



Dairy Extension  
Department of Animal Science  
101 Haecker Hall  
1364 Eckles Ave.  
St. Paul, Minnesota 55108  
(612) 624-4995



# Dairy Update

**MILKING MANAGEMENT, MILK QUALITY, AND  
MASTITIS CONTROL**

UNIVERSITY OF MINNESOTA  
DOCUMENT  
OCT 1989  
SPECIAL LIBRARY  
LIBRARY

Issue 96  
October 1989

Robert D. Appleman and Jeffrey K. Reneau, D.V.M.  
Extension Animal Scientists, Dairy Management, and

Ralph J. Farnsworth, D.V.M.  
Extension Veterinarian, Mastitis Control

Many Minnesota milk producers could improve their dairy farm profitability by:

- 1) reducing producers' incidence of clinical and subclinical mastitis;
- 2) improving milk quality by lowering producers' somatic cell count;
- 3) increasing milk production per cow; and
- 4) improving dairy farm income by increasing the price received for milk sold from premium pricing and increased milk sales.

This Dairy Update addresses the primary management factors involved in the production of high quality milk. Three articles are included:

- I. An Update on Milking Systems and Equipment
- II. An Update on Milking Procedures and Mastitis Control
- III. An Update on Innovative European Feeding and Management Systems

This Dairy Update is intended to provide some of the resource materials Specialized Livestock Agents need in conducting educational programs at the cluster (or county) level. The first article essentially replaces **NCR-86, Guidelines for the Installation, Maintenance and Analysis of a Pipeline Milking System**, published in 1981 and currently out-of-print. The second article can be considered a forerunner of an upcoming Extension Folder on **Milking Procedures and Mastitis Control**. The third article includes sections on future technology likely to be introduced in the U.S. dealing with: a) sensors used to detect mastitis; b) use of robotics in milking cows; an c) new technologies applicable to stall barn milking systems. Each article ends with a list of references cited.

This archival publication may not reflect current scientific knowledge or recommendations.  
Current information available from University of Minnesota Extension: <http://www.extension.umn.edu>

Other materials currently available (or under development) which should help in presenting a complete program include:

**Completed for use:**

1. Milking Routine Video
2. DHI/SCC Video
3. Current Concepts in Bovine Mastitis - a publication of the National Mastitis Council previously distributed to County Agricultural Agents
4. Series of 5 North Central Region folders on mastitis control prepared by the Michigan workers
5. 1989 4-State Proceedings on Dairy Management: Milking for Quality and Profit

**Developed sufficiently for demonstration and use by Count Agents:**

6. Expert system modules:
  - a) Bulk tank bacteriology
  - b) SCC report
  - c) Milking equipment analysis

**Under development:**

7. DHI/SCC Video worksheet
8. Milking routine folder or publication
9. Expert system "milking routine" module
10. Establishment of a "mechanical cow" in the University of Minnesota dairy barn at St. Paul for research and teaching demonstrations

**Table of Contents**

**MILKING MANAGEMENT**

<u>Page</u>	
1	<b>Milking Systems and Milking Equipment</b>
1	Influence of level of milk production
2	Influence of chore time activities
3	Determining the optimum number of milking units
3	Understanding milking equipment
5	Symptoms of poor milking equipment or procedures
5	Squeaks and squawks
6	Slow milkout
6	Uneven milkout
7	Claws flooding
7	Slugging at the receiver jar
7	Foaming at the receiver jar
7	Teat end irritation
8	Teat end rings, congestion, blue teats
8	Teat ends, doughnut shaped
8	Relationship to mastitis and somatic cell count

<u>Page</u>	
8	Vacuum supply system
8	How much air?
9	Impacts and reverse pressure gradients
9	Recommended vacuum pump capacities
11	Vacuum control
11	Vacuum level
11	Vacuum pipe sizing
12	Pulsation system
12	Pulsator rates
12	Pulsator ratios
12	Alternating vs simultaneous pulsation
13	Milk flow system
13	Milk pipeline diameter
14	Milk pipeline height
15	Milking unit
15	Role of clawpiece
15	Teat cup liners and shells
17	Fifteen hints to prolong liner life
18	Vacuum shut-off valve
19	Accessory equipment
19	Automatic take-offs
19	End of milking indicators
19	Backflushing
19	Dual level vacuum
20	Air vent in short milk tubes
20	Positive pressure stimulation
20	Deflector shields
20	Claws with 1-way valves or 4-tube machines
20	Hydraulic milking
21	Robotic milking
21	Maintenance of the milking system
24	<b>Milking Procedures and Mastitis Control</b>
24	Premilking routine
24	Clean cows prior to milking
24	Milkers' hands
25	Forestripping
25	Premilking teat sanitation
27	Predipping
28	Stimulation time
29	Preparation lag time
29	Machine milking procedures
29	Unit attachment and adjustment
29	Machine stripping
30	Overmilking
30	Unit removal
30	Milking sequence

<u>Page</u>	
31	Postmilking routine
31	Teat dipping
31	Efficacy
31	Spraying
31	Cold weather
31	Dry cow treatment
32	Contagious vs environmental mastitis
34	Bedding considerations
35	Bulk tank cultures
37	Cleaning milking equipment
37	Rinse
37	Wash
37	Rinse/sanitizer
40	<b>Innovative Feeding and Management Systems</b>
40	Feeding management
43	Behavior studies
43	Associated with feed intake
43	Food consumption
43	Water consumption
44	Associated with housing systems
44	Walking area
44	Resting area
44	Using sensors and developing management information systems
45	Digestion
45	Reproduction
46	Locomotion
46	Mastitis
47	Summary of sensing devices
47	Milking systems
47	Automated milking
48	How will cows react?
48	Challenges and opportunities
49	System costs
49	Stall barn technology

# MILKING MANAGEMENT

## I. An Update on Milking Systems and Equipment

Robert D. Appleman  
University of Minnesota, St. Paul

To achieve high levels of milk production, the dairy farmer must use a machine that will milk cows efficiently and completely. Continued use of faulty, improperly installed, or poorly maintained equipment can compromise udder health and/or result in poor quality milk. A recent review by Spencer (22) indicates that two factors, pulsation failure and the impact mechanism, consistently influence new infection rate.

"It's important to evaluate the entire operation before determining if new equipment is necessary. Too many dairymen with mastitis problems replace milking machine components with larger or newer models, when simply changing a few management practices and establishing a good milking routine would suffice. Many milking systems don't need to be updated. Instead, I recommend a good maintenance program." - T. Wyatt Smith (16).

### Influence of level of milk production.

The more milk cows produce, the easier it is to establish a good milking routine. When cows produce larger volumes of milk, the milking units are on the cows a longer time -- providing more opportunity to do the job correctly. A warning to milking equipment dealers: **Be careful speaking about "unrealistic throughputs" when producers have achieved a high level of milk production.**

With 3 units per operator (stall barn), the number of cows per operator per hour may vary from a low of 27 to a high of 35 cows (Table 1). With 6 units (parlor operation), throughput can be double that achieved with only 3 units.

Table 1. Influence of level of milk production per milking on number of cows milked per hour.

	Pounds of milk/cow/milking			
	20	30	40	50
Flow rate (lbs/min)	4.3	5.6	6.9	8.2
Time for milk flow (min/cow)	4.7	5.4	5.8	6.1
Unit idle time (.5 min)	.5	.5	.5	.5
<b>Effective milking time (min/cow)</b>	<b>5.2</b>	<b>5.9</b>	<b>6.3</b>	<b>6.6</b>
No. of cows/unit/hr	11.5	10.2	9.5	9.1
Cows/hr/operator when the number of units used simultaneously equals:				
3	35	31	29	27
4	46	41	38	36
5	58	51	48	46
6	69	61	57	55

## Influence of total chore time activities.

The amount of time required to successfully complete all activities associated with the milking process varies greatly with the barn or parlor design, the equipment present, and the operator. Based on data collected during milking on Upper Midwest dairy farms, milking chore labor may vary from 1.00 to 2.00 minutes per cow (Table 2). Seldom can it be reduced to the 45-second level, common in the Southwest region and depicted in column E.

Table 2. Influence of total chore time activities.

Chore activity	Barn or parlor type				
	A	B	C	D	E
	----- seconds -----				
Prepare cow for milking	30	25	20	30	20
Attach unit	15	13	11	10	10
Machine strip and detach unit	30	23	18	--	--
Milk transfer -- empty bucket or weigh jar	10	--	--	--	--
Dip teats	08	07	06	06	06
Cow entry and exit (plus feeding?)	27	22	17	14	09
<b>TOTAL SECONDS</b>	<b>120</b>	<b>90</b>	<b>72</b>	<b>60</b>	<b>45</b>
	----- minutes -----				
Total time/cow	2.00	1.50	1.20	1.00	0.75
Cows/hr, STEADY STATE	30	40	50	60	80
Cows/hr, with 10 min/hr of operator idle time or other duties not described	28	37	46	55	74

A = Typical of many stall barns or poorly designed parlors with no mechanization other than pipeline milking, below average cow entry patterns, and average operators.

B = Typical of many milking parlors with no mechanization, average cow entry patterns, and average operators.

C = Typical of a partially mechanized parlor, above average cow flow, and above average operators.

D = Typical of highly mechanized parlors, above average cow flow, and above average operators.

F = Typical of highly mechanized parlors, clean cows with dry udders, above average cow flow, and above average operators.

## Determining the optimum number of milking units to use for typical Upper Midwest dairies.

From 2 to 6 milking units can be utilized effectively in a typical Upper Midwest dairy, depending on: a) operator skills, b) how the parlor is equipped, and c) the level of milk production per cow (Table 3). In most modern stall barns with high producing cows, 3 units per operator appears to be optimum. In many standard parlors without automatic detachers (i.e., double-4 herringbone parlors), 4 units are optimal. When high levels of milk production are achieved, 5 units may be recommended. Double-6 herringbone parlors are recommended only when cow flow through the parlor and operator skills are both excellent.

Table 3. Procedure to use in determining the optimum number of milking units to use simultaneously.

Level of milk production:	1) When level of milk production limits no. of cows/hr/unit to:			
	11.5	10.2	9.5	9.1
	Low	Avg.	Good	Exc.
2) and total chore time activities limit cows milked/hr to:	3) then, the no. units/operator used simultaneously should be limited to:			
27-30	2 units	3 units	3 units	3 units
37-40	3	4	4	4
46-50	4	5	5	5
55-60	5	6	6	6
70-74	6	7	7	8

## Understanding Milking Equipment

There are four essential components of a pipeline milking system. They are: 1) the vacuum supply system, 2) the pulsation system, 3) the milk flow system, and 4) the milking units or clusters. The conventional milking machine performs two basic functions:

1. It imposes a controlled vacuum on the end of the teat to open the orifice and provide the differential pressure (suction) necessary for milk flow.
2. It massages the teat intermittently to provide stimulation and prevent blood congestion in the teat end.

These two functions must be performed by a properly designed and comfortable liner (inflation). In a recent revision of Current Concepts in Bovine Mastitis (13), it is stated that the milking machine may influence the development of mastitis in the following ways:

1. **It may be a carrier of pathogens from one cow to the next.** In one experiment, tracer bacteria placed on liners persisted for at least the next six cows (25).
2. **It may serve as a pathway of cross-infection within cows.** This transfer of organisms among teats may account for as much as 40 or 50% of all new infections in some herds. The new valve claws and four tube milk transport hoses may aid in reducing this type of infection. Response is likely to be small, however, in herds where infection rates are low (22).
3. **Malfunction may result in incomplete massage of the teat during the rest phase.** Pulsation failure may consist of the mechanical failure of the pulsator, shortness of the liner barrel, or too short a rest phase of the liner (22). These conditions may result in teat congestion, inflammation, and damaged, irritated tissue -- an invitation for ever-present bacteria to take hold.
4. **Abrupt loss of vacuum, permitting a reverse flow of milk.** This "impact" phenomena can create forces of sufficient magnitude to move mastitis causing organisms through the streak canal.

The general concept that illustrates the role of the milking machine in preventing new mastitis infections is illustrated in Figure 1. The problem with relating malfunctioning milking equipment to the incidence of mastitis is that reviews of research DO NOT reveal well established cause and effect relationships because: 1) most publications report on field observations which are difficult to interpret, 2) experiments often involve too few cows, 3) experiments are often of too short a duration, and 4) sometimes inadequate diagnostic techniques are employed (9). What is new (since 1979) in the concept depicted in Figure 1 is the addition of the word IMPACTS or reverse pressure gradients resulting from unintentional and excessive air inlets into the milking cluster shown in the large arrow at the right of the diagram. Fluctuating vacuum, by itself, isn't necessarily harmful - - but when combined with impacts or reverse flows, can result in the milking machine being involved in the transfer of organisms and causing new infections to become established.

Results of a field study involving 40 mastitis problem herds in Minnesota show that 20% of the shortcomings, and 40% of the farms studied, were related to malfunctioning milking equipment. Many farms had two to more shortcomings, some related to equipment (stray voltage) and the remainder dealing with management practices (milking procedures and mastitis control practices).

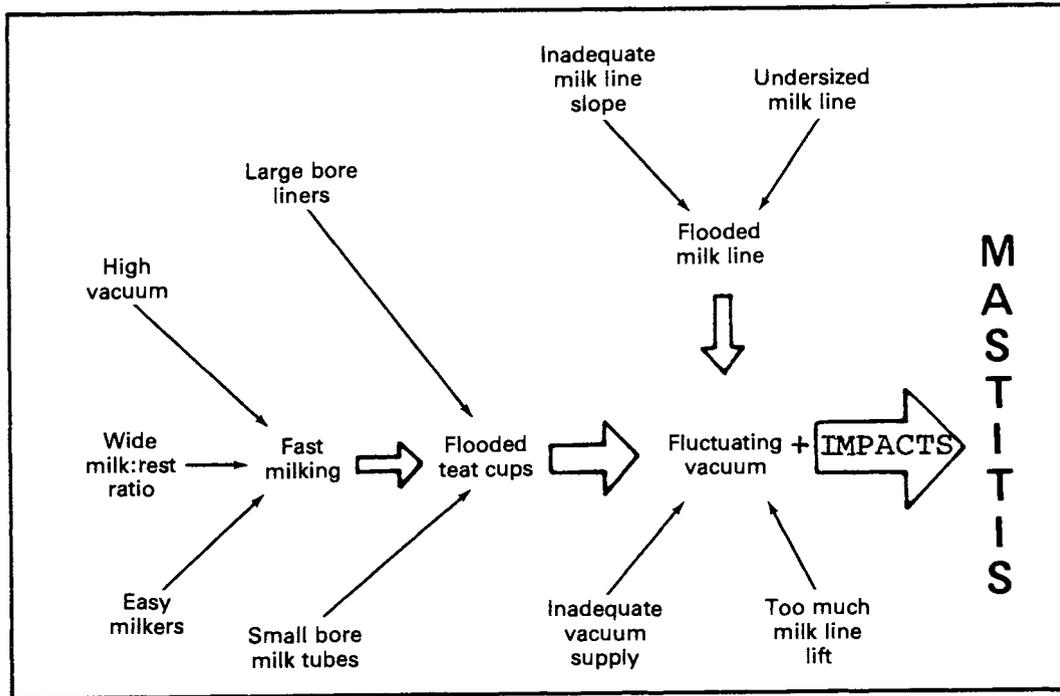


Figure 1. The apparent relationship combining fluctuating vacuum and impacts resulting in mastitis.

### Symptoms of Poor Milking Equipment or Procedures

When producers suspect they are experiencing equipment problems, the following symptoms are frequently listed. Identified under each symptom are possible factors (milking machine and other) causing such symptoms to occur. It may require the service of an expert knowledgeable in milking equipment to identify and correct milking machine problems.

#### A. Too many squeaks, squawks and unit fall-off problems.

##### Machine factors

1. Inadequate vacuum pump capacity;
2. Too many system air leaks;
3. Vacuum level set too low;
4. Milk lines too small;
5. Inappropriate shell/liner/claw weight combination; and
6. Liners used too long.

### Other factors

1. Careless attachment of cluster;
2. Poor alignment of cluster;
3. Too much air admission during machine stripping; and
4. Failure to shut off vacuum before detaching the cluster.

## **B. Slow milkout.**

### Machine factors

1. Inadequate air flow in claw (near teat end);
2. Vacuum level set too low;
3. Too much teat cup crawl (vacuum set too high or inappropriate choice of liner and shell);
4. Malfunctioning pulsators (or inappropriate pulsator setting); and
5. Pulsator hoses reversed (front and rear) when milk:rest ratios differ significantly.

### Other factors

1. Inadequate preparation of the cow;
2. Too long of delay in attaching the cluster; and
3. Overmilking.

## **C. Uneven milkout.**

### Machine factors

1. Malfunctioning pulsators;
2. Bent claw tubes, plugged hoses or other obstructions;
3. Water or milk trapped between shell and liner;
4. Liner twisted in the shell; and
5. Liner not seated properly.

### Other factors

1. Poor alignment of cluster; and
2. Individual cow factors (i.e., teat shape, teat scars, or teat injury).

#### **D. Claws flooding.**

##### Machine factors

1. Plugged air vents.

##### Other factors

1. Fast milking cows.

#### **E. Slugging at the receiver jar.**

##### Machine factors

1. Insufficient milkline slope;
2. Low spot in milkline; and
3. Excessive vacuum fluctuation.

##### Other factors

1. Excessive air inlet during machine attachment or detachment, or during unit fall-off.

#### **F. Foaming at the receiver jar.**

##### Machine factors

1. Excessive continuous air admission in the milk pipeline system; and
2. Too much air venting at the claw or liners.

NOTE: Either of these factors, especially in a high line system, may result in an oxidized flavor.

#### **G. Teat end irritation.**

##### Machine factors

1. Vacuum level set too high (over 16 inches);
2. Failure of liners to close due to pulsator malfunction; and
3. Poor choice of liner and shell length.

##### Other factors

1. Freezing and chapping of teats;
2. Physical injuries (stepped on teats, etc.);
3. Viral infection; and
4. Chemical burns (mistaken use of other chemicals as a teat dip).

## **H. Rings around base of teat, congested teat ends, and/or blue teats.**

### Machine factors

1. Malfunctioning pulsator; and
2. Improper choice of shell/liner combination.

## **I. Non-irritated, doughnut-shaped teat ends.**

### Other factors

1. Severe overmilking; and
2. Inadequate milk letdown stimulation.

NOTE: Non-irritated, doughnut-shaped teat ends are considered to be normal teat configuration.

## **J. Too much mastitis or too high somatic cell count.**

1. May or may not be machine related. The operator is responsible for determining the milking system is functioning and used properly.

### **The Vacuum Supply System**

The vacuum supply system includes the vacuum pump that provides a source of vacuum to the end of the teat to cause milk flow, supplies the energy to activate the liner and massage the teat, and moves milk through the system. There are two methods used for rating vacuum pumps. The American Standard Method (ASME) measures air at standard atmospheric pressure and temperature, and enables manufacturers to rate their pumps at 15 inches of vacuum. The New Zealand Method (NZ) measures the air at one-half standard atmosphere which is twice the volume when compared to the ASME. **Only ASME figures are included in this paper.** The regulator (or controller) is also considered to be a part of this system.

### **How much air enters the milking system?**

Each air vent in the claw typically allows a minimum of 0.3 CFM of air to enter the milking system to assist in moving milk through the system to the milk receiver jar or tank. This is adequate to maintain an air:milk ratio of 50:50, even when milk flow rates approach 20 pounds per minute. Smith, et al. (18) measured air usage during milking on 11 farms by averaging five 15-minute measurements when the reserve air ranged from 4.3 to 20.2 CFM per unit. Air usage averaged 0.61 CFM, ranging from 0.20 to 1.15 CFM per unit.

Liner slips occurring at any stage of milking can cause increased new infection rates. This was true whether the air slips consisted of a loud squeal (5.30 CFM) or were nearly inaudible (1.06 CFM) (14). When milking units fall off, or are kicked off, there may be 20 to 45 CFM of air entering the milking system (23). Thus, it should be readily apparent how these large, unintentional air inlets can have a dramatic influence on vacuum stability and milking machine performance.

### **Impacts and reverse pressure gradients.**

It has been shown that milk returning to the liner as it opens in the pulsation cycle can penetrate the teat and increase the risk of causing a new mastitis infection (7). This work shows that "impacts" are particularly harmful when both cyclic and irregular vacuum fluctuations occur simultaneously. The later these events occurred during milking, the greater were the chances of infection.

In milking systems with a low "reserve air" (0.6 CFM), sudden and large air admissions (5.6 CFM) resulted in reverse pressure gradients (RPG's) occurring about 75% of the time between the liner and teat cistern (7). Even with moderate levels of reserve air (4.2 CFM), this level of air admissions resulted in RPG's occurring 50% of the time. These RPG's occur most frequently during: 1) acute air admissions, 2) improper unit removal, and 3) during overmilking -- resulting in organisms being drawn into teat cistern.

### **Recommended vacuum pump capacities.**

While milking unit operating under normal conditions typically uses only 1 CFM per unit to effectively milk cows, the reason for there being so much concern about sizing vacuum pumps is that:

- 1) vacuum pump performance may decline over time;
- 2) milking systems may develop leaks; and
- 3) sudden, large unintentional air inlets occur frequently at the cluster whenever squeaks and squawks occur.

In new installations, recommended vacuum pump capacities are usually based on the factors shown in Table 4 (2). These standards assume that only one-third of the CFM capacity is available as "reserve air" to compensate for squeaks and squawks occurring during the milking process (Table 5). Furthermore, it has been shown that air usage during normal wash-up averaged 5.16 CFM per unit and ranged from 2.3 to 7.8 CFM per unit (18).

Table 4. Factors in determining CFM requirements (MMMC).

Component	ASME standard CFM
Milker unit with pulsator	6.0
Milk meter	1.0
Sanitary couplings, per 20	1.0
Milk inlets and stall cocks, per 10	1.0
Reserve for each regulator	3.0
Weigh jars, each	1.0
Minimum required for any system	35.0

Table 5. Recommended vacuum pump capacities and reserve air allowance for squeaks and squawks.

No. units	MMMC <sup>b</sup> standard	Calculated reserve for system that is:		Recommended reserve
		New	Old	
3	26 (35)	20 (29)	9 (18)	20-25 <sup>c</sup>
4	33 (35)	25 (27)	11 (13)	20-25
6	47	39	16	20-25
8 <sup>a</sup>	61	45	20	20-25
12 <sup>a</sup>	89	65	30	40-50 <sup>d</sup>
16 <sup>a</sup>	117	85	39	40-50

<sup>a</sup> Typically a herringbone parlor with only one-half of the units attached at the same time.

<sup>b</sup> 7 CFM/milker unit and meter + 5 for couplings and regulator.

<sup>c</sup> 1 unit on floor drawing air.

<sup>d</sup> 2 units on floor drawing air.

( ) Recommended minimum required for any system (MMMC).

## **Vacuum control.**

The ideal location of the vacuum control is near the moisture trap adjacent to the receiver. The regulator (controller) can then respond quickly to air admissions in the milkline portion of the system. This location has advantages of being: 1) located in one of the cleaner rooms in the barn (milkroom or parlor pit); and 2) convenient for frequent observation and maintenance. However, this location may not be desirable, depending on the type of controller selected, because of the high noise levels generated by the regulator valve. Moving the regulator a few feet away will not make much difference in regulator performance. Some controllers are very sensitive, and when mounted on balance tanks or large pipes, they tend to cycle or oscillate. In such instances they must be moved a slight distance away.

A good regulator sustains vacuum level within 1/2-inch of mercury when 90% of the reserve air is admitted into the system (20). Any regulator that permits the vacuum to drop more than 1-inch should be replaced or repaired if cleaning does not result in improved performance.

## **Vacuum level.**

The level of vacuum has no clear relationship to the incidence of mastitis. Milking rate increases with increasing vacuum; however, as vacuum increases, the volume of strippings also increases. There is, however, an increase in teat orifice erosion and hyperkeratosis when vacuum levels exceed 17.7 inches of mercury (22).

There are really only three factors which govern the proper choice of vacuum level. One is personal opinion. Secondly, milk line height has a major influence. We suggest that high lines be operated between 14 and 15 inches, and that low lines range from 13 to 14 inches. The liner (inflation) of choice is the third factor governing the choice of operating vacuum level. Liners with a high resistance to collapse should be operated at a higher rate. Both milkline height and liner type are discussed in more detail later in this paper.

## **Vacuum pipe sizing.**

The vacuum pipe size for the pulsators is an important consideration. Research has shown that the sizes suggested by 3A Standards (1) (shown in Table 6) are more than adequate to supply vacuum to pulsators. It should be noted that the Milking Machine Manufacturers Council (2) recommends a 3-inch pipe for 15 or more units. While it is suggested that owners of large systems consider this recommendation, oversizing the pulsator pipe does little, if anything, to improve performance. Vacuum pulsator lines should be looped to: 1) a vacuum distribution (balance) tank, or 2) a vacuum pulsator header line. It is important, however, to keep the pulsator line clean and free of accumulated debris such as soured milk that may have entered the pulsator line when a liner split or a milk bucket overflowed.

Table 6. Minimum size of main vacuum supply pipelines and pulsator line for pipeline milking systems.

<u>Main vacuum supply</u>		<u>Pulsator line</u>	
<u>No. of units</u>	<u>Pipe size (inches)</u>	<u>No. of units</u>	<u>Pipe size (inches)</u>
1 to 10	2	2 to 4	1-1/4
11 to 13	2-1/2	5 to 7	1-1/2
14 or more	3	8 or more	2

### The Pulsation System

Pulsation consists of the intermittent admission and evacuation of atmospheric air from the teat cup chamber. The collapse of the liner against the teat relieves the teat of blood and fluid congestion and intermittently shuts off milk flow through the streak canal. The basic parameters are rate, ratio and phase. No ideal characteristics have been established. Mostly it is a matter of personal choice.

**Pulsator rates** of most milking machines perform ideally at 45 to 60 pulsations per minute. Within these limits, milking speed increases with an increase in rate; however, stripping yield also increases.

**Pulsation ratios** reflect the percent of time the liner is open vs closed. Most systems operate in the range of 50:50 to 70:30. The wider ratios (i.e., 70:30) increase milk flow rates.

**Pulsation phase** compares simultaneous (4 x 0) and alternating (2 x 2) pulsation. Alternating pulsation has become more popular in recent years, probably because it tends to reduce cyclic variation.

Results of research (13, 21, 24) have shown that simultaneous pulsation gives the highest cyclic vacuum fluctuations. At high milk flow, the drop in vacuum during the massage phase is too high to give satisfactory massage pressure on the teats. In low-line installations it can give an "over-vacuum" which should be avoided as it might cause hemorrhages in the teat end tissues and might increase teat cup crawl. However, when large claws and larger air-bleed holes are utilized, simultaneous pulsation provides for efficient milking, fewer impacts and a low risk for cross flow. Alternate even pulsation gives moderate milking efficiency, low cyclic vacuum fluctuations, but a high impact risk. In light of current knowledge of the teat end impact mechanism, we are advising against the use of this combination of pulsation characteristics. Alternating wide ratio pulsation (i.e., 60:40 milk:rest ratio) gives efficient milking, and moderate fluctuations and impact risk. It seems to be the most advantageous compromise and there seems to be a trend worldwide toward the use of this combination.

## The Milk Flow System

Cows are producing more milk each year, and because of the automation available today, the number of milking units being used simultaneously is increasing. Furthermore, with the grouping of cows according to the level of milk produced, the volume of milk entering the milk pipeline system at a given point in time is much greater than that usually found in stall barns. These factors all contribute to the demand for larger diameter milk pipeline to provide for both: 1) the flow of milk, and 2) the rapid removal of air admitted into the system.

### Milk pipeline diameter.

The volume of milk per minute flowing through a milk pipeline, depending on individual cow average milk flow rates and the number of cows milked simultaneously, is shown in Table 7. It's not unusual for a six-fold increase to occur. Experience has shown that a 1-1/2-inch milk pipeline can handle 2 milking units with a total flow rate of about 18 pounds of milk per minute adequately. Comparable volumes of milk in larger lines, after providing for the additional air requirements because more units are being used in conjunction with the larger lines are: 2-inch line = 38 lbs; 2-1/2-inch line = 68 lbs; and 3-inch line = 105 lbs.

Recommended pipeline sizes for various combinations of average milk flow rate and number of cows milked simultaneously are shown in Table 8.

Table 7. Milk volume in the pipeline is dependent on milk flow rates and number rates and number of milking units used.

Individual cow average flow rate (lb/min)	<u>Cows milked simultaneously/slope</u>				Multiplying factor
	3	4	6	8	
	----- lbs milk/min -----				
4	12	16	<b>24</b>	32	1.5x
6	<b>18</b>	24	<b>36</b>	48	2x
8	24	32	<b>48</b>	64	4x
12	36	48	<b>72<sup>a</sup></b>	96	6x
16	48	64	<b>96</b>	128	12x

<sup>a</sup> Six high producing cows milked simultaneously in a parlor will add 6 times as much milk to the milk pipeline each minute as three average cows in varying stages of lactation and milkout typical of a stall barn operation.

Table 8. Determining appropriate size for milk pipeline.

Individual cow average flow rate (lb/min)	Pipeline diameter (inches)	Cows milked simultaneously/slope <sup>b</sup>			
		3	4	6	8
4		12	16	24	32
6	1-1/2 <sup>a</sup>	18	24	36	48
8		24	32	48	64
12	2	36	48	72	96
16	2-1/2	48	64	96	128
	3				

<sup>a</sup> 1-1/2" line no longer recommended.

<sup>b</sup> MMMC recommendations for maximum number of units per slope:  
2" line = 4 units; 2-1/2" line = 6 units; 3" line = 9 units

NOTE: High-producing, fast-milking herds may require the next larger pipeline.

### Pipeline height.

The higher the milk is elevated, the more milk will flow into the main milk hose thereby increasing the resistance. This results in a lowered vacuum at teat end (Table 9) (14). With high-producing, fast-milking cows milked in stall barns with the milkline at 7 feet, effective vacuum levels may drop 5 to 6 inches. This is why vacuum levels on high-line installations are usually set at 15 inches, but only 13 to 14 inches on medium height (2 to 5 feet) and 12 to 13 inches on low level lines. Milking speed should be faster in low-line parlors compared to that achieved in high-line installations with similar pulsation characteristics since the effective milking vacuum is nearly 1 inch higher during peak milk flow.

Table 9. Vacuum decrease in inches expected due to milk pipeline height and milk flow rate.

Elevation (ft)	Milk flow rate (lbs)			
	4.4	8.8	13.2	17.6
	Expected drop in vacuum (inches)			
0.0	0.3	1.2	2.0	2.9
1.3	0.9	2.1	2.9	3.4
3.9	1.4	2.6	3.4	4.2
5.2	1.8	3.2	3.9	4.9
7.0	2.3	3.7	4.4	5.7

### The Milking Unit

The milking unit consists of the clawpiece, four shells and liners (inflations), and accessory tubing. There is a complex interrelationship of claw weight and shell and liner design. Liner slip appears to have a most significant adverse effect on udder health. Its opposite, teat cup crawl, can also adversely influence milking performance by increasing "strip yield." Teat penetration of the liner, bore size and elasticity, and mouthpiece construction appear to be influential. **The reader is advised that it is many times unwise to mix these components from different manufacturers since they may not be compatible.**

#### Role of the clawpiece.

The trend among milking machine manufacturers is to increase claw volume which lowers vacuum fluctuations considerably and has a positive effect on the massage of the teats during milking (14). It is mainly of importance for simultaneous pulsation and has only a marginal influence with alternate pulsation.

There are several new claw designs on the market -- including four-chambered claws, shields, and no claws with elongated short milk tubes. These new innovations are designed to reduce new infection rate by eliminating the effects of "impacts." Research data is limited and variable, but generally positive with up to a 10% reduction in new infection rates. If present equipment is in need of updating, this equipment should be considered.

#### Teat cup liners and shells.

The teat cup liner and shell form the pulsating chamber which allows milk to be removed from the teat. It is important that teats penetrate into the liner barrel to provide "relief" of the teats during the massage phase. The deeper the teat penetrates, the smaller the collapsing volume under the teat, the higher the pressure difference between the outside and inside of the liner must be to collapse the liner and provide adequate pressure for an acceptable massage. This means that vacuum at the teat end during peak milk flow (13.2

lbs/min) should exceed 9.0 inches, assuming it requires about 4.4 inches of vacuum to keep the milking unit attached (14).

It may be that in some liners, teats less than 2 inches long may not be massaged adequately. Rasmussen (19) has found that when liners with a "short mouthpiece chamber" (1.9 vs 3.0 cm from the mouthpiece to the point of teat massage) were utilized during a 30-week trial that: 1) cows were more comfortable and moved around less during milking; 2) teats became less elongated; 3) teats maintained their original color better; and 4) cows developed fewer cases of new mastitis infections when challenged with mastitis causing organisms. On the other had, use of the shallow mouthpiece bore liner resulted in an increased occurrence of air slips.

It has been demonstrated that fewer "air slips" occur when wide-bore liners (those typically used in Ireland) are used compared to the narrow bore liners common in the U.S. (15). If the vacuum pump capacity and air flow system appears to meet standards, and if producers continue to experience too many "air slips", then one might find it beneficial to try a different liner -- one having a slightly larger bore width. Avoid extremes -- don't overdo it. Be sure the liners selected are compatible with the shells being used.

The development and manufacture of milking machine liners is a complex operation calling for specialized knowledge of materials, processes, and the operation of milking machine. First, there are two broad categories of rubber (natural and synthetic). Natural rubber provides great resilience and stretch but isn't very resistant to butterfat or sunlight. Thus, most liners consist of a blend of natural and synthetic rubbers to provide the proper balance of properties and service. Those properties that are balanced include: 1) softness (involving hardness, thickness and stiffness); 2) resistance to tearing, abrasion, butterfat, ozone, sunlight and oxidation; 3) resilience; and 4) permanent set (11).

Research and field experience help set trends in liner design. Today's high producing cows have required changes in liner design -- providing for much faster milk evacuation than earlier models. There are few published reports containing objective evaluations of liner performance. In Table 10, I've attempted to summarize what is known about those liner characteristics that seem to contribute to teat cup crawl (thus, causing milkout problems) vs those that appear to cause more air slips (which result in more impacts).

Table 10. Liner evaluation: components contributing to teat cup crawl vs impacts impacts or reverse pressure gradients.

<u>Teat cup crawl</u> <u>(milkout problems)</u>	<u>Components</u>	<u>Teat cup air slips</u> <u>(impacts or RPG's)</u>
Wide	1. Barrel width	Narrow
Stiff and inflexible	2. Mouthpiece firmness	Soft and pliable
Deep	3. Mouthpiece depth	Shallow
Higher	4. Vacuum level	Lower
Great	5. Teat penetration	Little

Liners come in a myriad of shapes, with variations in every part of the liner from the mouthpiece to the milk tubes. Most are round, some are oval, a few are triangular or even square. They reflect different ideas, different approaches to match a particular milking machine with the cow. I'm unaware of any published objective evaluations indicating superiority in milking performance for one shape over another.

Silicone liners are being used by some producers and are reportedly easier on teat ends. Its big advantage is its long life (6,000 cow milkings). The liner appears to be softer and may collapse with as little as 4 inches of vacuum. Thus, it is possible that milking speed may slow down. Some experts feel that silicone inflations don't provide as good of a massage as rubber liners do. Further, it is important to make sure the current CIP wash-up system will adapt to silicone inflations (5).

Inflations used longer than the number of cow milkings recommended by the manufacturer should be replaced. These limits are usually about 1,200 cow milkings for synthetic rubber liners; 800 cow milkings for natural rubber liners; and 6,000 cow milkings for silicone liners. Use the following equation to calculate the number of milkings per liner:

$$\left( \begin{array}{c} \text{No. cows} \\ \text{milked} \end{array} \times \begin{array}{c} \text{No. milkings} \\ \text{per day} \end{array} \times \begin{array}{c} \text{No. days} \\ \text{used} \end{array} \right) \div \begin{array}{c} \text{No. units} \\ \text{used} \end{array} = \begin{array}{c} \text{No. cow} \\ \text{milkings} \end{array}$$

Example: (60 cows x 2X x 40 days) ÷ 4 units = 1,200 milkings

### **Fifteen helpful user hints to prolong liner life.**

Dairy farmers expect a lot from their liners (inflations). They are expected to be gentle, lively, strong and durable all at the same time. When abused through neglect or lack of understanding, liner life as well as milking performance and herd health can suffer greatly (10). Listed below are 15 liner use tips.

1. **Adhere to a strict liner replacement schedule.** Liners become softer and change shape with use. Each day of overuse just makes it that much more difficult for the cow to adjust to new liners.
2. **Be patient after installing new liners.** New inflations feel different to cows; some may milk slower for a few days.
3. **When inflations have multiple take-up rings, pull the new inflation through the shell to only the bottom take-up ring.** Pulling new liners past the first ring causes too much tension on the liner wall, requiring more vacuum before collapse occurs.
4. **Use liners designed for the shells in which they're being used.** Use in the wrong shell can cause liners to split or to collapse incorrectly.
5. **Change liners in sets of four.** It's unwise to change only one since its milking characteristics will change and will be different from the remaining three liners.

6. **Store unused liners in a dark place away from sunlight and electric motors.** Sunlight ages rubber, and electric motors produce ozone that can attack rubber and cause cracking.
7. **Keep liners away from fly spray.** Contact with petroleum-based products can cause liners to swell and become misshapen and useless.
8. **Handle the claw assembly (cluster) with care.** Dropping the cluster or hitting it against stall partitions can cause cuts or pin holes which tear with use. This abuse can cause the milking system to function improperly.
9. **When removing a liner from the claw, always push the liner tube forward on the nipple first to break the seal.**
10. **Always pull liners straight off the claw; not at an angle.** This helps eliminate tears and splits.
11. **Always rinse teat cups in cold or tepid water immediately after completion of each milking.** Never let milk dry on liners. Always rinse, wash and rinse again after each milking.
12. **Use the right style brush in the liner.** The wrong brush can cause scratching and tearing of rubber within the liner chamber.
13. **When manually washing liners installed in the shells, connect an air tube between nipples of adjacent shells.** This procedure will prevent water from getting between the interior of the shell and the liner. Even one spoonful of water in this cavity can cause the liner to malfunction.
14. **When reassembling units, be sure all air tubes are aligned properly.** Kinked or crimped air tubes reduce air flow and may result in improper teat massage.
15. **Be careful not to twist the liner within the shell.** Twisted liners will not open and close properly, and the quarter may not milk out.

#### **Vacuum shut-off valve.**

When the end of milking is reached, the vacuum supply to the cluster should be shut off and the unit removed from under the cow. Machine operators should not insert a thumb into the mouthpiece to break the vacuum. This allows such a sudden rush of air to enter the cluster that it tends to cause an impact to occur and possibly spread contaminations from one quarter to another (3).

## **Accessory Equipment and New Developments**

Numerous options are available as an adjunct to the basic milking system. These include: 1) automatic take-offs; 2) end-of-milking indicators; 3) backflushing; 4) dual level vacuum; 5) air vent in short milk tubes; 6) positive pressure pulsation; 7) deflector shields; and 8) claws with one-way valves and four-tube machines. Other developments being researched include: 10) hydraulic milking; and 11) robotic milking. Each topic is discussed briefly.

### **Automatic take-offs.**

Automatic detachers remove the milking unit from the cow at the end of milking by monitoring milk flow to determine the end point of milking, usually occurring when milk flow is reduced to less than one-half pound per minute. Detaching units should have these capabilities: 1) delay approximately 30 seconds between the end of substantial milk flow and actual unit detachment; 2) a positive shut-off of vacuum to the milking unit before it is removed to minimize the number of impacts occurring; 3) retraction of the milking unit from under the cow combined with a raising of the unit to prevent teat cups from dropping on the floor; and 4) capability of operating in a manual mode. Older sensing tubes need to be checked routinely to replace collapsed rubber tubing.

Automatic detachers will not improve the milking performance of a poor operator. They will, however, allow a good operator to do an even better job provided the parlor is of sufficient size (i.e., double-6 herringbone) to provide an opportunity to increase efficiency (cow throughput).

### **End of milking indicators.**

New sensors are becoming available for use in stall barns and parlors not equipped with automatic detachers. These sensors inform the person milking when milk flow is low and the unit should be removed. This has value in helping prevent overmilking.

### **Backflushing.**

A backflushing mechanism helps remove bacteria from within the milking cluster, thereby reducing mastitis by lowering the exposure of teats during milking. Research has demonstrated a 15 to 20% decrease in new infection rate for contagious pathogens, but had little effect on the incidence of infection for environmental pathogens. It is recommended for herds with contagious mastitis problems.

### **Dual level vacuum.**

Dual level vacuum units that change vacuum based upon milk flow haven't been found effective in reducing new infection rate (22).

### **Air vent in short milk tubes.**

No difference in cross-contamination among quarters was found by placing air vents in the short milk tube of liners vs the usual location in the claw unless the claw was fitted with non-return valves. The absence of air vents, however, increases mastitis incidence in the conventional machine. This finding emphasizes the need to be sure the air vents, regardless of location, are kept open (8).

### **Positive pressure pulsation.**

German researchers (6) reported no difference in milk yield between cows with positive pressure stimulation between the shell and liner for one minute at the onset of milking and cows manually stimulated for one minute. Compressed air stimulation, however, did result in an increased yield of 2.27 lbs per day when compared to the usual short-term stimulation of about 0.2 minutes. Bradsmas (4) also found a small increase of one pound of milk daily from using overpressure. Spencer (22), on the other hand, cited the work of Hamann and Duck indicating that positive pressure pulsation increased somatic cell count of milk. In addition, he cited several workers that found little or no benefit from high speed pulsation used to promote stimulation; there is, in fact, some suggestion of a progressive decline in milk yield response to premilking stimulation.

### **Deflector shields.**

The use of deflector plates in milking machine liners to shield the teat end from impacts reduced the new infection rate by 10.5% in field studies (22). Since the average reduction in infection following the use of improved machines in herds using basic mastitis control procedures is usually less than 20%, it seems probable the use of deflector plates closely represents the reduction in new infection rate that is machine related.

### **Claws with one-way valves and four-tube machines.**

Claws with one-way valves to provide protection against cross-contamination and impacts have been shown to reduce new infections. Further, new infections were reduced dramatically with the use of four separated long milk tubes (22). Further research on the minimum length of the separated milk tubes required, and field studies under conditions of natural exposure, would be desirable.

### **Hydraulic milking.**

Hydraulic milking is the result of including a valve or ball in each short milk tube or in the bottom of the inflation. The faster and greater the milk flow within a cycle, the higher the vacuum. Milk flow rate is increased, and since the valve responds rapidly to reverse air flow -- the number and intensity of impacts are reduced. But, when little milk is flowing, the liner opens more slowly -- and strip yield is increased. Also, there is more difficulty in removing the cluster (12, 17).

## **Robotic milking.**

Much research to develop both the equipment and management practices necessary to successfully automate the entire milking process through the use of robotics is underway in Europe, especially in The Netherlands. The driving force behind this development is to help the family dairy farmer maintain profitability by: 1) milking cows 3 to 4 times daily automatically; 2) limiting the length of the work day; and 3) improving family life. Many technical problems exist and need to be resolved before a robotic milking system is marketed. My guess is that a practical system will not appear in the U.S. before 1995, perhaps not until the year 2000.

### **Maintenance of the Milking System**

The milking machine is used more hours per year on most dairy farms than any other piece of equipment, yet often receives little or no maintenance. Service technicians using the proper test equipment should go over the producer's milking machines every 6 months or after 1,250 hours of use, whichever is sooner. A scheduled maintenance program can result in fewer emergency service calls, longer equipment life, and more efficient milking.

The dairy farm operator has responsibilities too. The following recommended inspections are to be carried out daily, weekly or monthly.

**Daily:** Check the milking vacuum level; be sure the regulator is functioning properly; inspect the inflations and short tubes for leaks; make certain there is no water between the shells and liners; check and clean plugged air inlets on the claw; be certain the pulsators are operating properly; and install clean filters in milk-filtering equipment each milking.

**Weekly:** Check pulsator filters and clean or replace as needed; fill the oil reservoir on the vacuum pump; check tension on vacuum pump belts; change inflations when use limits are reached; and be certain supply of sanitizers, detergents, etc. are adequate.

**Monthly:** Check and change vacuum pump oil as recommended; clean or change regulator filters; lubricate stall gates and other equipment requiring lubrication; clean vacuum supply lines if needed; and make a thorough check of all system components. Prepare list that advises the serviceman of any problems experienced.

Any equipment not listed should be serviced according to manufacturer's recommendations. It is advisable to purchase an hour meter to provide accurate record of operating time.

## REFERENCES CITED

- 1 Anonymous. 1977. 3A accepted practices for the design, fabrication and installation of milking and milk handling equipment. *J. of Food Protection* 40:652.
- 2 Anonymous. 1985. The modern way to efficient milking, 12th edition. Milking Machine Manufacturers Council. FIEI. Chicago, IL. pp. 1-40.
- 3 Anonymous. 1988. Mastitis desk reference. West Agro, Inc. Kansas City, MO. p. 58.
- 4 Bradsmas, S. 1978. The relation between milking, residual milk and milk yield. *Proc., Intl. Sym. on Machine Milking*. Natl. Mastitis Council. Arlington, VA. pp. 47-56.
- 5 Corbett, R. 1988. A look at silicone. Dec. 10 issue of Dairy. p. 16.
- 6 Frommhold, W. and G. Wehowsky. 1978. The automation of stimulation and stripping. *Proc., Intl. Sym. on Machine Milking*. Natl. Mastitis Council. Arlington, VA. pp. 378-387.
- 7 Galton, D.M., D.J. Aneshansley, L.G. Peterson, C.S. Czarniecki and N.R. Scott. 1988. Pressure gradients across the teat canal during machine milking. *Proc., Milking Systems and Milking Mgt. Sym.* NRAES. Ithaca, NY. pp. 114-121.
- 8 Griffin, T.K., A.J. Bramley and F.H. Dodd. 1980. Milking machine modifications in the control of bovine mastitis. *Proc., Intl. Workshop on Machine Milking and Mastitis*. Moorepark, County Cork, Ireland. p. 19.
- 9 Kingwill, R.G., F.H. Dodd and F.K. Neave. 1979. Machine milking and mastitis. *Machine Milking*. N.I.R.D. Reading, England. *Tech. Bull.* 1:231-285.
- 10 Kirby, K. 1986. Eighteen helpful user hints prolong life of milker inflations. *Dairy*. Webb Publ. Co., St. Paul, MN. 42(12):24-25.
- 11 Kirby, K. 1988. Manufacturing considerations for milking machine liners. *Proc., Milking Systems and Milking Mgt. Sym.* NRAES. Ithaca, NY. pp. 154-157.
- 12 Lind, O. 1988. Unpublished data. Tumba, Sweden.
- 13 National Mastitis Council. 1987. Management and environmental factors in mastitis. *Current Concepts of Bovine Mastitis*. Natl. Mastitis Council. Arlington, VA. p. 22.
- 14 Nordegren, S.A. 1980. Cyclic vacuum fluctuation in milking machines. Ph.D. dissertation. Univ. of Hohenheim, W. Germany. pp. 1-161.

- 15 O'Callaghan, E. 1988. Liner slips and its causes. Proc., Milking Systems and Milking Mgt. Sym. NRAES. Ithaca, NY. pp. 137-149.
- 16 Smith, T.W. 1986. A comprehensive look at controlling mastitis. The Upjohn Co., Kalamazoo, MI. Publ. UJ4786TV:1-26.
- 17 Smith, T.W. 1988. Milking machine research review. Proc., Natl. Mastitis Council. Arlington, VA. pp. 35-37.
- 18 Smith, T.W., N.G. Peterson, W.C. Fairbanks and S.E. Bishop. 1986. Air flow utilization in milking parlors under milking and washing conditions. J. Dairy Sci. 69:176 Suppl. 1.
- 19 Rasmussen, M.D. 1988. Unpublished data. Natl. Inst. of An. Sci. Foulum, Denmark.
- 20 Southwick, L. 1988. Troubleshooting milking systems. Proc., Milking Systems and Milking Mgt. Sym. NRAES. Ithaca, NY. pp. 176-181.
- 21 Spencer, S.B. 1988. Pulsation characteristics. Proc., Milking Systems and Milking Mgt. Sym. NRAES. Ithaca, NY. pp. 150-153.
- 22 Spencer, S.B. 1989. Recent research and development in machine milking - a review. J. Dairy Sci. 72:1907-1917.
- 23 Tan, J., K.A. Janni and R.D. Appleman. 1989. Dynamic variations in vacuum milking systems. Am. Soc. Agr. Engr. Paper No. 89-6065.
- 24 Thiel, C.C. 1978. Influence of the milking machine on intramammary infection. Proc., Int. Sym. on Machine Milking. Natl. Mastitis Council. Arlington, VA. pp. 242-246.
- 25 Woolford, M.W., J.H. Williamson and D.S.M. Phillips. 1980. Aspects of milking machine design related to intramammary infection. Proc., Intl. Workshop on Machine Milking and Mastitis. Moorepark, County Cork, Ireland. p. 45.

## **MILKING MANAGEMENT**

### **II. An Update on Milking Procedures and Mastitis Control**

Robert D. Appleman and Jeffrey K. Reneau  
University of Minnesota, St. Paul

Two of the principles of good milking management are to "produce high quality milk -- clean and normal" and to "maintain good udder health and minimize mastitis." Milking is the most important position on the dairy farm. Only those that enjoy milking and have the desire to consistently use recommended milking practices should be involved in the process of milking cows.

Regardless of how cows are milked, there are three important aspects to consider. They are: A) premilking preparation of the cow; B) the procedure utilized in milking; and C) postmilking procedures. Following the standards set forth in this paper helps ensure good milking procedures and sanitation standards. Other sections in this paper deal with mastitis control (sections D and E) and cleaning milking equipment (section F).

#### **A. PREMILKING ROUTINE**

##### **1. Clean Cows Prior to Milking**

Clean cows increases the efficiency of milking by reducing time and labor required to clean udders as well as reducing the potential for new mastitis infections. This can be accomplished by clipping udders, flanks and tails prior to freshening; by maintaining clean, dry stalls that are bedded daily; and by making certain that cow alleys and exercise pens are cleaned frequently, well-drained and free of manure accumulations. If the teats and udder of more than 5% of the cows are contaminated with manure at time of milking, make the changes necessary to cause improvement. The goal is to minimize the number of bacteria on the teat (2).

##### **2. Milkers' Hands**

Hands may become contaminated early in the milking routine and then be a means of transfer of mastitis pathogens to an uninfected teat. Complete hand sanitation is nearly impossible under practical conditions. If milkers wear smooth rubber gloves and dip them in a sanitizing solution between cows, transfer of organisms can be reduced. Manipulation of udders and teats and contact with contaminated objects such as strip cups and barn equipment should be minimized during milking (3).

Special care must be exercised in Strep. ag.-free herds to assure that this organism is not introduced on the hands of a milker working elsewhere in an infected herd. This bacterium has been isolated from milkers' hands as long as 10 days after their last contact with infected cows (3).

### **3. Forestripping**

Forestripping is the removal by hand manipulation of the teat those first few squirts of milk prior to machine application. The purpose of forestripping is to: 1) check for abnormal milk as an early detection method for clinical mastitis; 2) remove high SCC or high bacterial count milk from the teat canal; 3) be sure that the teat canal is open for the free flow of milk; and 4) stimulate oxytocin release to enhance milk letdown. Forestripping can be done either before or after washing; however, forestripping before washing may be preferable in most milking routines and does offer a strong stimulus for milk letdown upon initial contact with the cow. Forestripping is best accomplished in a stall barn by using a strip cup making the detection of abnormal milk more obvious. Under no circumstances should foremilk be stripped on the floor of a stall or into the milker's hand; however, it is an acceptable procedure to forestrip onto the floor in a milking parlor. Early discovery of clinical cases assures more timely treatment and enables diversion of high SCC milk from the bulk tank assuring standards for milk quality premium are met.

### **4. Premilking Teat Sanitation**

Methods and effectiveness of premilking preparation have always varied among producers. There is, however, an increasing concern about environmental mastitis. Research indicates that wetting any portion of the udder above the teats without thorough drying will result in dirty and bacteria-contaminated water entering the teat cup, thereby increasing the risk of new infections and lowering milk quality (6).

Cleaning only the teats with water, or a postmilking disinfectant dip, plus manual drying with a dry individual paper towel is needed to reduce bacteria numbers and remove sediment and chemical residues. Udder surface above the teats should not be wetted; and if it is, it must be thoroughly dried. The following series of tables from research by Galton in New York (6, 7) give dramatic evidence to the importance of proper premilking preparation. The main points from each of a series of tables are highlighted here.

**Table 1. Cleaning both udder and teat surfaces:**

Wetting the udder surface, as well as teats, without adequate drying can increase bacteria in milk due to drainage from the udder surface.

An udder wash sanitizer has relatively small benefit in reducing bacteria in milk because of its low concentration and short contact time.

Manual drying is of major benefit in reducing bacteria, due to "physical action" of wiping as well as "drying."

Procedures on both UDDER and TEAT surfaces			Bacteria in milk <sup>a</sup>	Primary factor
<u>Water hose</u>	<u>Wash sanitizer</u>	<u>Manual drying</u>	<u>% change</u>	
X			+13	Water drainage
X	X		-10	Sanitizer
X	X	X	-68	Manual drying

<sup>a</sup> Percent change of bacteria in milk compared to no preparation.

**Table 2. Cleaning teats only.**

Premilking preparation should clean teats only.

"Dry wiping" can remove some bacteria (largely as part of sediment) due to physical action. The degree of result depends on how dirty teats are. It alone is never the best procedure.

Drying teats prevents movement of bacteria in water, and the physical action during manual drying is beneficial.

Procedures on TEATS only					Bacteria in milk <sup>a</sup>	Primary factor
<u>Dry towel</u>	<u>Water hose</u>	<u>Wet towel</u>	<u>Wash sanitizer</u>	<u>Manual drying</u>	<u>% change</u>	
X					-38 <sup>b</sup>	Physical effect
	X				-65	Drainage from udder surface
	X		X		-67	
	X			X	-76	Drying
	X		X	X	-88	Drying plus sanitizer
		X			-71	Damp, but no drainage from udder surface
		X	X		-62	
		X		X	-79	Drying
		X	X	X	-78	

<sup>a</sup> Percent change of bacteria in milk compared to no preparation.

<sup>b</sup> Result depends on "dirtiness."

**a. Predipping.**

Predipping teats with a teat dip solution approved for premilking teat sanitation is a recent practice being recommended by some researchers and extension workers. Teats must be free of gross manure or dirt contamination prior to predipping if this procedure is to be consistently successful. If they are dirty, the teats must be washed prior to predip application. Predipped teats must be allowed a 30-second contact time for the disinfectant to kill

bacteria and then be thoroughly wiped dry with a separate paper towel. Proper procedures will probably require more time to prepare the cow for milking; however, this procedure may be helpful in herds experiencing "environmental" mastitis.

**Table 3. Effectiveness of premilking teat dipping (predipping).**

Predipping with a post milking teat dip plus drying, is nearly as effective as using water (hose or wet towel) and sanitizer plus drying, in reducing bacteria. This is due to higher concentration of disinfectant in the postdip used as a predip.

Manual drying must be involved to dry up water or to remove predip residues.

Procedures on TEATS only				Bacteria in milk <sup>a</sup>	Primary factor
<u>Wet towel</u>	<u>Predip</u>	<u>Wash sanitizer</u>	<u>Manual drying</u>	<u>% change</u>	
X				-27	Liquid scrubbing
X		X		-30	
X			X	-63	Liquid drying
X		X	X	-68	
	X			-34	Germicide
	X		X	-54	Germicide drying

<sup>a</sup> Percent change in milk compared to no preparation.

**b. Stimulation time.**

The recommended stimulation time (actual rubbing of the teats) during the washing and drying process approach 20 seconds. Doing this helps: 1) obtain cleaner and dryer teats; and 2) promote better milk letdown stimulation. There is concern among dairy farmers about what is perceived as "added time" to the milking routine.

Reneau and Farnsworth (14) have conducted studies comparing typical (short-term) teat washing time vs a prescribed teat washing procedure involving a minimum of 3 vertical motions up and down the sides of each teat plus 1 or 2 horizontal motions across the teat end. Wash time was increased by 5 seconds when the definitive prescribed routine was utilized, but cows milked per hour in a double-8 herringbone parlor actually increased by two (control = 72 and prescribed procedure = 74). This increase in efficiency was the

result of providing a longer stimulation time, which was especially beneficial on the lower producing late lactation cows.

The importance of rubbing the teats dry with an individual dry towel cannot be emphasized too much. Galton and Merrill (7) found that teat skin bacteria were reduced by 80 to 85% when teats were rubbed with a wet towel, but were reduced by 95% when manually dried with a dry towel. There were no differences among three types of paper towels used (Single Fold, Sani-Prep, Kowtowl).

**c. Preparation lag time.**

Maximum flow rates will be achieved if milking units are applied approximately 1 to 1-1/2 minutes after the beginning of teat stimulation. Placement of units on sooner than this isn't a problem if the teats are dry; however, preparation lag times of longer than 2 or 3 minutes may result in less efficient milking. While the range in acceptable prep-lag time varies from 20 seconds to nearly 3 minutes, it is important for the machine operator to try to be consistent as this will benefit milk ejection by enhancing conditioned responses associated with the milking process (5).

**B. MACHINE MILKING PROCEDURES**

**1. Unit Attachment and Adjustment**

Lines should be applied to teats with minimal vacuum leakage by keeping the inflation stem bent over the claw ferrule until the liner slides onto the teat. The long milk hose should be adjusted immediately to avoid liner slippage and/or uneven milkout.

Liner slips and squawks allow air to move milk droplets at a rapid speed which may result in mastitis causing bacteria to impact teat ends. If liner slips occur on more than 5% of the cows milked, it is suggested that milk producers first check their milking procedures and unit alignment, then check with their equipment dealer concerning liner selection, vacuum pump capacity, milking vacuum level and regulator response (1).

**2. Machine Stripping**

Machine stripping should not be a routine procedure; it should be used in the fewest possible instances, the exception being for "problem" cows due to injury, udder shape, mastitis or udder edema (8).

To machine strip, apply downward pressure on the claw and massage each quarter in gentle downward motion. Machine stripping should be completed in 5 to 15 seconds per cow requiring machine stripping. Don't squeeze the inflation milk

tube to detect milk flow as this will cause vacuum to vary and may force bacteria into the teat (2).

### **3. Overmilking**

Much has been written and said about the effects of overmilking in relation to teat damage and increased mastitis. However, when milking machines are installed correctly and operated properly, research has shown that little, if any, teat damage occurs from moderate overmilking. Excessive overmilking is usually the result of too many units being used, too much time spent machine stripping, or a work routine that is unorganized and unnecessarily long (9, 10, 11, 12).

No one recommends excessive overmilking. In the absence of automatic take-offs, and when the milking routine cannot be improved, then it is recommended the number of units used be reduced so the machine operator can consistently remove the units at the appropriate time (8).

A visible means of observing end of milk flow is recommended. Never squeeze or pinch liners; doing so alters vacuum levels and may result in reverse air flows. Depending on clear plastic milk hoses can be misleading since milk may go back and forth and appear to be flowing when it isn't. End-of-milking indicators are becoming available and have value in helping prevent overmilking.

### **4. Unit Removal**

The vacuum should always be shut off prior to unit removal. All milking systems should be equipped with a shut-off valve located conveniently near the claw. Further, the operator should avoid the practice of removing teat cups one by one. To purposely break vacuum during unit removal will cause a serious airslip that may result in a new mastitis infection.

### **5. Milking Sequence**

Another factor to be considered in the milking routine is the milking order. Chronically infected cows, which because of their value are not culled from the herd, should be milked last. It is well known that isolation of cows infected with contagious pathogens such as Staph. aureus and Strep. ag. will slowly spread to other cows. In stall barn herds, this can be effectively accomplished by milking uninfected cows first and infected cows last. Use of the DHI SCC report to determine which cows have high somatic cell counts is helpful in sorting out infected cows. Ideally, uninfected cows should be located in one end of the barn where the milking order begins.

## C. POSTMILKING ROUTINE

### 1. Teat Dipping

Use of an effective germicidal teat dip after each milking is highly effective and is more important than the other milking hygiene practices combined in reducing new infections by contagious bacteria. Several studies have shown about 50% reductions in new infections with use of an effective germicidal teat dip (3).

#### a. Efficacy.

Many products for teat dipping are available to dairymen. Unfortunately, very few have been tested on enough cows for a long enough time under field conditions. Chlorhexidine (0.5%), iodophor (0.5 to 1.0% available iodine), and hypochlorite (4%) dips effectively reduced new infections in multiple controlled field studies. Hypochlorite compounds may cause irritation and should have less than 0.05% sodium hydroxide (NaOH) to minimize teat chapping and irritation. Recently, dodecyl benzene sulfonic acid, at a concentration of 1.94%, has been shown effective in a limited number of herds in several studies; effectiveness of this product in reducing coagulase-negative staphylococcal infections is questionable (3).

#### b. Spraying.

In most studies of postmilking teat disinfection, the germicide was applied by dipping but under field conditions the germicide is sometimes more conveniently applied by spraying. Special care is required to assure proper coverage of the teat skin when sprayers are used (3). Minimally, the bottom two-thirds of teat surfaces should be completely covered.

#### c. Cold weather.

Teat skin surfaces that are washed by the milking process lose some of their natural oils and become more vulnerable to frostbite. Thus, the question is how to manage teat dipping during winter. The preferred option is to teat dip every cow regardless of weather **but** under severe cold conditions, allow a 30-second contact time and then wipe teats dry prior to cows leaving the parlor (13). This preventive step is recommended any time the wind chill index exceeds  $-25^{\circ}$  F ( $-20^{\circ}$  with 5 mph wind;  $-3^{\circ}$  with 10 mph;  $5^{\circ}$  with 15 mph;  $10^{\circ}$  with 20 mph; and  $15^{\circ}$  with 30 mph wind).

### 2. Dry Cow Treatment

Antibiotic treatment at drying off is a proven method of mastitis control (3). Therapy with an effective antibiotic in a slow-release base has the following advantages:

1. The cure rate is higher than for treatment during lactation.
2. Incidence of new infections during the dry period is reduced.
3. Damaged tissue may be regenerated before freshening.
4. Clinical mastitis at freshening is reduced.
5. Risk of antibiotic contamination of salable milk is minimal.

Dry cow treatment effectiveness is enhanced by the use of slow-release products that maintain therapeutic levels of antibiotics for long periods in the dry udder. The preferred time to treat is after the final milking of lactation. However, products now available do not persist throughout the dry period and thus are ineffective in preventing infections which occur just before calving. Re-treatment during the dry period does not enhance effectiveness. Products designed for lactating cows should not be used to treat cows at drying off (3).

#### D. CONTAGIOUS VS ENVIRONMENTAL MASTITIS

Bacteria are the cause of most mastitis. While there are many different bacteria pathogens, there are two primary categories of mastitis pathogens; contagious pathogens and environmental pathogens (15).

**Contagious pathogens** are those pathogens whose primary source is an infected quarter. They are spread from quarter to quarter or cow to cow by contaminated hands, milking equipment, poor premilking preparation procedures, etc. Postmilking teat disinfection is the single most important control for this type of bacteria.

**Environmental pathogens** are those mastitis pathogens whose primary source is the environment in which the cow lives. They are spread to the cow by exposure of the teats via direct contact with contaminated bedding, etc. Keeping cows clean and dry is the most important way to control this type of mastitis.

It is important to remember the basic principles when attempting to apply new mastitis control technology. Each concept used in the control of mastitis must reduce either the rate of infection or the duration of the infection in order to successfully reduce the level of infection.

Level of infection = New infection rate + Duration of the infection

The speed in which the present level of mastitis is reduced will depend more on the duration of infections and is highly dependent on the type of bacteria infection involved. Herds heavily infected with Staph. aureus mastitis should expect that the reduction of the herd mastitis level will require a much longer period (18 months) than a herd heavily infected with Strep ag. or "environmental" mastitis.

It is important to emphasize that procedures to control contagious mastitis and environmental mastitis may differ. A well-balanced mastitis control program will include procedures to prevent both contagious and environmental pathogens. Of those

mastitis control procedures that have proven beneficial, the following (Table 4) are a suggested order of priority relative to their impact in control of the disease.

Table 4. Mastitis control practices of proven efficacy against contagious and environmental pathogens.

Level of priority	Mastitis control practice	Mechanism for reducing the level of contagious mastitis	
		Reduction in new infection rate	Reduction in duration of infections
*A	Teat dipping (postmilking)	+++	
	Dry cow therapy	+++	+++
	Milking hygiene	+++	
	Milking machine function (air slips)	+++	
**B	Segregating infected cows	++	
	Culling		++
***C	Backflush	+	
	New claw designs	+	
	Vitamin E and selenium supplementation	+	+
****D	Vaccination (Staph. aureus)		+

Level of priority	Mastitis control practice	Mechanism for reducing the level of environmental mastitis	
		Reduction in new infection rate	Reduction in duration of infections
*A	Management of environment (ventilation, bedding, alleys, etc.)	+++	
	Milking hygiene	+++	
	Milking machine function (air slips)	+++	
**B	Teat dipping - germicide	++	
	Teat dipping - barrier	++	
	Dry cow therapy (environmental streps)	++	
	Predipping	++	
	New claw design	++	
***C	Vitamin E and selenium supplementation	+	+
****D	Backflushing	0	0
	Vaccination	?	?
	Culling/segregation	0	0

\*A = Very important. Every farm should include these factors in a mastitis control program.

\*\*B = Important. However, unless those procedures listed under category A are being used, benefits may not be realized.

\*\*\*C = Moderately important. When those procedures listed under categories A and B are being used, the addition of these may improve mastitis control on some farms.

\*\*\*\*D = Minor importance.

0 = No published evidence indicating these practices have value.

## 1. Bedding Considerations

Teats are heavily exposed to environmental bacteria in the interval between milkings. Control of environmental infections should focus on reducing this exposure from environmental sources. The most effective method to reduce new infections in the interval between milkings is to provide a clean, dry environment.

Cows in confinement housing are generally at greater risk than those on pasture. Many bedding materials will support large populations of both environmental streptococci and coliform bacteria. There is a relationship between the numbers of coliform bacteria in bedding and the incidence of coliform infection. A general guideline is that bedding with coliform numbers greater than 1 million per gram is likely to contribute to increased coliform mastitis. Finely chopped organic beddings such as sawdust, shavings, recycled manure, pelleted corn cobs, etc., may contain more than 1,000 million coliforms per gram. In contrast, fresh cow manure seldom contains more than 10 million per gram (3).

The appearance of bedding can be misleading with respect to coliform contamination as numbers are frequently higher in relatively fresh, clean-appearing sawdust than in old and badly soiled material.

Daily total replacement of sawdust in the back 1/3 of stalls reduces exposure to coliform bacteria. Also, replacement of sawdust with clean, long straw reduces exposure to coliforms but may increase exposure to environmental Strep. Attempts to maintain low coliform numbers in organic bedding materials with lime or chemical disinfectants are generally not practical as frequent, even daily, application is necessary to be effective. Composting recycled manure before it is used as bedding will reduce coliform numbers, but numbers may become very high after it is in use. Use of inorganic bedding materials such as sand and crushed limestone will decrease exposure to coliform bacteria and has effectively controlled coliform outbreaks in problem herds (3).

Other means to reduce environmental exposure are:

1. Avoid overcrowding.
2. Provide ventilation adequate to maintain low humidity and dissipate heat.
3. Keep the environment as free as possible of accumulated manure and urine.
4. Prevent cow access to muddy lots or corrals, wet areas under shades, mud holes, marshy areas and pools of standing water.

## E. BULK TANK CULTURES

The contagious pathogens (Staph. aureus, Strep. ag., mycoplasma) found in milk come from infected mammary glands. Bulk tank culturing is a useful and direct means of monitoring mastitis caused by these pathogens. Environmental pathogens in bulk tank milk are rarely from infected mammary glands but do reflect teat surface contamination. Environmental pathogens come and go, depending on weather conditions, level of stall management, and repeatability of the milking routine. Use of bulk tank cultures, a method developed at the University of Minnesota (4), has proven especially useful in determining the potential for infection with environmental organisms.

The number of organisms shown in Table 5 are based on a specific procedure, utilizing 5 consecutive daily frozen bulk tank samples. The numbers have been developed based on experience in numerous herds where the results of bulk tank cultures have been compared to on-site evaluation and whole herd microbiological examinations.

Table 5. Bulk tank microbiology and identification of herd problems.

Type of bacteria	Low levels	Moderate levels	High levels	Very high
<u>Streptococcus agalactiae</u>	0-50	100-200	200-400	>400
<u>Staphylococcus aureus</u> (coag. pos.)	<50	50-150	150-250	>250
Non-ag Strep.	500-700	700-1200	1200-2000	>2000
Coliforms	<100	100-400	400-700	>700
<u>Staphylococcus</u> species (coag. neg.)	<300	300-500	500-750	>750

The source, means of spread, and effective control measures for common mastitis pathogens in bulk tank milk are shown in Table 6 (3, 4).

Table 6. Source, means of spread, and effective control for common mastitis pathogens.

Type of bacteria	Usual source	Major means of spread	Effective control measures
<b>Contagious pathogens</b>			
<u>Streptococcus agalactiae</u>	Infected udders	Cow-to-cow at milking time	Teat dipping; dry cow treatment; lactation treatment
<u>Staphylococcus aureus</u>	Infected udders; teat sores	Cow-to-cow at milking time	Teat dipping; dry cow treatment; segregation; cull chronically infected cows
<b>Environmental pathogens</b>			
<u>Environmental Streptococci</u>	Environment	Environment-to-cow	Improve barn, free stall and holding area sanitation; teat dipping; dry cow treatment
Coliforms	Environment	Environment-to-cow	Improve barn, free stall and holding area sanitation; improvement bedding management
<u>Staphylococcus species</u>	Environment, normal skin inhabitant	Environment-to-cow	Improve premilking sanitation, including teat scrubbing; improve teat dipping technique

## **F. CLEANING MILKING EQUIPMENT**

Regardless of the type and design of the milking installation, there are three phases in cleaning milking equipment: rinse, wash, and sanitize. Smith (16) has these comments regarding the three phases.

### **1. Rinse**

Immediately after milking, while the equipment is still warm, rinse the system with clear water of between 100 to 110° F. Water temperature below 100° F may congeal milk fat and make its removal most difficult. Water temperature above 165° F may "cook" protein onto stainless steel surfaces. Not only can water hotter than 165° F precipitate proteins and produce a milkstone-like surface, it can damage milking machine components made of plastic materials. Increasing water temperature above 165° F is not the solution to equipment wash-up problems. This initial rinse removes the residual milk from the system; therefore, the water must not be recirculated through the system. Discharge the rinse water and continue the rinse cycle until the return water is clear.

### **2. Wash**

While the initial rinse water is draining throughout the milking system, make sure the wash vats are being filled with 145 to 160° F water. Circulate alkaline detergent throughout the milking system for a minimum of 10 minutes. Monitor the water temperature to ensure the temperature never drops below 130° F or manufacturer's recommendation, at which temperature proteins can be redeposited onto stainless steel surfaces.

The hot alkaline detergent (145 to 160° F) removes the milk fat, while the addition of chlorine to an alkaline detergent formulation aids in milk protein removal. However, a chlorinated alkaline detergent is not a sanitizer. The returning wash water should be at a temperature above 130° F, a pH between 11 to 12, and at least an available chlorine content of 100 to 130 ppm. Test kits are available from milking equipment and dairy chemical (soap, detergent, etc.) dealers to determine water characteristics.

### **3. Rinse/Sanitizer**

A clear, cold water rinse should immediately follow the wash phase.

Prior to the next milking, a sanitizing rinse should be circulated throughout the system. Sanitizing solutions are available, however, that will effectively rinse and sanitize the system after the wash phase. Chlorine sanitizers are commonly cheaper in price, but have harmful, deteriorating effects on rubber products. Iodine-acid (phosphoric) sanitizers are available that will not harm rubber parts, but they are more expensive. The cold water sanitizer solution should provide a

3 to 4 pH with 12 to 25 ppm available iodine. When chlorine is used, the recommended level should be 100 ppm.

**Safety precaution: Never mix chlorine and acid products.**

When sanitizers are used after the wash phase, the system should be acid rinsed weekly to prevent and remove any mineral deposits. Mineral deposits can interfere with the normal function of some automatic detaching sensors and other milking machine components that function (or monitor) due to milk conductivity.

### REFERENCES CITED

- 1 Appleman, R.D. 1989. Milking systems and equipment alternatives for stall barns and parlors. Proc., Dairy Management: Milking for Quality and Profit. Dept. of An. Sci., Univ. of Minnesota, St. Paul. pp. 1-17.
- 2 Bringe, A.N. 1989. Techniques for harvesting quality milk. Proc., Dairy Management: Milking for Quality and Profit. Dept. of An. Sci., Univ. of Minnesota, St. Paul. pp. 18-24.
- 3 Eberhart, R.J., et al. 1987. Current concepts of bovine mastitis. Natl. Mastitis Council. Arlington, VA. 47 pages.
- 4 Farnsworth, R.J. 1982. Integrating microbiology into mastitis programs. Proc., Natl. Mastitis Council. Arlington, VA. pp. 26-30.
- 5 Galton, D.M. and W.G. Merrill. 1987. How critical is timing of milking machine attachment? Proper Milking Procedures. Cornell Univ., An. Sci. Mimeo. Series No. 106. 3 pages.
- 6 Galton, D.M. and W.G. Merrill. 1987. Good milking preparation produces higher quality milk and better udder health. Proper Milking Procedures. Cornell Univ., An. Sci. Mimeo. Series No. 106. 15 pages.
- 7 Galton, D.M. and W.G. Merrill. 1988. Effectiveness of premilking udder preparation practices on milk quality and udder health. Proc., Milking Systems and Milking Mgt. Sym. NRAES. Ithaca, NY. pp. 127-136.
- 8 Merrill, W.G. and D.M. Galton. 1987. Machine stripping and excessive overmilking should not be routine procedures. Proper Milking Procedures. Cornell Univ., An. Sci. Mimeo. Series No. 106. 4 pages.
- 9 Micke, C.F. and R.D. Appleman. 1973. Simulating herringbone and side-opening milking parlor operations. J. Dairy Sci. 56:1063-1069.
- 10 Mix, L.S., et al. 1978. Chore reduction for confinement stall dairy systems. Dairy Chore Reduction, P.O. Box 211, Ft. Atkinson, WI. 64 pages.

- 11 Mix, L.S., et al. 1978. Chore reduction for free stall dairy systems. Dairy Chore Reduction, P.O. Box 211, Ft. Atkinson, WI. 64 pages.
- 12 Morey, R.V., N.E. Valentine and R.D. Appleman. 1980. Simulation of milking operations in stanchion barns. Am. Soc. Agr. Engr. 23:462-467.
- 13 Reneau, J.K. 1987. Teat dipping during cold weather. Univ. of Minnesota, Dept. of An. Sci. Dairy Update No. 85. 4 pages.
- 14 Reneau, J.K. and R.J. Farnsworth. 1988. Taking time for good premilking teat sanitation does not slow overall milking time. Univ. of Minnesota, 1988-89 MN Dairy Rep. AG-BU-2235. pp. 36-38.
- 15 Reneau, J.K., R.J. Farnsworth and R.D. Appleman. 1987. Current concepts in udder health. Univ. of Minnesota, 1987-88 MN Dairy Rep. AG-BU-2235. pp. 13-22.
- 16 Smith, T.W. 1985. Cleaning and sanitizing the milking system. Univ. of California, Coop. Ext. Newsletter 15(12):1-3.

## **MILKING MANAGEMENT**

### **III. Innovative European Feeding and Management Systems**

R.D. Appleman  
University of Minnesota, St. Paul

Dairying has traditionally been labor intensive and is an enterprise with a need for routine monitoring of daily events. It is an industry that is well suited for the application of electronics and automation. Thus, bioengineering and biotechnology are two emerging technologies likely to have substantial impact on producing milk in the U.S. and Canada.

The internationalization of agriculture and the globalization of research and development is a tremendous force helping shape the future of the nation's dairy industry (5). There are many international firms, both governmental and private, doing research and development on the automation of feeding, milking and management of the dairy cow herd. This R & D effort is especially prominent in The Netherlands, Sweden, Denmark and Germany. Thus, the objectives of my Single Quarter Leave in the fall of 1988 were: a) to become better acquainted with recent European developments; and b) to assess the practical application and potential adoption of these technologies in the U.S. (2).

#### **FEEDING MANAGEMENT**

The European community, at least the Scandinavian countries, Germany and The Netherlands, are intensifying their research effort beyond that of "feeding concentrates", and are investing money and time into the development of equipment to control the amount and frequency of forages offered to individual cows whether they are housed in stall barns or in groups (free-stalls).

Why is there concern and a change occurring? At least 6 reasons are given, namely:

1. cows have little "nutritional wisdom";
2. herd sizes are increasing and availability of labor at critical times is limited;
3. milk production per cow is increasing;
4. automation and increasing throughput in parlors limits opportunity to "feed according to production";
5. limited bunk space affects social behavior of milk cows; and
6. there is an increasing concern about forage intake and protein digestion.

How much expression of choice is there when cows have an option of consuming two or more forages? In a 1981 review article, Coppock, et al. (6) states:

"Although grazing cattle select a diet (at least from an abundant sward) higher in digestibility and lower in fiber than the total plant available to them, there is a large and consistent variation among Holstein cows in their preference for excellent stored forages whenever they are given a two-choice option. This expression occurred either with a simultaneous choice or when the choice was limited to one forage in the a.m. and the other in the p.m. In one typical

comparison the variation in consumption among 30 cows offered corn silage and alfalfa hay simultaneously ranged from 23.6 to 77.7% corn silage DM. The opportunity to select a preferred forage is most serious when two forages such as corn silage and alfalfa are offered because of the great difference in their nutrient profiles which greatly limits precision of concentrate formulation to match some 'average' forage ratio. There was no indication that cows that selected the low protein forage (corn silage) and were then protein deficient would through time switch their choice to the higher protein forage (alfalfa)."

Even when only one forage is offered, there is considerable variation in forage intake among cows of similar milk producing ability, age and weight. Researchers in The Netherlands (7) measured individual average daily intake of forage dry matter offered to 10 cows housed in free-stalls, each producing approximately 75 lbs milk daily, and fed concentrates individually in a computerized grain feeder. Forage consumption averaged 32.7 lbs per day during the 3-week experimental period. With 2 standard deviations equaling + or - 5.6 lbs, a "low consuming" cow will eat only 70% as much forage dry matter as a "high consuming" herdmate producing a similar amount of milk.

Linn and Otterby (10) concluded it was impossible to draw definite conclusions regarding the best feeding strategy for high producing dairy cows due to a paucity of research information. While it has been established that cows fed twice daily consume from 12 to 16 meals per day and cows fed 22 times per day consume more than 22 meals daily, feeding frequency appears to have little benefit on increasing feed intake or milk production. They suggested that a minimum of four daily feed offerings, alternating between forages and concentrates, appears to be the most desirable method of feeding ration components individually.

More recently, Robinson (16) projected milk production responses to increased frequency of feeding a TMR (Table 1), basing his conclusions on diet fermentability and quality of management. Clearly, he feels any benefits derived will be more pronounced among early lactation cows in the lesser-managed herds, especially when diet fermentability is high.

Table 1. Projected benefits of increased feeding frequency of TMR's.

Management quality	Diet fermentability	Stage of lactation		
		Early	Mid	Late
Poor	High	+++++	+++	+
	Medium	++++	++	
	Low	++	+	
Good	High	+++	++	
	Medium	++	+	
	Low	+		

Benefits: 5 +'s > 4 +'s > ---- > 0 +'s

Regarding feed sequencing, Robinson (16) concluded there may be feedstuff types that will optimally manipulate rumen fermentation. For example, if a producer fed forages first in the morning, this would: a) form a fiber mat in the rumen; b) improve buffering capacity; and c) reduce particle passage provided the forage is medium to long chop length, thereby increasing net fiber digestion.

While many U.S. farmers have learned to feed a total mixed ration (TMR) to groups of cows, there are many producers on both continents looking forward to controlling the forages offered to cows on an individual basis. This is especially true among producers already equipped with and utilizing computerized cow identification and concentrate feeding systems. A schematic of feeding systems currently available, and how they compare in relative efficiency, is shown in Figure 1.

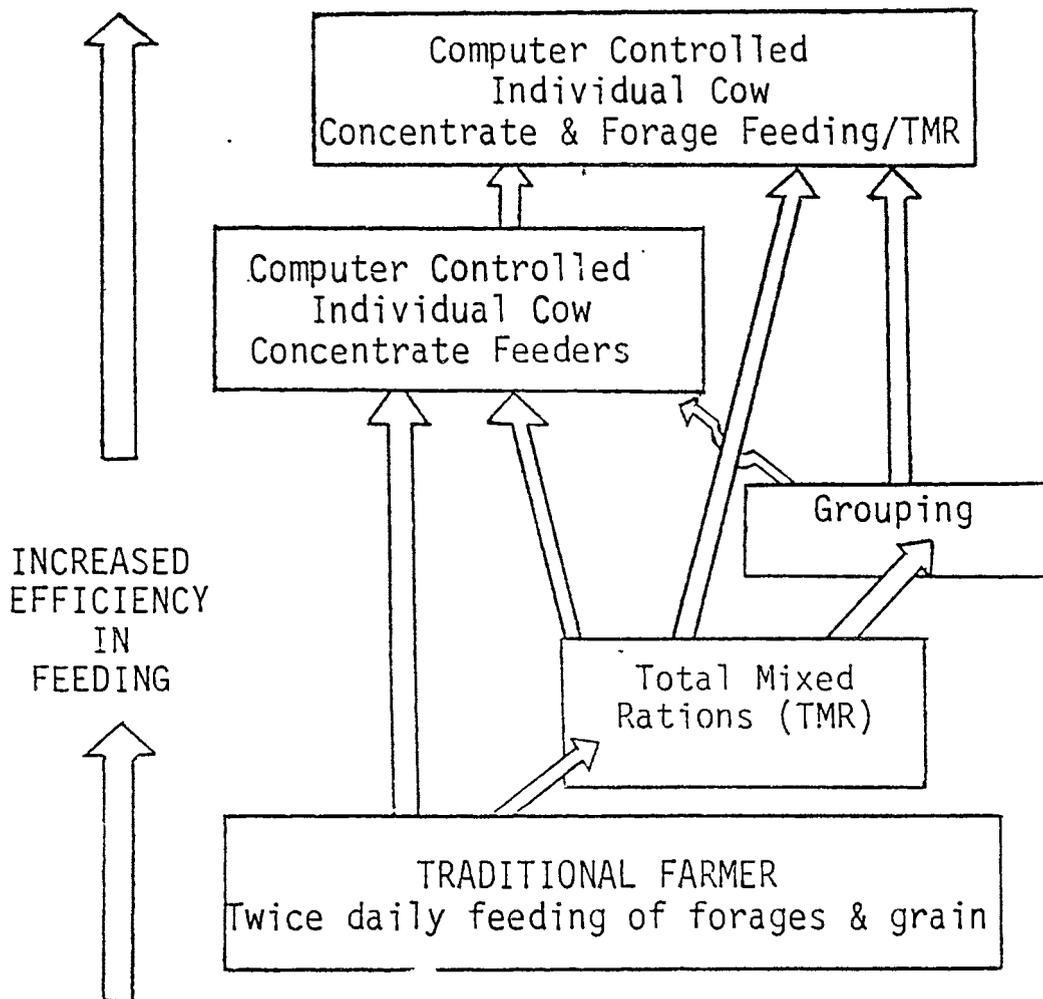


Figure 1. Schematic of feeding systems relative to efficiency in feeding the dairy herd.

Computerized individual cow forage feeders are commercially available today in Europe. The control system on the feeding device may either: a) utilize an individual cow's ID transponder, or b) be stall location dependent. Such systems work in either tie-stall or free-stall barns.

## **BEHAVIOR STUDIES**

The European and Scandinavian researchers appear to have placed more emphasis than U.S. researchers on cow behavior and how it might interact with facilities, equipment and procedures thereby influencing cow comfort and performance. While the points listed below are by no means the result of an exhaustive review, they do represent conclusions made by European or Scandinavian researchers that may have application to many situations in the U.S.

### **I. Associated With Feed Intake**

**A. Food consumption:** According to Metz (12), competition for food by loose-housed cattle depends on the following factors:

1. **Type of food** -- consumption time and attractiveness. The first influences the chances for competition; the latter affects willingness to compete.
2. **Spatial limitations** -- feeding space and physical structure. The first influences the chances for competition; the latter how much protection from attack is provided a subordinate animal.
3. **Temporal limitations** -- competition is likely to be increased when access to food is limited.
4. **Social factors** -- social tolerance of herd members vary (age, experience, etc.). Group size is a major factor; first lactation heifers don't compete as well against cows; first lactation heifers from the same rearing group are less aggressive and feed intake is more uniform than among animals from different rearing groups.

**B. Water consumption:** Monica Andersson (1) has concluded from her studies that:

1. Cows prefer to drink in connection with feeding. Some cows delayed their consumption of hay when water was restricted for 2 h during feeding.
2. If eating time was restricted to 2.5 h/feeding with no water for the first 2 h, feed consumption, water intake and milk yield were significantly lower than with 24 h feed and water availability.
3. When pairs of tied-up cattle shared a water bowl, dominate cows ate more food, drank more water and produced significantly more milk than

submissive cows. The submissive cows may have suffered from chronic stress.

## **II. Associated With Housing Systems**

### **A. Walking area**

1. Animals should be adapted at an early age to the type of floor they will be kept on as cows (15, 20).
2. German researchers have suggested that rubber-covered slats are helpful in improving locomotion and preferred by animals having to lie down on slotted floors (9).
3. More concern should center on providing cows an opportunity to avoid confrontation with other cows (locomotion, daily rhythm of animals, synchronous behavioral performance) (20).

### **B. Resting area**

1. The amount of time spent lying is reduced proportionally to the reduction in the number of lying places. The effects were larger for the lower ranking animals in the dominance hierarchy (19).
2. A priority exists for lying above eating, at least for some portions of the day (19).
3. Cows intend to achieve a rather fixed amount of lying, and that their well-being is seriously impaired when lying time is restricted for several hours (13).
4. A high proportion of mountings in a "confined idling space" (26 sq. ft./animal) adjacent to free-stall entrances was directed to cows in the free-stalls. Most mountings were by cows in estrus. When more idling area was available (144 sq. ft./animal), non-estrus cows initiated almost one-half of the sexual interactions (14).

## **USING SENSORS AND DEVELOPING MANAGEMENT INFORMATION SYSTEMS**

The possibilities of using computers to aid animal control and management are unlimited. Such systems are just beginning to emerge. The selection and development of sensors suitable for detecting physiological change in animals must: a) be economical; b) be easily attached or applied to the animal; and c) not disturb the production process. Milk yield devices, body weight determinations, and measurements that can be associated with automated feeding systems are especially valuable. In addition, some special sensors monitoring animal physiology may be required.

Health problems and less-than-optimal reproductive management are major causes of lowered profitability. Their effects are magnified by failure to detect the condition soon after onset. Health care can be divided into four main categories. Minnesota researchers (11) has shown the relative costs of labor and treatment for each of four categories of health disorders to be quite similar (Table 2). An assessment of sensors and/or monitors developed or needed for each category follows.

Table 2. Health care (labor and treatment) costs in the University of Minnesota, Crookston dairy herd.

Category	Description	% of total
Digestion	Displaced abomasum, hardware, off-feed, ketosis and milk fever	28
Reproduction		28
Locomotion	Hoof care, foot rot and joint injury	25
Mastitis		18

## I. Digestion

Wiktorsson, representing the Swedish University of Agricultural Sciences in Uppsala, Sweden, stated that "a system which allows individual feeding of forages in a free-stall system provides economic benefits in: a) feed consumption; b) lower health risk due to underfeeding in early lactation; c) less risk of overfeeding in late lactation; and d) fewer conflicts in cow behavior" (21).

My assessment of European data relative to early identification of digestive disorders indicates that a drop in milk yield, change in electrical conductivity, and a loss in body weight all occur too late to be of much value; however, measuring and recording the amount of concentrates and forages consumed may be quite helpful (17, 18). In one trial where ketosis was induced, forage consumption was down 63% (22 lbs/day) within 24 hours, while concentrate consumption was down only 38% (6.6 lbs/day), milk yield dropped only 7% (4.4 lbs/day); and body weight loss was only 2% (22 lbs). What is lacking is evidence that such a drastic drop in forage intake occurs when this condition occurs.

## II. Reproduction

Sensors to provide an accurate and timely detection of estrus onset are of primary importance. Many aids have been developed and tested; most are helpful but tend to have either a low diagnostic ability or a high error rate. My assessment, based on the findings of Schlunsen, et al. (17, 18), is that improved estrus detection can be best

achieved by utilizing a computer management system to simultaneously evaluate several measurements, namely:

1. calendar prediction, based on: a) previous heat, or b) veterinarian's evaluation;
2. pedometer (activity) measurement in free-stall herds and/or pulse rate measurement in stall-barn herds; and
3. milk yield, and in free-stall barns possibly milk temperature.

### III. Locomotion

I'm unaware of any research completed, although it has been proposed by Metz and Wierenga (15), to indicate if cows can tell us when they are developing feet and leg problems. If foot rot or other infectious conditions occur, shouldn't one expect the cow to be less active? Perhaps these infections could be detected early by assessing: a) a rapid drop in activity (pedometer reading) not associated with estrus; b) a rapid drop in forage intake among cows in free-stall barns because of lowered feeding frequency; c) a drop in milk yield; and d) a corresponding increase in milk temperature.

If hoof condition is abnormal and stressful to the cow -- even in the absence of an infection -- would it be possible to detect the onset of this condition from a gradual downward trend in activity (pedometer reading) and forage consumption (in free-stall barns)? I would encourage an assessment of the potential value of these measurements at any research institution where the needed data is being collected.

### IV. Mastitis

There has been much research in the early detection of subclinical mastitis. Reasons behind these efforts include: a) the success of the somatic cell count testing program in DHIA; and b) the development of temperature and electrical conductivity sensors which were easily adapted to parlor milking systems. These applications are especially beneficial to producers who can effectively maintain milk quality (low somatic cell counts); thereby qualifying for price premiums.

Another recent development which has potential application is the ProStaph™ ELISA antibody test. This test, developed at Pullman, Washington, is designed to aid dairy farmers that are totally committed to the elimination of "Staph. aureus" mastitis through the establishment of a well-defined milking order, combined with a good milking system and excellent milking procedures.

On the other hand, treatment during lactation is normally limited to clinical cases -- and visual observation is satisfactory. Treatment of subclinical mastitis during lactation, especially the common pathogens (Strep. ag. and Staph aureus), isn't cost effective. Many subclinical infections occurring from organisms originating in the environment (E. coli, etc.) are self-cured. The questions that need answering, then, are these:

1. How much clinical mastitis is caused by organisms in the environment?
2. Would frequent monitoring of milk yield, temperature and electrical conductivity identify these cows earlier, thereby making it possible to start treatment before the cow becomes so extremely ill?
3. Would the installation of the needed sensors and the constant monitoring required by the computerized "management information system" be cost effective?

### **Summary of Sensing Devices**

Tremendous progress has been made in the development of: a) sensors for detecting physiological change in animals; and b) management information systems to assess and evaluate data collected. Currently the Europeans are expanding their research in at least two areas, namely:

1. measuring forage consumption on an individual cow basis; and
2. animal behavior as it relates to new equipment and production systems effects on dairy cattle health, performance and well-being.

### **MILKING SYSTEMS**

To achieve high levels of milk production, the dairy farmer must use a machine that will milk cows efficiently and completely. Two primary differences between American and European standards are apparent. One, American standards call for a larger vacuum supply system to overcome too much inadvertent air admission during unit attachment, machine stripping and unit removal which may result in impacts (reverse flow of milk droplets) and an increased incidence of mastitis. Two, Europeans more typically utilized wide-bore liners which minimize impacts but result in more "teat cup crawl" and require the operator to do more machine stripping.

For a more complete discussion on American standards for modern milking systems, the reader is referred to the proceedings of the 1989 4-State Dairy Management Seminar (3).

#### **I. Automated milking**

Much research and investment to develop both the equipment and management practices necessary to successfully automate the entire milking process is underway in Europe, especially in The Netherlands. What are the reasons? Gravert (4) listed 5 primary objectives for developing automated milking systems (AMS) utilizing robotics, namely:

1. to reduce the cost of producing milk;
2. to improve working conditions of dairy farmers;
3. to improve animal welfare;
4. to improve the quality of milk and milk products; and
5. to achieve better protection of the environment.

## **A. How will cow react to robotic milking?**

The research in The Netherlands (8) summarized here are the results of 2 experiments involving simulated automated milking systems (AMS). These researchers have shown:

1. Cows will voluntarily approach a milking stall from 4 to 7 times daily (avg. = 5.4) when concentrates are being offered.
2. Cows will be milked from 3.0 to 5.4 times daily (avg. = 4.0). In these experiments, cows were milked only when they had not been milked during the preceding 3 hours and expected milk production exceeded 7.7 lbs.
3. Milk yield and total protein production isn't particularly affected by variable milking intervals. In contrast, fat production exceeds expectations when the milking interval is less than 6 hours duration and is less than expected when the interval exceeds 7 hours.
4. The test group didn't differ significantly from cows in the control (2X milking) group in reproductive performance, incidence of mastitis, somatic cell count or teat health (openness, erosions or eruptions).
5. Cows laid down more when milked more frequently. This was especially true in those cows producing 55 lbs milk or more daily and when forages were offered ad lib at the feeding fence. These results suggest high producing cows had less trouble lying down in free stalls, and were more comfortable while lying, when milking frequency was increased.

In summary, it is concluded that AMS can create favorable conditions for cows. More frequent milking probably better meets the requirements of high producing cows.

## **B. Challenges and Opportunities**

The ultimate potential for robot attachment and the details on method and configuration remain speculative. The two Dutch companies involved in the development (Vicon and Gascoigne Melotte) are approaching the challenges differently. The Vicon unit milks from the side; the Gascoigne Melotte moves under the cow from between the rear legs.

Many technical problems are anticipated. The greatest challenges appears to be in: a) locating the teat; b) preparing (washing) the udder for milking; and c) cleaning and sanitizing the entire milk transfer system during periods when no milk is flowing in the system. Regarding the first challenge, several methods for locating the teat are being tried, including photogenics, ultrasonics and infra-red sensing.

### **C. System Costs are Unknown**

The cost to equip AMS's remains an unknown. While estimates have been as low as \$50,000 (U.S. money) for a 60-cow herd, many dairymen and research scientists interviewed suspect the actual cost for each complete unit will exceed \$100,000. At this time, it isn't known how many cows each AMS unit will serve. Estimates range from 20 to 100 cows.

Automated milking systems won't be cost effective simply by saving labor. Undoubtedly additional income must be generated from the sale of additional milk. While AMS's may eventually be cost effective in well managed, high producing family farms of 50 to 150 cows housed in free-stalls, the real driving force behind its adoption is that 3 or 4-times-a-day milking: a) interrupts family life; b) places a stringent limitation on a farmer's work day; and c) is hard work. My guess is that practical systems will not appear in the U.S. or Canada before 1995, perhaps not until the year 2000.

For a more complete discussion of AMS and its potential for adoption in America, the reader is referred to the proceedings of the 1989 4-State Dairy Management seminar (4).

### **II. Stall Barn Technology**

Most dairy farmers in Sweden house their cows in tie-stall barns quite similar to those in Minnesota and the northern U.S. The primary difference is that in Scandinavia cows generally "face-in" to facilitate feeding efficiency. Often times there will be 4 rows of cows, with the barn being much wider and more difficult to ventilate properly.

Producer concerns are similar to those expressed in the U.S., namely a desire to:

1. improve the efficiency of milking (reduce labor costs);
2. reduce the health hazards involved in the milking process (lifting of heavy equipment, bending and squatting required to apply and remove the milking machine cluster);
3. mechanize or automate the securing and release of cattle upon entry and exit from stalls;
4. increase feeding frequency but control the amounts of concentrates and forages fed each cow; and
5. improve the health, reproductive performance, level of milk production, and profitability of the dairy herd.

Many innovations observed were new to this author and presumably are new to the U.S. farmer; some are still being developed and evaluated; several could be introduced to the U.S. and their value assessed. A partial listing of these ideas include:

1. an overhead tract system to support milking equipment (clusters, meters, automatic take-offs) as it is transported from the milkroom to various locations between pairs of cows;

2. a portable rack for transporting all milking clusters to the cow-stalls that also permits clean-in-place (CIP) washing and sanitizing of equipment in the milkroom;
3. inverted "U-neck" stanchion design that allows maximum vertical head movement while cows are lying or standing, but restricts lateral movement to prevent: a) boss-cow aggression, or b) robbing of feed allocated to a neighboring cow;
4. a self-locking function with central control permitting cows to be released in groups but return individually; this system may be used advantageously when stall-barn cows are milked in a parlor;
5. justification for: a) individual watering cups (1/stall) to prevent aggressive cows from limiting water intake by adjacent submissive cows, and b) water temperature control (warmed water in winter months); and
6. automatic computerized concentrate feeders and forage feeders to control amounts fed each cow.

## REFERENCES CITED

- 1 Andersson, M. 1984. Drinking water supply to housed dairy cows. Dept. of Anim. Nutr. and Mgt., Swedish Univ. of Agr. Sci., Report 130:1-123.
- 2 Appleman, R.D. 1988. Single quarter leave report. Dept. of Anim. Sci., Univ. of Minnesota. 17 pages.
- 3 Appleman, R.D. 1989. Milking systems and equipment: alternatives for stall barns and parlors. Proc., Dairy Management: Milking for Quality and Profit. Dept. of Anim. Sci., Univ. of Minnesota. Pages 1-17.
- 4 Appleman, R.D. 1989. Automating the entire milking process utilizing robotics. Proc., Dairy Management: Milking for Quality and Profit. Dept. of Anim. Sci., Univ. of Minnesota. Pages 55-61.
- 5 Boehlje, M.D. 1988. Megatrends impacting agriculture. Dept. of Agr. and Appl. Econ., Univ. of Minnesota, Staff Paper P88-30.
- 6 Coppock, C.E., D.L. Bath and B. Harris, Jr. 1981. From feeding to feeding systems. J. Dairy Sci. 64:1230-1249.
- 7 Ipema, A.H. and W. Rossing. 1987. Automatic individual feeding of dairy cattle. Proc., 3rd Sym. on Automation in Dairying, Wageningen, The Netherlands. Pages 41-51.
- 8 Ipema, A.H., H.K. Wierenga, J. Metz, A.C. Smits and W. Rossing. 1988. The effects of automated milking and feeding on the production and behavior of dairy cows. Proc., Automation of Feeding and Milking. PUDOC, Wageningen, The Netherlands. Pages 11-24.
- 9 Irsps, H. 1988. Personal communication and observation at Instit. of Prod. Engr., Fed. Res. Cen. for Agr., Braunschweig, Germany.
- 10 Linn, J.G. and D.E. Otterby. 1988. Feeding strategies in dairy nutrition. Proc., Minnesota Nutr. Conf., Univ. of Minnesota. Pages 13-22.
- 11 Mahoney, C.B., L.B. Hansen, C.W. Young, J.K. Reneau and G.D. Marx. 1985. Large cows have more digestive problems than small cows. Minnesota Dairy Report, Univ. of Minnesota. Pages 39-40.
- 12 Metz, J.H.M. 1983. Farm animal housing and welfare. Proc., Program of Coordination of Research on Animal Welfare. Commission of European Communities Martinus Nijhoff Publishers, Boston. Pages 164-170.

- 13 Metz, J.H.M. 1985. The reaction of cows to a short-term deprivation of lying. *App. Anim. Behavior Sci.* 13:301-307.
- 14 Metz, J.H.M. and P. Mekking. 1984. Crowding phenomena in dairy cows is related to available idling space in a cubicle housing system. *App. Anim. Behavior Sci.* 12:63-78.
- 15 Metz, J.H.M. and H.K. Wierenga. 1987. Behavioral criteria for the design of housing systems for cattle. Proc., Seminar on Cattle Housing Systems, Lameness and Behavior. Commission of European Communities. Martinus Nijhoff Publishers, Boston. Pages 14-25.
- 16 Robinson, P.H. 1989. Dynamic aspects of feeding management for dairy cows. *J. Dairy Sci.* 72:1197-1209.
- 17 Schlunsen, D., H. Roth, H. Schon, W. Paul and H. Speckmann. 1987. Automatic health and estrus control in dairy husbandry through computer aided systems. *British Soc. for Res. in Agr. Engr.* 38:263-279.
- 18 Schlunsen, D., H. Schon and H. Roth. 1988. Possibilities of a computer aided health and reproduction control in dairy husbandry. Proc., Automation in Feeding and Milking. PUDOC, Wageningen, The Netherlands. Pages 46-56.
- 19 Wierenga, H.K. and J.H.M. Metz. 1986. Lying behavior of dairy cows influenced by crowdings. Ethology of Domestic Animals, Ed. by Martin Nichelmann. Privat. I.E.C. Toulouse. Pages 61-66.
- 20 Wierenga, H.K. and D.J. Peterse. 1987. A housing system which reduces the incidence of claw and leg disorders. Proc., Seminar on Cattle Housing Systems, Lameness and Behavior. Commission of European Communities. Martinus Nijhoff Publishers, Boston. Pages 185-187.
- 21 Wiktorsson, H. 1987. Feeding and management of dairy cows for efficient production and good health. Dept. of Agr. Engr., Swedish Univ. Agr. Sci., Report 117:1-4.