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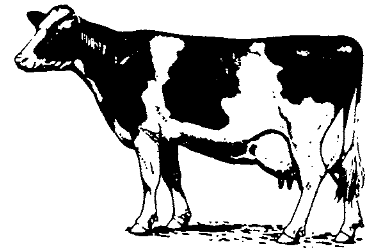
MINNESOTA EXTENSION SERVICE

UNIVERSITY OF MINNESOTA
ANIMAL SCIENCE EXTENSION

Department of Animal Science
101 Haecker Hall
1364 Eckles Avenue
St. Paul, Minnesota 55108
(612) 624-4995 *FAX:* (612) 625-1283



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EFFECT OF COW PREP ON MILK FLOW, QUALITY AND PARLOR THROUGHPUT

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Jeffrey K. Reneau and John P. Chastain
University of Minnesota, St. Paul, MN

Introduction

Premilking cow prep is proven to be an important step in achieving maximum milk yield, quality and udder health. Several studies indicate an advantage in milk flow rates and machine on-time by optimizing teat stimulation and prep-lag (Table 1). Milk quality and udder infection are improved by good prep procedure (9, 10, 15). However, milkers, compelled by the speed of premilking cow prep rather than thoroughness, often fail to achieve either adequate teat sanitation or consistent milk letdown stimulus. In herds where there is more than one milker, there is usually a great variation in milking routine. All of these factors can contribute to lower milk quality, yield and poor udder health as well as inefficient milking.

Quite often, there are great differences in opinion by respected milk quality consultants regarding what is optimal premilking cow prep. Unfortunately, this may confuse many dairy farmers. The truth of the matter is that there is no single premilking cow prep method that is best for every farm. There are, however, proven scientific principles that should always be considered when adapting premilking cow prep to your farm. In the "real world," nothing is perfect; there will be tradeoffs between what is optimal and practical. Herd size, regional differences in weather, housing and labor force as well as whether milk quality premium programs are offered may influence what premilking cow prep is most appropriate for your farm.

The purpose of this paper is: 1) to review the principles that govern optimal cow prep and milking efficiency, 2) to present results of a model based on literature values that demonstrates the effect of prep-lag time and milk flow rate on parlor throughput, and 3) provide regional scenarios that estimate the potential economic impact of optimizing premilking cow prep. It is hoped that this discussion will help farm managers adapt premilking cow prep procedures that best satisfy scientific principles and maximize economic returns.

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Table 1. Summary of studies comparing no stimulation prior to machine application and optimized stimulation and prep-lag.

Authors/yr	No stimulation[†]				Manual stimulation + prep lag = 60[‡]				Study design
	Milk yield, lb/milking	Milk flow rate, lb/min	Machine on time, min	n	Milk yield, lb/milking	Milk flow rate, lb/min	Machine on time, min	n	
Sagi et al., 1980 (21)	25.8*	4.3	6.5	12	26.2*	5.6	6.0	12	Lsq
Sagi et al., 1980, Expt 1 (22)	22.2*	4.3	5.4	12	23.2*	5.6	4.4	12	Lsq
Sagi et al., 1980, Expt 2 (22)	26.9*	5.2	5.4	4	27.3*	5.8	4.8	4	Lsq
Gorewit et al., 1985 (11)	28.7*	4.2	6.8	12	28.2*	5.8	4.8	12	Lsq
Reneau & Farnsworth, 1994 (19)	20.7*	4.0	5.3	54	21.7*	4.3	5.1	54	Lsq
Avg. U.S. studies	22.8	4.2	5.7	94	23.5	4.9	5.1	94	
Mayer et al., 1984 (14)[§]	23.5	2.9	9.2	21	25.1	3.8	7.6	21	Lsq
Avg. all studies	22.9	3.9	6.3	115	23.8	4.7	5.5	115	

† No stimulation, only machine attachment.

‡ At least 20 seconds manual stimulation with total prep-lag of 60 seconds.

* No statistical difference detected in milk yield; all other measures were statistically significant at $P < .05$.

§ All comparisons were statistically significant including milk yield at $P < .05$. German study with Fresian-Brown Swiss cross cattle.

Milk Letdown

Almost everyone is familiar with the concept of milk letdown and the role of oxytocin in achieving it. However, few realize that milk letdown is more involved than the simple action of oxytocin on the mammary myoepithelial cell that surrounds each milk secreting alveolus. Studies have shown that milk ejection is not entirely dependent on the action of oxytocin and that there are also many other factors that control the effectiveness of oxytocin response (12, 13, 14, 24).

The effect of teat stimulation on sympathetic tone in the mammary gland is a second milk letdown mechanism. Teat stimulation initiates a local autonomic reflex resulting in a decrease in smooth muscle tone around mammary ducts and teat sphincters. There is also an increase in blood flow to the mammary gland as well as a decrease in the response threshold of the myoepithelial cell to oxytocin (12). Although the local autonomic reflex letdown mechanism is independent of oxytocin for its effect, this mechanism potentiates oxytocin response. These two mechanisms work together to accomplish efficient milk removal.

The effects of oxytocin on the mammary myoepithelial cell and the uterine smooth muscle cells are similar, and they are mediated by oxytocin receptors. Progesterone and estrogen levels regulate the availability of oxytocin receptors on uterine smooth muscle cells and are thought to have a similar effect on the mammary myoepithelial cell. Adequate levels of calcium in the diet are needed to ensure normal contraction of any smooth muscle cell including the mammary myoepithelial cell. The trace mineral, magnesium, plays a role in oxytocin receptor availability and smooth muscle contractility. It is by this direct means that dietary magnesium affects milk butterfat percent. Cobalt and manganese have also been found to influence the effectiveness of the oxytocin response (12, 13, 20, 23). Clearly, milk letdown is a complex mechanism.

It has been generally observed that milk letdown response varies with stage of lactation. Late lactation cows typically require more stimulus to achieve good milk letdown than early lactation cows. It can be reasoned that, during early lactation, milk letdown is more intense because: 1) a more distended myoepithelial cell will contract with a greater force and 2) the cyclic exposure to estrogen in early lactation maintains the sensitivity of oxytocin receptor sites to oxytocin thus achieving a more powerful oxytocin response (23).

After the cow is pregnant and under the hormonal influence of progesterone, the affinity of oxytocin receptor sites for oxytocin declines, and smooth muscle cells become less responsive (20). It can be theorized that the hormonal changes accompanying pregnancy shift milk letdown dependence from the oxytocin mechanism to the local autonomic reflex controlled mechanism. It is thought, but not yet proven, that teat stimulation is more critical in eliciting the local autonomic reflex milk letdown mechanism than the oxytocin milk letdown mechanism.

Prep Time

Prep time is defined as the time taken to manually clean and dry the teat surface. The object is to be sure that the teat surfaces are consistently clean and dry before the milking machine is attached and that adequate teat massage has occurred to stimulate milk letdown. Recent studies demonstrate that less than 10 seconds is inadequate stimulus for consistent milk letdown response in all cows. While 10 seconds will provide adequate milk letdown stimulus for American Holsteins in early lactation, it is not adequate for late lactation cows. European Fresians and Jersey cattle require more stimulus for a consistent milk letdown response (17). Studies show that good cleaning and drying with separate towels will reduce bacterial populations on teat surfaces by 75% (9). Predip data demonstrate that improved teat sanitation reduces intramammary infection rate (8, 10, 15). It appears that a teat cleaning and drying procedure that results in a quality stimulus of 10 to 20 seconds is adequate to consistently achieve milk letdown while effectively sanitizing teat surfaces in most cases.

Cow cleanliness has a great effect on cow prep efficiency. It is estimated that dirty cows will easily double cow prep time and, thus, unnecessarily slow down parlor throughput. Design and evaluation of cow prep procedure should always be done within the context of general herd sanitation.

Forestripping, to check for clinical mastitis, is a recommended premilking cow prep procedure. Forestripping is a very powerful milk letdown stimulus and, therefore, is best used early during the cow prep procedure. However, if the premilking cow prep procedure is greater than 20 seconds, the addition of forestripping will add little advantage to milking efficiency (17). Therefore, in those circumstances where a minimal cow prep (10 seconds) is considered appropriate, forestripping should be included in the cow prep procedure to ensure consistent milk letdown response.

Prep-lag Time

Prep-lag time is the time between the beginning of teat preparation to the application of the milking machine (Figure 1). Recent U.S. and Denmark studies have determined that prep-lag timing is of critical importance in optimizing milking efficiency. These studies report the ideal prep-lag time to be 1.3 minutes, or 1 minute and 18 seconds (17). The range of 1 to 1.5 minutes is accepted as the optimal prep-lag time for all stages of lactation. Prep-lag times of greater than 3 minutes were found to result in more residual milk and lower milk yields regardless of stage of lactation (17). Exceedingly long prep-lag times are more common in stall barn milking and likely to limit herd performance. Use of end-of-milking indicators are helpful in alleviating this problem.

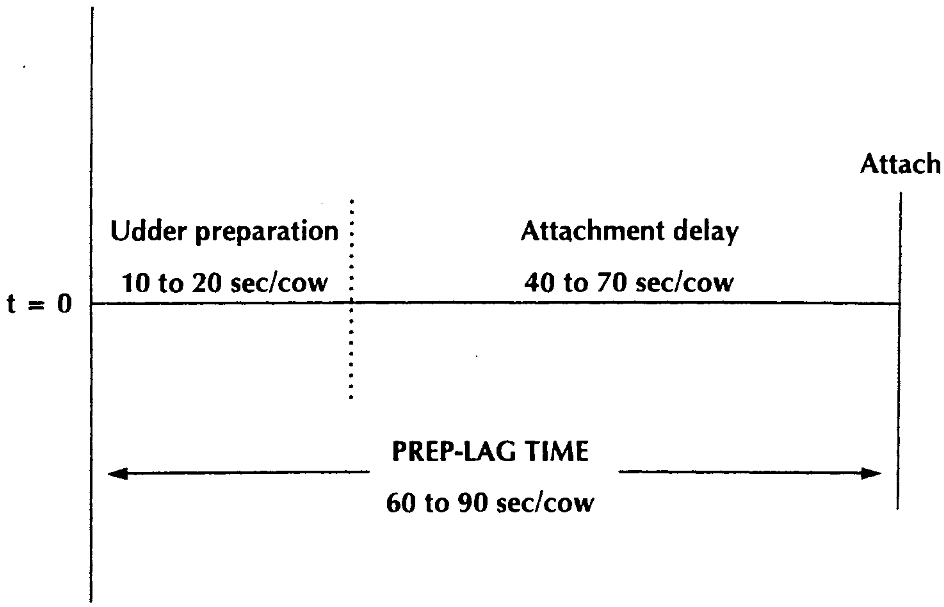

Figure 1. Division of prep-lag time into periods for udder preparation and attachment delay.

Standardization of Routine

Cows love routine. They perform best when all feeding, milking or any other management routine is done the exact same way every day. Complete lactation studies demonstrated a 5.5% increase in lactational yield when a standardized milking routine was used compared to an impulsive and variable milking routine (16). This evidence supports the recommendation that one goal of every milking routine is to milk every cow exactly the same at every milking regardless of stage of lactation or who is milking.

Model to Describe the Effect of Prep-lag Time and Milk Flow Rate on Throughput

A rule-based model was written to describe the effects of prep-lag time and milk flow rate on throughput in herringbone and parallel parlors. The model is simply a collection of equations and values that were developed to represent the available literature (1, 2, 3, 4, 6, 7, 11). The model was developed for herringbone and parallel parlors up to double-20 in size. Rapid-exit was included for herringbone parlors with 10 or more stalls per side. The labor efficiency of each size parlor was set to be equal to the mean of the literature values used to calibrate the model. The model does not differentiate between herringbone and parallel parlors since the data indicates that the difference in throughput is slight or nonexistent (2). A description of the model is provided in Appendix A.

The most important rule used in the model is an equation that was developed to describe the impact of milk yield (lb/cow/milking) and prep-lag time (as defined in Figure 1) on milk flow rate. Milk flow rate and yield determine the unit on-time in a parlor and can have a significant impact on throughput. A graph of this equation is shown in Figure 2. The equation is given in the Appendix (Equation A.4). The relationship was developed based on information provided in the literature (1, 7, 11, 17) and reflects observed trends. The graph clearly indicates that milk flow rate increases significantly with increases in milk yield and prep-lag time. Furthermore, as prep-lag time was increased from 60 to 90 seconds, the increase in milk flow rate was not as great.

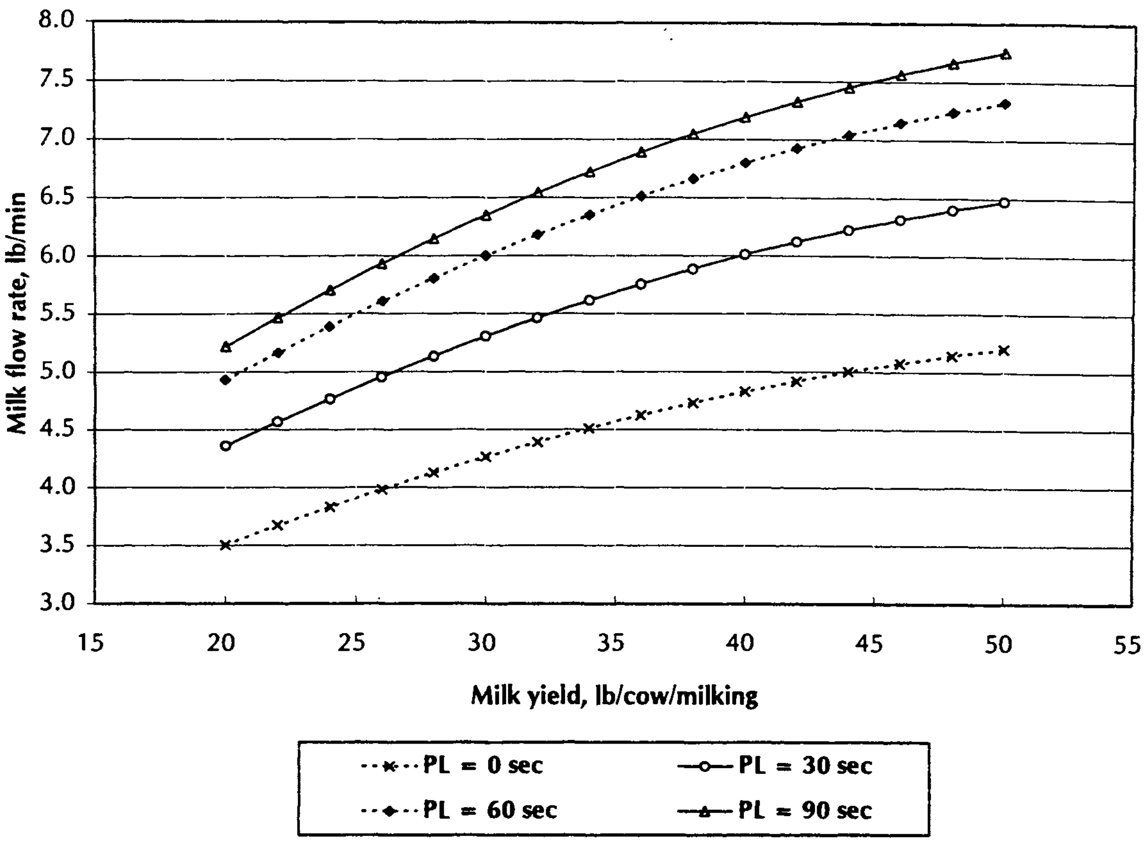

Figure 2. Variation of milk flow rate used in the model (Equation A.4).

Model Results

The model was used to calculate the effects of prep-lag time and the resulting milk flow rate on steady-state throughput rates of double 6, 8, 10, 12, 16 and 20 parlors with one operator. Prep-lag time was varied from 0 to 120 seconds, and milk yield was varied from 20 to 40 lb/cow/milking. Optimizing prep-lag is any combination of 10 to 20 seconds stimulation with an attachment delay to make a total of 60 seconds prep-lag time. The amount of time spent on non-prep tasks and delays was held constant. It should be noted that actual values can easily vary ± 10% around the model estimates due to variations in milk flow rates between herds, grouping of cows, operator skill and cow cleanliness.

Model results are shown in Tables 3a through 3f. The shaded regions in the table indicate the maximum throughput rates for the parlor. As was stated previously, research indicates that the optimum prep-lag time is from 60 to 90 sec/cow (17). The model results indicate that the optimum throughput rate also occurred at 60 seconds of prep-lag if milk yield was 25 lb/milking or more. That is, the increase in milk flow rate associated with a higher quality udder preparation procedure was more than sufficient to offset the additional time required. For a low producing herd, 20 to 25 lb/cow/milking, the optimal throughput rate often occurred at 30 to 40 sec/cow prep-lag. However, a prep-lag of 60 sec/cow was not detrimental.

The model also indicated that throughput rate suffers if too little or too much time is devoted to prep-lag. If the prep-lag time is between 0 and 30 sec/cow then the lower milk flow rate reduces throughput rate. If prep-lag time is more than 60 sec/cow then the increase in milk flow rate is not adequate to offset the additional prep-lag time. Therefore, to achieve optimal throughput, milk flow rate must be optimal. Milk flow rate is optimized at a prep-lag time of 60 sec/cow based on our review of the literature.

Potential Benefits of Optimizing Udder Preparation

The potential benefits of optimizing udder preparation and throughput are: 1) increase in milk yield due to a decrease in somatic cell count (SCC) where increased SCC was caused by inadequate cow prep, 2) increase in milk price due to reduced SCC, or 3) decrease in labor costs. The benefits will be calculated for a 400-cow dairy in the Southeast, a 400-cow dairy in the Upper Midwest, and a Southwestern dairy that operates the parlor 21 hours per day. All three herds are assumed to have an initial production of 19,800 lb/cow/yr. The equations used to calculate yield increases, milking shifts and labor costs are described in the following sections.

Yield reduction due to SCC. The reduction in milk yield due to SCC is well documented and is shown in Table 2. Equations are provided in the table to facilitate calculation of yield losses based on the linear SCC score (LS) for first lactation and older cows. The yield benefits of reducing SCC depends on the percentage of heifers in the herd and the magnitude of decrease in SCC. An increase in yield due to a reduction in SCC is calculated as the average yield *loss* at the high SCC value minus the average yield *loss* at the low SCC value. In all of the scenarios that will be presented, the cull rate was assumed to be 33%. Therefore, the average yield *loss* at a given SCC is (0.33 × MYL for heifers) + (0.67 × MYL for older cows).

Table 2. Relationship between somatic cell count (SCC), linear SCC score (LS), and daily yield loss (18).

Average SCC	LS	Daily yield loss, lb/cow/day	
		First lactation	Older cows
....	0 - 2	0	0
100,000	3	1.39	2.76
200,000	4	2.85	5.67
400,000	5	4.31	8.59
800,000	6	5.76	11.50
1,600,000	7	7.22	14.41
3,200,000	8	8.68	17.32
6,400,000	9	10.13	20.24

Regression equations to relate LS to daily milk yield loss (MYL).

First Lactation : $MYL = 1.457\ LS - 2.98$

Older Cows : $MYL = 2.913\ LS - 5.98$

Milking-time throughput, set-up and clean-up time. The values shown in Table 3 are estimates of the steady-state throughput (SST) and is a measure of parlor performance at full capacity. Total milking throughput or milking-time throughput, as defined by Barry et al. (5), includes all of the delays associated with group changes, cows milked with a bucket, time when the milking area is not full of cows at the end of groups, unit falloffs, and any other delay. Milking-time throughput (MTT) is typically less than steady state and is a better measure of what the operator experiences. Milking-time throughput includes all delays but not the time for parlor set-up and clean-up. Barry et al. (5) developed the following regression equation that relates steady-state throughput to milking time throughput for 30 herringbone parlors ranging from double-6 to double-12 :

$$MTT = 0.92\ SST, \quad (r^2 = 0.96) \qquad (1)$$

Barry (5) also determined that the average set-up and clean-up time for the 30 parlors in the study was 0.5 hours.

Calculation of labor costs. Labor costs are determined by the length of the milking shift and the labor rate. The length of a milking shift was estimated by the following equation:

$$\text{Milking shift} = 0.5 + (\text{No. of cows milked/MTT}) \qquad (2)$$

The labor rate was assumed to be $9/hr and includes social security tax, worker's compensation insurance and unemployment tax. Annual labor cost was calculated as follows:

$$\text{Annual labor cost} = (\text{Milking shift}) \times (\text{No. of milkings}) \times (\text{No. of oper.}) \times 365 \times \$9 \qquad (3)$$

The total herd size includes both lactating and dry cows. It was assumed that 84% of the herd was lactating in all cases. The annual production per cow was calculated as the average daily production times 300 days. All of the herds were assumed to be milked twice each day with 1 operator.

Table 3. Estimates of steady-state throughput rates (c/hr) for automated herringbone and parallel parlors assuming one operator using the rule-based model described in Appendix A.

Automatic detachers, crowd gate, power entry, rapid exit on herringbone parlors with 10 stalls per side or more. Actual throughput rates can be 10% higher or lower than the values shown in this table depending on operator skill.

Table 3a. Steady-state throughput (SST) for a double-6

Prep-	Milk yield, lb/cow/milking							
lag, sec	20	25	27	30	33	35	37	40
0	58	52	50	48	46	44	43	41
10	61	55	53	51	48	47	46	44
20	63	57	55	53	50	49	48	46
30	65	59	57	54	52	50	49	47
40	65	60	58	55	53	51	50	48
60	65	60	58	56	53	52	51	49
90	62	57	56	54	52	51	49	48
120	57	53	52	50	48	47	46	45

Table 3b. Steady-state throughput (SST) for a double-8

Prep-	Milk yield, lb/cow/milking							
lag, sec	20	25	27	30	33	35	37	40
0	71	65	63	60	57	55	54	52
10	75	68	66	63	60	58	57	55
20	77	70	68	65	63	61	59	57
30	79	72	70	67	64	63	61	59
40	79	73	71	68	65	64	62	60
60	79	73	71	68	66	64	63	61
90	76	70	69	66	64	63	61	59
120	70	66	64	62	60	59	58	56

Table 3c. Steady-state throughput (SST) for a double-10

Prep-	Milk yield, lb/cow/milking							
lag, sec	20	25	27	30	33	35	37	40
0	83	76	73	70	67	65	64	61
10	87	79	77	74	71	69	67	65
20	89	82	80	76	73	71	70	67
30	91	84	81	78	75	73	72	69
40	92	85	82	79	76	75	73	70
60	91	85	83	80	77	75	74	71
90	87	82	80	77	75	73	72	70
120	82	77	75	73	71	69	68	66

Table 3d. Steady-state throughput (SST) for a double-12

Prep-lag, sec	Milk yield, lb/cow/milking							
	20	25	27	30	33	35	37	40
0	95	87	84	81	77	75	73	71
10	99	91	88	85	81	79	77	75
20	101	94	91	87	84	82	80	77
30	103	96	93	89	86	84	82	80
40	104	97	94	91	87	86	84	81
60	104	97	94	91	88	86	85	82
90	100	94	92	89	86	84	83	80
120	93	88	86	84	81	80	78	76

Table 3e. Steady-state throughput (SST) for a double-16

Prep-lag, sec	Milk yield, lb/cow/milking							
	20	25	27	30	33	35	37	40
0	120	110	107	103	99	96	94	91
10	125	115	112	108	104	101	99	95
20	128	119	116	111	107	105	102	99
30	130	121	118	114	110	107	105	102
40	131	122	119	115	111	109	107	103
60	131	122	120	116	112	110	108	105
90	126	119	116	113	109	107	105	103
120	118	112	110	106	104	102	100	97

Table 3f. Steady-state throughput (SST) for a double-20

Prep-lag, sec	Milk yield, lb/cow/milking							
	20	25	27	30	33	35	37	40
0	124	116	113	109	106	103	101	98
10	128	120	117	114	110	108	106	102
20	131	123	120	117	113	111	109	106
30	133	125	122	119	115	113	111	108
40	134	126	124	120	117	115	113	110
60	133	126	124	121	118	116	114	111
90	129	123	121	118	115	113	112	109
120	123	117	115	112	110	108	107	104

Scenario 1: 400-cow Southeastern dairy, double-8 herringbone. Milk quality premiums are typically not offered to dairy producers in the Southeastern United States. This scenario was developed to investigate the potential benefits of reducing SCC by optimizing udder preparation and improving cow cleanliness through better management of the housing area. The major assumptions and calculations for this dairy are shown in Table 4. It was assumed that the SCC was reduced from 600,000 to 300,000. The change in milking routine required an increase in prep-lag from 30 sec/cow to 60 sec/cow. The most important results are: 1) milk yield increased from 66 to 68.4 lb/cow/day, 2) labor cost decreased by $591/yr, 3) the increase in milk value was $35,136/yr, and 4) the increase in milk value will pay for 88% of the labor costs. Therefore, the

potential economic benefits of reducing SCC can be substantial in regions that do not have the benefit of milk quality premiums.

Table 4. Potential benefits of optimizing milking routine on a dairy in the Southeast region of the United States.

Herd size =	400 cows	Milk Price =	$12.20/cwt
Percent in milk =	84%		No Premium
Cull rate =	33%		
Parlor type =	Automated Double-8 Herringbone		
Base conditions		Expected improvements after improving cow cleanliness and optimizing milking routine (increase in production is due to decrease in SCC, see Table 3.)	
Prep-lag =	30 sec/cow	Prep-lag =	60 sec/cow
SCC =	600,000	SCC =	300,000
LS =	5.5	LS =	4.5
Production =	66 lb/cow/day	Production =	68.4 lb/cow/day
SST (Table 3b) =	64 cows/hr	SST (Table 3b) =	65 cows/hr
MTT (Equation 1) =	59 cows/hr	MTT (Equation 1) =	60 cows/hr
Shift length =	6.19 hr/milking	Shift length =	6.10 hr/milking
Labor cost =	$40,668/yr ($9/hr)	Labor cost =	$40,077/yr ($9/hr)
Labor cost/cwt =	$0.51/cwt	Labor cost/cwt =	$0.49/cwt
Value of milk =	$966,240/yr	Value of milk =	$1,001,376/yr
		Increase in milk value =	$35,136/yr
		Increase in milk value/labor cost =	0.88

Scenario 2: 400-cow Upper Midwest dairy, double-8 herringbone. This scenario is the same as Scenario 1 except the dairy is located in the Upper Midwest where significant milk quality premiums are offered (Table 5). It was assumed that the dairy producer receives a $0.10/cwt premium for every 100,000 of SCC below 500,000 and a similar deduction for every 100,000 above 500,000. In this scenario, a 300,000 reduction in SCC provides a $0.30/cwt price increase. The increase in yield is worth $59,472/yr or 1.48 times the labor cost to run the parlor. The payment of milk quality premiums obviously makes optimizing cow prep favorable.

Table 5. Potential benefits of optimizing milking routine on a dairy in the Upper Midwest region of the United States.

Herd size =	400 cows	Milk price =	$12.20/cwt
Percent in milk =	84%	± $0.10/cwt for every 100,000 SCC	
Cull rate =	33%	Premium below 500,000, deduct above	
Parlor type =	Automated Double-8 Herringbone		
Base conditions		Expected improvements after improving cow cleanliness and optimizing milking routine (increase in production is due to decrease in SCC, see Table 3.)	
Prep-lag =	30 sec/cow	Prep-lag =	60 sec/cow
SCC =	600,000	SCC =	300,000
LS =	5.5	LS =	4.5
Milk price =	$12.10/cwt	Milk price =	$12.40/cwt
Production =	66 lb/cow/day	Production =	68.4 lb/cow/day
SST (Table 3e) =	64 cows/hr	SST (Table 3e) =	65 cows/hr
MTT (Equation 1) =	59 cows/hr	MTT (Equation 1) =	60 cows/hr
Shift length =	6.19 hr/milking	Shift length =	6.10 hr/milking
Labor cost =	$40,668/yr ($9/hr)	Labor cost =	$40,077/yr ($9/hr)
Labor cost/cwt =	$0.51/cwt	Labor cost/cwt =	$0.49/cwt
Value of milk =	$958,320/yr	Value of milk =	$1,017,792/yr
		Increase in milk value =	$59,472/yr
		Increase in milk value/labor cost =	1.48

Scenario 3: A Southwestern dairy, double-16 parallel operated 21 hours per day. Southwestern dairy producers have the advantage of a dry climate but lower milk prices and no premiums. Therefore, it was assumed that the producer could alter milking routine alone and reduce SCC from 300,000 to 200,000. The initial prep-lag was assumed to be 20 sec/cow and was optimized at 60 sec/cow. Furthermore, the producer will operate the double-16 parallel 21 hours per day or 10.5 hours/shift. The percent in milk was set at 84% and Equation 2 was used to calculate the herd size for each operating point of the parlor. The results of the calculations and other assumptions are given in Table 6. Optimizing the milking routine increased the milking-time throughput rate by 5 cows/hr and the milk production by 1.2 lb/cow/day. This would allow the producer to increase herd size from 1,167 to 1,226 cows and increase milk value by $185,099/yr or 2.68 times the labor cost.

Table 6. Potential benefits of optimizing milking routine on a dairy in the Southwest region of the United States.

Milking shift =	10.5 hr/milking	Milk price =	$11.50/cwt
Percent in milk =	84%		No premium
Cull rate =	33%		
Parlor type =	Automated Double-16 Parallel, 1 operator		

Base conditions		Expected improvements after improving cow cleanliness and optimizing milking routine (increase in production is due to decrease in SCC, see Table 3.)	
Prep-lag =	20 sec/cow	Prep-lag =	60 sec/cow
SCC =	300,000	SCC =	200,000
LS =	4.5	LS =	4.0
Production =	66 lb/cow/day	Production =	67.2 lb/cow/day
SST (Table 3b) =	107 cows/hr	SST (Table 3b) =	112 cows/hr
MTT (Equation 1) =	98 cows/hr	MTT (Equation 1) =	103 cows/hr
Herd size =	1,167 cows	Herd size =	1,226 cows
Labor cost =	$68,985/yr ($9/hr)	Labor cost =	$68,985/yr ($9/hr)
Labor cost/cwt =	$0.30/cwt	Labor cost/cwt =	$0.28/cwt
Value of milk =	$2,657,259/yr	Value of milk =	$2,842,358/yr
		Increase in milk value =	$185,099/yr
		Increase in milk value/labor cost =	2.68

Conclusions

The following conclusions were developed based on a review of the literature and a rule-based model of the effects of prep-lag and milk flow rate on parlor performance.

- Premilking cow prep is important to ensure adequate milk letdown stimulus and teat sanitation. A teat cleaning and drying procedure that results in a quality stimulus of 10 to 20 seconds is adequate in most cases.

- Proper prep-lag time is crucial to optimizing milk flow rates and reducing machine on-time. Consistent applications of milking machines 60 to 90 seconds after beginning cow prep are ideal.

- Optimal parlor throughput can only be achieved if optimal milk flow rate is achieved. Model results indicated that optimal milk flow and throughput were obtained when a high quality cow prep routine was accompanied by a prep-lag time of 60 sec/cow.

- Model results indicate that spending too little or too much time on cow prep tends to reduce parlor throughput.

- Optimization of cow prep should be a standard practice in areas with quality premiums.

- Improvements in SCC can be economically beneficial in areas where quality premiums are not available due to the increase in milk yield.

- Model results indicate that optimizing cow prep and throughput may allow large dairies that milk 21 hr/day to increase herd size.

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APPENDIX A

Description of a Rule-Based Model of the Influence of Prep-lag Time and Milk Flow Rate on Steady-State Throughput for Herringbone and Parallel Parlors

A rule-based model is simply a set of equations or values that are developed from data or theory to describe the response of a system. In this case, a set of rules was developed to calculate the effect of prep-lag time and milk flow rate on parlor throughput.

The relationship that was used to calculate steady-state throughput rate (SST) is:

$$SST = \frac{60 \times \text{Stalls per Side}}{(MTD + UOT)} \qquad (A1)$$

The variable MTD represents the time spent per cow (min/cow) for all milking tasks and delays. The value of MTD was calculated as follows.

$$MTD = \frac{PL + APD + RLD}{60} \qquad (A2)$$

PL =	Prep-lag Time	0 to 120 sec/cow
APD =	Unit attachment, detachment, adjustment, and post-dip	16 sec/cow (Armstrong, et al, 1990)
RLD =	Time for release, load, and all other tasks and delays. This variable was used to calibrate the model to throughput values in the literature.	

The unit on-time (UOT) was calculated using the following relationship.

$$UOT = \frac{MY}{MFR} \qquad (A3)$$

MY =	Milk Yield	lb/cow/milking
MFR =	Milk Flow Rate	lb/min

The milk flow rate in Equation A3 was calculated using the following equations that were developed based on the results of Gorewit and Gassman (1985), and Rasmussen et al., (1992).

$$MFR = MFF \times MFL \qquad (A4)$$

$$MFF = 0.80 + 0.0076\ PL - 3.61x10^{-5}\ PL^2$$

(Developed from Gorewitt and Gassman, 1985)

$$MFL = 1.765 + 0.1548\ MY - 0.0012\ MY^2$$

(Developed from Appleman, 1988; and Bridges et al., 1992)

Model Calibration

The model was calibrated by setting the value of MFF to 1.0, PL to 30 seconds, and adjusting the value of RLD until the model predicted the mean of the throughput values found in the literature (Armstrong et al., 1990; Armstrong, 1988; Armstrong, 1992; Bickert, 1980; Bridges, et al., 1992). Calibration data were for automated double-4, 6, 8, 10, 12, 16, and 20 herringbone and parallel parlors. One operator was used in each parlor. Rapid-exit was included for herringbone parlors with 10 stalls per side or more.

A comparison of the model calculations with the calibration data is shown in Figure A1. The values of RLD that provided the calibration are provided in Table A1. It should be noted that these values do not relate to values in any other model. They simply force the rule-based model to conform to the mean of the data in the literature.

Table A1. Values of RLD that resulted from model calibration.

Stalls per side	RLD sec/cow
4	10.8
6	12.6
8	45.0
10	75.6
12	97.8
16	120.6
20	220.8

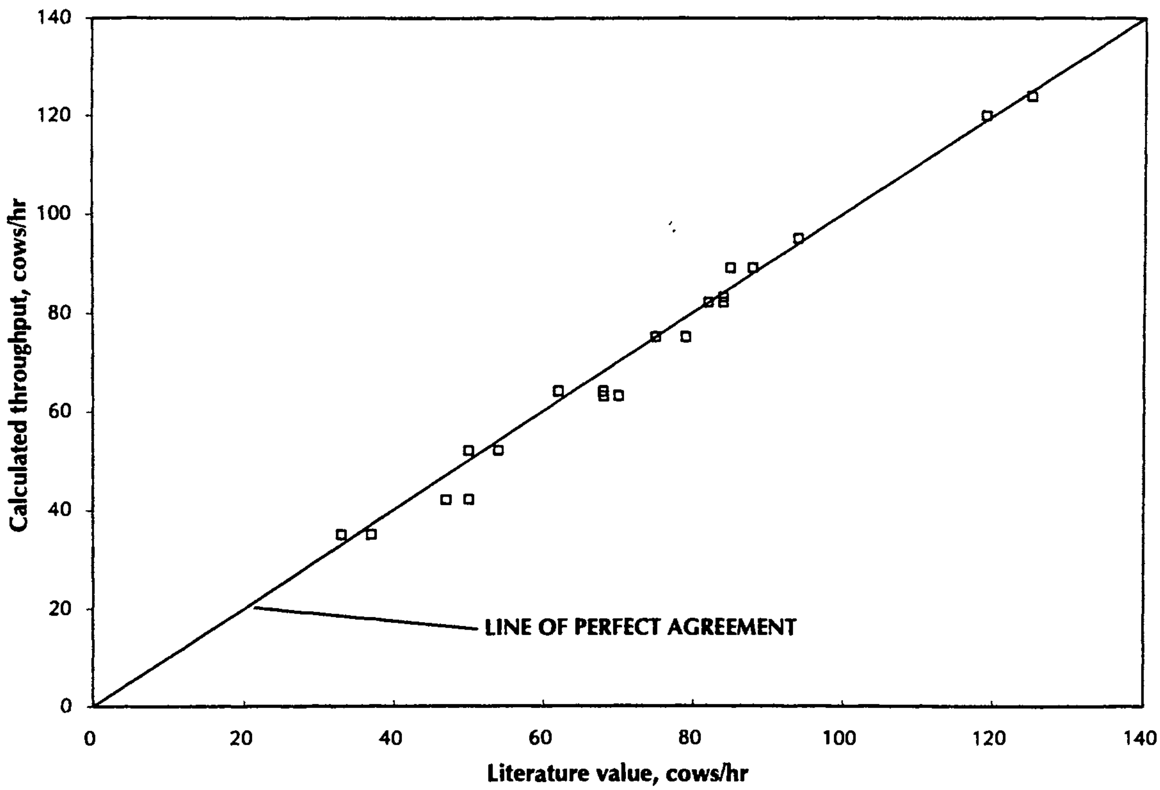

Figure A1. Comparison of calculations with throughput values used to calibrate the model.