

SIZING MILKLINES: RECENT RESEARCH RESULTS AND RECOMMENDATIONS.

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(4/13/93)

National Mastitis Council 32nd Annual Meeting, Kansas City, Missouri

Fluid flow in dual purpose milklines typically varies between "stratified flow" (when milk flows in the lower part of the milklines and air can flow in a clear, continuous path above the milk) and "slug flow" (when intermittent slugs of milk fill the entire cross-section of the milklines). Slug flow conditions almost always induce a transient drop in milklines vacuum greater than 2 kPa. Transient vacuum drops caused by slug flow are characterized by a rapid drop in milklines vacuum below the average stable level, and rapid recovery when the slug enters the receiver. The key performance indicator of stratified flow, therefore, is that any transient drop in milklines vacuum should not exceed 2 kPa (0.6" Hg) at the designed milk and air flowrates, including the transient air flows normally associated with cup changing and liner slips.

Our recommendations for sizing milklines are based on this performance guideline to ensure that stratified flow is the normal flow condition for milking high-producing cows in parlors or stanchion barn installations, now and into the next decade. Stratified flow is the preferred flow condition to maintain a reasonably stable vacuum supply to the cluster during milking. Nevertheless, transient vacuum drops associated with occasional slug flow conditions will have little or no effect on milking performance, mastitis, cell count or milk quality.

Our recommendations are based on the collated results of five studies described in two papers which form part of this presentation, as follows.

Transition Between Stratified Flow and Slug Flow Conditions in Milklines. by Doug Reinemann, Odd Ronningen, Graeme Mein and John Patoch (1993)

1. Theoretical studies of fill depth based on line diameter, slope, and milk flowrate using Mannings equation for open channel flow, prediction of vacuum drop due to air flow in pipelines assuming stratified milk flow, and transition to slug flow using existing flow pattern maps.
2. Laboratory studies to determine the maximum milk carrying capacity of 48, 60, 73 and 98mm (2, 2.5, 3 and 4 inch) milking pipelines which will maintain stratified flow conditions with varying milk and air flowrates.
3. Measurement of the instantaneous flowrate of air admitted, during cup changing or cluster fall-off, through different clusters.

Predicted Maximum Milk Flowrates in Milking Systems.

by Steve Stewart, Pierre Billon and Graeme Mein (1993)

4. Milk flow characteristics of individual cows (milk flowrates throughout milking, times to the start and end of the peak flow period, and milking times) were measured in high producing commercial and research herds.
5. Maximum predicted milk flowrates in milklines were computed using data from study #4 together with field data on unit attaching rates.

Conclusions and Recommendations to ensure Stratified Flow in Milklines.

From Studies 1 and 2:

Increasing milkline slope greatly reduces the risk of slug flow and increases the effective carrying capacity of milklines by reducing average fill depth for any given milk flowrate.

Occasionally, a vacuum drop of 2 kPa (0.6" Hg) or more results from frictional losses due to high air flowrate in unusually long milklines. Under all but the most extreme conditions, however, milkline length is not limiting and is not an important design factor for specifying milkline size.

Transient air admission has a marked effect on milkline slugging because the relative velocity of air to liquid is the dominant factor influencing the transition from stratified flow to slug flow. Therefore, "unplanned" transient air admission (the intermittent air flows associated with cup changing, liner slip and cup fall-off) induces slugging at much lower air and liquid flowrates, compared with the effects of steady air admission (the air entering the milkline from air vents in the cluster or in some milk meters, and from leaking fittings or milk hoses).

Higher levels of continuous air admission should have little effect on the risk of slugging, for any given transient air flowrate, because mean fill depth in the milkline decreases as the steady air flowrate increases (within the normal range of practical interest).

Transient vacuum drops less than 2 kPa (0.6" Hg) in the milkline, due to "unplanned" air admission through one cluster, have little or no effect on the normal cyclic vacuum changes in other clusters. However, vacuum fluctuations in the claw are usually increased whenever the milkline vacuum fluctuation exceeds 2 kPa (0.6" Hg). Figures 1 to 4 in Reinemann et al (1) summarize the flowrate criteria for determining slug-free conditions for 48, 60, 73 and 98 mm milklines under normal milking practice. The curves indicate the transition zones from stratified flow to slug flow conditions at different milkline slopes. Guidelines for different milkline diameters and slopes can be predicted by using this information to calculate the superficial velocities for air and milk flowrates.

From Study 3:

A design guideline of 100 L/min (3.5 scfm) transient air admission per slope for a looped milklime, or 200 L/min (7 scfm) for a dead-ended line, appears to be a reasonable allowance for liner slip and cup changing for most operators and conditions. However, these guidelines will not prevent slugging in the milklime when a cluster falls or is kicked off (unless claws with effective, automatic shut-off valves are used) or when cups are attached or removed carelessly, with no attempt to limit air entry.

From Studies 4 and 5:

The expected maximum milk flowrates in any given milklime can be predicted from computer models based on typical flowrate curves for individual cows and on the expected rates of attachment of individual units. Figure 5 in Stewart et al (2) shows an example of the predicted maximum flowrate for a herd with a mean peak milking rate of 3.5 L/min (7.7 lb/min) and units attached at intervals of 10, 15, 20, 30 or 60s.

Our recommendation is to use the curves in Figure 6 (2) for predicting maximum expected milk flow rate for any given number of units. The purpose of our study was to establish guidelines for sizing milklimes to milk high producing, fast milking cows in the top strings of excellent herds now and for the next decade. Guidelines for these herds cannot be logically based on the average of cows in today's herds. The more conservative approach is to base guidelines on the peak flowrates of the upper 25% of cows currently available. Therefore Figure 6, for cows with mean peak flowrates of 5.5 L/min (12.1 lb/min), is the preferred model.

Examples of Maximum Number of Milking Units per Slope:

From data supplied by Dennis Armstrong and Stephen Spencer, videos of milking performance supplied by Drs. Jim Jarrett and Paul Blackmer, and discussions with Drs. Andrew Johnson and John Dahl, typical attachment rates in US milking systems are as follows.

Parlors with 1 operator: With a good routine, 4 units are applied at 15 s intervals followed by a 30 s delay, then 4 units applied at 15 s intervals. With a poor routine, units are applied at 7.5 to 10 s intervals per slope.

Parlors with 2 operators: With a good routine, units are applied at 15 s per unit per slope. With a poor routine, units are applied at 10 s per unit per slope. These unit attachment rates have been included in the model to predict maximum milk flowrates in milklimes.

Stanchion Barn: Given typical milking rates of 6 to 9 cows per unit per hour, attachment rates are limited to 60 s per unit per slope. Because attachment rates may be faster with 2 operators, we have used a more conservative interval of 30 s in Table 3.

Some examples of the maximum number of milking units per slope to ensure stratified

flow for selected design criteria are given in Tables 1 to 3. These Tables are derived by combining the criteria for stratified flow (from 1) together with predictions of the maximum expected milk flowrate (2).

References

1. Reinemann, D.J., O. Ronningen, G.A. Mein, and J. Patoch. 1993. Transition between stratified flow and slug flow conditions in milklines. Proc. 32nd Annual Meeting of the National Mastitis Council.
2. Stewart, S., P. Billon, and G.A. Mein. 1993. Predicted maximum milk flowrates in milking systems. Proc. 32nd Annual Meeting of the National Mastitis Council.

Table 1. Parlor, with units attached every 10 sec per slope

Peak flowrate	5.5 L/min/cow (12 lb/min)
Steady air admission	10-20 L/min/unit (0.35-0.7 scfm)
Transient air admission	100 L/min/slope (3.5 scfm)

Nominal Line Size	Number of units per slope					
	Slope					
	0.5%	0.8%	1%	1.25%	1.5%	2%
48 mm (2 inch)	2	3	3	4	4	5
60 mm (2.5 inch)	4	5	6	7	8	10
73 mm (3 inch)	6	9	10	13	16	24
98 mm (4 inch)	21	(28)	(32)	(35)	(38)	(43)

Note: Figures in Tables 1 and 2 indicate an unlimited number of units for 96 mm (4") line above 0.8% slope. If more than 2 operators are attaching units on the same slope, the attachment rate may be quicker than 10 s per unit per slope. The figures in parentheses then apply.

Table 2. Parlor, with design conditions as for Table 1 except for transient air admission of 200 L/min/slope (7 scfm/slope).

Nominal Line Size	Number of units per slope					
	Slope					
	0.5%	0.8%	1%	1.25%	1.5%	2%
48 mm (2 inch)	1	1	2	2	3	3
60 mm (2.5 inch)	3	4	5	6	7	8
73 mm (3 inch)	4	7	8	10	12	17
98 mm (4 inch)	18	(26)	(31)	(33)	(36)	(40)

Table 3. Stanchion barn with units attached every 30 sec per slope

Peak flowrate	5.5 L/min/cow (12 lb/min)
Steady air admission	10-20 L/min/unit (0.35-0.7 scfm)

Slope	Number of units per slope					
	Nominal Line size					
	48mm	60mm	73mm	48mm	60mm	73mm
Transient air:	100 L/min/slope (3.5 scfm)			200 L/min/slope (7 scfm)		
0.5 %	2	4	6	1	3	4
0.8 %	3	5	(9)	1	4	(7)
1.0 %	3	7	(11)	2	5	(8)
1.2%	4	(8)	(13)	2	6	(11)

Note: * indicates no limit to the number of units.