through	27	18.6	1.5
U shaped	12	17.9	3.3
L shaped	1	23.0	-
Herringbone	1	24.0	-
Stanchion parlors	29	15.3	1.5

Pipeline milkers

Pipeline milkers were used in 42% of the milking parlors. The number of cows milked per man hour was significantly greater ($P > .05$) in the parlors using pipeline milkers. When the variances for the two groups were compared, the variance for the parlors having a pipeline milker was found to be greater ($P > .01$). These data are shown in Table 8 (page 26).

Herd size

The herds were divided into three groups based on herd size, the high third, middle third, and low third. The data for these groups are shown in Table 9 (page 26).

Table 8

HERD SIZE, LEVEL OF PRODUCTION, AND COWS MILKED PER MAN HOUR IN MILKING PARLORS WITH AND WITHOUT PIPELINE MILKERS

Number of herds	Pipeline	No Pipeline
Number of herds	50	69
Number of cows milked	40.5	25.6
Production per cow per milking (lb.)	16.5	16.2
Cows milked per man hour	20.4	15.4
Standard deviation of mean (cows milked/man hour)	1.4	0.7

Table 9

COWS MILKED, LEVEL OF PRODUCTION, AND COWS MILKED PER MAN HOUR FOR HERDS OF DIFFERENT SIZES

	High Third	Middle Third	Low Third
Number of herds*	245	245	245
Cows milked per herd	34.9	21.0	12.9
Production per cow per milking (lb.)	16.9	15.9	15.7
Cows milked per man hour	16.8	14.3	12.1
Standard deviation of mean (cows milked/man hour)	0.4	0.3	0.3

*Two herds were discarded at random in order to have an equal number of herds in each group.

Results of the statistical analysis showed that the number of cows milked per man hour in the different groups were significantly different ($P < .05$). The correlation analysis (see Table 1) showed the correlation between herd size and cows milked per man hour to be 0.37. These results indicate that the rate of milking is faster in larger herds. It should be noted in Table 6 that the herd sizes are different for the three types of housing. This undoubtedly also influences the rate of milking in these three groups.

Man-machine balance

A series of two-way tables, Numbers 10, 11, 12, and 13, were constructed to analyze the differences due to man-machine balances. From these tables the effect of the different man-machine relationships on the efficiency of the milking operation can be observed. As the number of operators increased, the total number of cows milked increased, but the output per man hour decreased sharply. As the number of units per man increased, the output per man hour increased; however, the output per machine hour decreased. This held true for both pounds of milk and number of cows.

These results indicate a depressing effect of the second man on the efficiency of the milking operation. The efficiency at which each machine is operated decreased as the number of machines per operator increased. From these results it seems that the efficiency of the milking operation is ultimately dependent on the number of machines operated and the efficiency at which they are operated.

Table 10

DISTRIBUTION OF 737 MICHIGAN DHIA HERDS ACCORDING TO THE NUMBER OF MEN MILKING AND NUMBER OF MILKING MACHINES USED

Number of Machines Used	Number of Men Milking				
	1	2	3	4	Total
1	18	5			23
2	304	76	1		381
3	159	99	7	1	266
4	14	38	4		56
5		1	2		3
6	1	3	3		7
7		1			1
Total	496	223	17	1	737

Table 11

AVERAGE NUMBER OF COWS MILKED PER HERD FOR THE DISTRIBUTION OF HERDS AS SHOWN IN TABLE 10

Number of Machines Used	Number of Men Milking				
	1	2	3	4	Total
1	7.8	11.6			8.7
2	17.8	19.4	27.0		18.1
3	26.7	27.0	23.0	25.0	26.7
4	36.5	34.9	43.8		35.9
5		25.0	48.0		40.3
6	98.0	49.7	57.7		60.0
7		139.0			139.0
Total	20.9	26.2	37.2	25.0	22.9

Table 12

COWS MILKED PER MAN HOUR FOR THE DISTRIBUTION
OF HERDS AS SHOWN IN TABLE 10

Number of Machines Used	Number of Men Milking				
	1	2	3	4	Total
1	8.4	6.6			8.0
2	15.0	7.8	6.8		13.5
3	19.9	10.5	5.8	4.2	16.0
4	22.3	12.5	9.1		14.7
5		18.8	9.8		12.8
6	49.0	14.1	14.8		19.4
7		19.9			19.9
Total	16.6	9.9	8.7	4.2	14.4

Table 13

COWS MILKED PER MACHINE HOUR FOR THE DISTRIBUTION
OF HERDS AS SHOWN IN TABLE 10

Number of Machines Used	Number of Men Milking				
	1	2	3	4	Total
1	8.4	13.2			9.4
2	7.5	7.8	10.1		7.6
3	6.6	7.0	5.8	5.6	6.7
4	5.6	6.2	6.8		6.1
5		7.5	5.9		6.4
6	8.2	4.7	7.4		6.4
7		5.7			5.7
Total	7.2	7.2	6.6	5.6	7.2

The DHIA Supervisor

The effect of the DHIA supervisor on the rate of milking was found by comparing the means for cows milked per man hour on test day and cows milked per man hour on other days. The comparison indicates that the milking time is increased by 4.7 minutes per milking when the DHIA supervisor is weighing the milk and taking samples.

SUMMARY AND CONCLUSIONS

A survey was made of the milking operation in 737 Michigan DHIA herds. The results of this survey indicate that the average Michigan DHIA member milks his cows at the rate of 14.4 cows per man hour. In the average herd there were 23 cows milked, producing an average of 32.7 pounds of milk per day. The milking time was about 5 minutes longer per milking on test day.

Correlations were made among six factors related to the milking operation. The results of this analysis indicate that cows milked per man hour should be the criterion used to measure the overall efficiency of the milking operation. It may be desirable to use another criterion when making some specific comparisons.

The distribution of cows milked per man hour, in the population, was found to be nearly normal. It was skewed slightly to the left because the slowest milking rates were closer to the mean than the fastest milking rates.

Several factors affecting the rate of milking were studied, using cows per man hour as the criterion of efficiency. The study indicated that herd size, type of housing, use of pipeline milkers, and the relationship between the number of operators and the number of milking machines had a significant effect on the rate of milking in Michigan DHIA herds ($P > .05$). The factors that did not affect the rate of milking

($P < .05$) were breed, level of production, and make of milking machine.

In order to compare the efficiency of the different makes of milking machines directly, comparisons were also made using cows milked per machine hour and pounds of milk milked per man hour as measures of efficiency. No significant differences were found ($P < .05$).

The milking rates for seven types of milking parlors were compared by constructing 95 per cent confidence intervals about the means. The confidence intervals all overlapped considerably, indicating that no single type of parlor was superior. Only one herringbone parlor was included in the study.

The effect of the presence of the DHIA supervisor was found to be very slight. The milking time, per milking, was increased by less than five minutes when the supervisor was weighing the milk and taking samples.

LITERATURE CITED

(1) Baker, R. H., and Bailey, R. A., "Plan Dairy Chores," Ohio Agr. Exp. Sta. Res. Bul. 706. 1952.

(2) Baxter, E. S., Clarke, P. M., Dodd, F. H., and Foot, A. S., "Factors Affecting the Rate of Machine Milking," J. Dairy Res. 17:117. 1950.

(3) Beck, G. H., Fryer, H. C., and Atkeson, F. W., "Variations in the Response of Dairy Cows to a Standard Method of Machine Milking," J. Dairy Sci. 34:598. 1951.

(4) Beck, G. H., Fryer, H. C., and Roark, D. B., "Use and Interpretation of Milk Flow Curves in Measuring Variations in the Response of Cows to Machine Milking," J. Dairy Sci. 34:58. 1951.

(5) Brayshaw, C. H., "Men, Milk and Machines," J. Ministry of Agr. 62:445. 1955.

(6) Brown, B. A., Snyder, W. W., Hoglund, C. R., and Boyd, J. S., "Labor Requirements for Herringbone and Other Milking Systems," M.S.U. Quart. Bul. 41:905. 1959.

(7) Byers, G. B., "Effect of Work Methods and Building Designs on Building Costs and Labor Efficiency for Dairy Chores," Ky. Agr. Exp. Sta. Bul. 589. 1952.

(8) Byers, G. B., "Three Types of Dairy Housing Compared," Purdue Work Simplification Newsletter. 22:19. 1951.

(9) Cargill, B. F., "Methods Engineering Analysis of Loose Housing Dairy Barns," M. S. Thesis, Dept. of Agr. Engr., M.S.C. 1952.

(10) Caruolo, E. V., Dembiczak, C. M., Mochrie, R. D., Johnson, R. E., Eaton, H. D., Spielman, A. A., and Beall, G., "Effects of Vacuum Level and Milking Duration on Guernseys and Holsteins Differing with Respect to Lactation Number and Status of Udder Health. II. Milk Yield, Milking Time, and Rate of Milk Flow," J. Dairy Sci. 38:1283. 1955.

(11) Cleaver, T., "Time-Travel Studies on Dairy Farms," Agr. Engr. 33:137. 1952.

(12) Clough, P. A., and Dodd, F. H., "The Relationship Between Milk Secretion and Rate of Milking by Machine," J. Dairy Res. 24:152. 1957.

(13) Cullity, M., "The Rate of Milking with Machines," J. Agr. of W. Australia, 2nd. Series. 26:99. 1949.

(14) Dixon, W. J., and Massey, F. J., "Introduction to Statistical Analysis," Second Edition, McGraw-Hill, New York. 1957.

(15) Dodd, F. H., "Normal Variations in the Rate of Machine Milking," J. Dairy Res. 20:301. 1953.

(16) Dodd, F. H., and Foot, A. S., "Experiments in Milking Technique: 1. Effect of Washing the Udder with Hot Water, 2. Effect of Reducing Milking Time," J. Dairy Res. 15:1. 1948.

(17) Dodd, F. H., and Foot, A. S., "The Importance of Milking Machine Rate in Dairy Cow Management and Breeding," J. Dairy Res. 20:138. 1953.

(18) Dum, S. A., "Dairy Practices, Costs, and Returns, in New Castle County, Delaware," U. of Del. Agr. Exp. Sta. Bul. 294. 1952.

(19) Fellows, I. F., Frick, G. E., and Weeks, S. B., "Production Efficiency on New England Dairy Farms: 1. A Preliminary Appraisal of Cost Reduction Opportunities," Conn. Storrs Agr. Exp. Sta. Bul. 283. 1952.

(20) Foot, A. S., "The Rate of Milking by Machine," J. Dairy Res. 6:313. 1935.

(21) Gregorie, A. T., Mochrie, R. C., Elliott, F. I., Eaton, H. D., Spielman, A. A., and Beall, G., "Effect of Vacuum Level and Milking Duration on Milk Production, Milking Time and Rate of Milk Flow in Mastitis Free First Calf Heifers," J. Dairy Sci. 37:276. 1954.

(22) Harshbarger, K. E., "Observations on the Rate of Milk Removal," J. Dairy Sci. 33:382. 1950.

(23) Holms, J. C., "Efficient Dairy Chore Practices. 1. Chore Travel in Dairy Barns," U. of New Hampshire Agr. Exp. Sta. Circ. 72. 1946.

(24) Hupp, E. W., "Some Factors Associated with the Rate of Milk Flow in Dairy Cattle," Ph.D. Thesis, Dept. of Dairy, M.S.U. 1958.

(25) Ipsen, E. J., "Personal Communication." 1959.

(26) Knoop, C. E., and Monroe, C. F., "Influence of Pre-milking Preparations of Cows' Udders Upon the Let-down of Milk," J. Dairy Sci. 33:623. 1950.

(27) Mochrie, R. D., Hale, H. H., Dembiczak, C. M., Eaton, H. D., Plastridge, E. N., Johnson, R. E., and Beall, G., "Effects of Vacuum Level and Milking Duration on Guernseys and Holsteins Differing with Respect to Lactation Number and Status of Udder Health. 1. Udder Health," J. Dairy Sci. 38:1273. 1955.

(28) Morris, W. H. M., "The Milking of Cows. A Methods Study," Ph.D. Thesis, Cornell University, Sept. 1953.

(29) Morris, W. H. M., and Boyd, L. L., "Efficiency of the Milking Operation," Agr. Engr. 36:595. Sept. 1955.

(30) Parsons, G. S., "Increasing Efficiency on Farms Producing Milk for Manufacturing Purposes," Paper E6 presented at the 53rd Annual Meeting of the American Dairy Science Assn., J. Dairy Sci. 41:751. 1958.

(31) Ely, F., and Petersen, W. E., "Factors Involved in the Ejection of Milk," J. Dairy Sci. 24:211. 1941.

(32) Roark, D. B., Beck, G. M., and Fryer, H. C., "Differences in Response Under Prescribed Variations in Methods Employed to Stimulate Milk Let-down," J. Dairy Sci. 35:1017. 1952.

(33) Rorholm, N., and Eugene, S. A., "Use of Man-machine Analysis in Improving Milking Routine," Purdue Work Simplification Newsletter, 22:20. 1951.

(34) Sandvik, Cysten, "The Relationship Between Milking Rate and Milk Yield," J. Dairy Res. 24:316. 1957.

(35) Smith, G. J., "Some Factors Affecting Rate of Machine Milking," Australian J. of Dairy Tech. 9:3. 1954.

(36) Smith, V. R., and Petersen, W. E., "The Effect of Increasing Negative Pressure and Widening the Vacuum Release Ration on the Rate of Removal of Milk from the Udder," J. Dairy Sci. 29:45. 1946.

(37) Stewart, W. E., Schultz, L. H., and Coker, S. P., "Studies on the Rate of Machine Milking of Dairy Cows: 1. Normal Variations," J. Dairy Sci. 40:258. 1957.

(38) Stewart, W. E., and Schultz, L. H., "Effect of Vacuum and Pulsation Rate on Rate of Milking," Abstract P-28, J. Dairy Sci. 39:926. 1956.

(39) Stewart, W. E., and Schultz, L. H., "Rate of Machine Milking of Dairy Cows: II. Effect of Vacuum and Pulsation Rate," J. Dairy Sci. 41:849. 1958.

(40) Ward, G. M., and Smith, V. R., "Total Milk Production as Affected by Time of Milking After Application of a Condition Stimulus," J. Dairy Sci. 32:17. 1949.

(41) Whittlestone, W. G., How, C., "A Survey of Machine Milking," New Zealand J. Agr. 73(5):441. 1946.

(42) Whittlestone, W. G., "Studies on Milk-Ejection in the Dairy Cow. The Effect of Stimulus on the Release of the 'Milk-Ejection' Hormone," New Zealand J. Sci. Tech. 32A:1. 1951.

(43) Whittlestone, W. G., "The Characteristics of the Milk-Ejection Curve of Normal Dairy Cows Under Standard Milking Conditions," New Zealand J. Sci. Tech. 28A:188. 1946.

(44) Whittlestone, W. G., "The Effect of the Level of Stimulus Applied by the Pulsator on the Rate of Machine Milking," New Zealand J. of Sci. and Tech. 27A:445. 1945.

(45) Whittlestone, W. G., "Efficient Machine Milking," Abst., Dairy Science Abstracts. 18:292. 1956.

(46) Williams, S. W., "Labor Usage in Milking," Vt. Agr. Exp. Sta. Bul. 517. 1944.