NEW GUIDELINES FOR SIZING MILKLINES

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INTRODUCTION

A new ISO standard, for construction and performance of milking systems will be published in 1995, (ISO, 1994). The revised standard for milklines is based on recent research conducted at the University of Wisconsin-Madison, Milking Research and Instruction Laboratory, together with measurements of peak milking rates in France and theoretical flow calculations in Norway (Billon, 1993; Mein, 1993).

The standard will incorporate the following simple performance standard for vacuum stability in the milkline: *not more than 2 kPa transient drop in milkline vacuum below the receiver vacuum during normal milking conditions including cup changing and liner slips.*

The purpose of the new performance standard is to ensure an acceptable degree of vacuum stability during milking. Vacuum fluctuations less than 2 kPa in the milkline have been shown to have no effect on the vacuum level or vacuum fluctuations normally occurring in the claw (Reinemann and Mein, 1994). This level of vacuum fluctuation will therefore have no practical effect on milking characteristics, milk quality or incidence of mastitis. The new performance standard implies that stratified flow should be the normal flow condition in the milkline.

Normal flow conditions

- slug-free conditions for at least 95% of the milking time for the herd.
- include attachment of milking units to the milkline and attaching units to the cow.
- do not include unit fall off

Technique of the operator has a large effect on vacuum stability

Occasional slugs in the milkline, which are almost unavoidable in practice especially when units fall off, should not be regarded as evidence of a system failure. Occasional slugging may adversely affect milking performance, or increase the risk of mastitis, only if the transient drop in milkline vacuum is sufficient to cause one or more teatcups to slip or fall. Chronic slugging in the milkline is likely to have much the same effects on milking performance and milk quality as raising the milkline height by about 0.3 to 0.5 m, i.e., slower milking and more liner slips because of lower mean claw vacuum. Slug flow conditions may also have a marginal effect on milk quality because acid degree values in milk are raised.

DESIGN CRITERIA

While the emphasis of the new standard has shifted from a design specification to a performance standard, there is still a need for design guidelines. The transition from stratified to slug flow for milklines can be determined from the following equation (Reinemann and Mein, 1995):

$$Q_m = \frac{8.9(10)^6 \, S \, d^5}{Q_{aTotal}}$$

$$Q_{aTotal} = Q_{aTransient} + 2.2\, Q_m$$

Q_m = Volumetric milk flowrate (L/min)
S = Milkline slope (%)
d = Internal pipe diameter (mm)
Q_{aTotal} = Total (steady + transient) volumetric air flowrate per milkline slope, standard conditions (L/min)
$Q_{aTransient}$ = Transient volumetric air flowrate per milkline slope, standard conditions (L/min)

The total volumetric air flow rate in a milkline is made up of steady air admission from the cluster air vent and transient air admitted during unit attachment and liner slips. A steady air to milk flow ratio of 2.2:1 (e.g., 10 L/min steady air flow per 4.5 L/min milk flow) is typical of modern milking cluster air vents. The milk flow rate at the transition from stratified to slug flow can be calculated by substituting equation 2 into equation 1 and solving the resulting quadratic equation for Q_m.

The five most important design criteria for determining the minimum number of milking units on a milkline are: diameter and slope of the milkline, air admission into the milking system, peak milking rates of cows, and the rate of unit attachment.

Diameter: Increasing the pipeline diameter has the greatest single effect on carrying capacity. As shown in the accompanying example tables, doubling the milkline diameter increases the effective milk-carrying capacity of a milkline by at least nine times.

Slope: Milk flow is induced by gravity and by the air flowing over the milk surface. Friction between the air and milk surfaces causes the milk to flow because of the momentum transfer from air to milk. Greater milkline slope increases the influence of gravity as a driving force causing milk flow. Increasing milkline slope reduces the risk of slug flow by reducing the average fill depth for any given milk flowrate. As shown in the example tables, doubling the milkline slope increases the effective milk-carrying capacity by 50% or more.

Regions of lower slope or "flat spots" in a milkline will reduce its effective milk-carrying capacity. The likelihood of milkline slugging is influenced more by such flat spots than by the overall mean slope, in much the same way as the strength of a chain is limited to that of its weakest link. The effective milk-carrying capacity is also reduced by bends or other fittings which increase frictional losses. Compensation may be made by increasing the slope of a milkline in the region of bends and fittings, especially near the receiver where both the milk and air flowrates are highest.

Air admission: The relative velocity of air to milk is the main factor influencing the transition from stratified flow to slug flow conditions. Therefore, intermittent ("transient") air admission has a marked effect on milkline slugging. This implies that the milking staff have an important role in helping to maintain vacuum stability by taking care to limit the amount of intermittent air admitted when they attach or detach milking units. A design guideline of 50-100 L/min per slope for intermittent air flow into a looped milkline is a reasonable allowance for liner slip and cup changing for operators who take care to limit air admission during cup changing. For the more typical operators, this allowance should be doubled. The benefits of looping a milkline result from the reduction in the air flowrate per slope when air is admitted during attachment of milking units or when liner slips occur. The air flowrate per slope is reduced because the air can flow to the receiver through both arms of the loop according to the easiest flow path.

Peak milking rates of cows: The average peak milking rate per cow and rate of attaching milking units to individual cows, are the two main factors which determine the maximum predicted milk flowrate in the milkline. Average peak flowrates for typical high-producing herds are about 4 L/min per cow at present. The new ISO standard will include example tables for mean peak milking rates of either 4 or 5 L/min per cow. The higher figure is based on measurements of the fastest 20% of cows in high-producing French and American herds.

The average peak flowrate of cows in a herd can be estimated in one or more of the following ways (equations 3-5). When making these measurements a representative group of not less than 10 cows from the herd should be used.

$$Q_p = 0.5 + 0.5\,Y_2$$

$$Q_p = Y_1 - Y_2$$

$$Q_p = 0.2 + 1.5\,\frac{Y}{T}$$

Where:
Qp = Estimated herd average peak flowrate per cow (L/min).
Y = Mean milk yield per milking from 10 or more cows (L).
Y_2 = Mean yield in first 2 minute of milking from 10 or more cows (L).
Y_1 = Mean yield in first 1 minute of milking from 10 or more cows (L).
T = Mean milking time per cow from 10 or more cows (min).

Table 1 shows examples of the maximum number of units per milkline slope for a group of cows with an average peak milking flowrate of 4 L/min per cow and units attached at intervals of 10 seconds. As a general guideline, a mean peak flowrate of 4 L/min per cow will be sufficient for most herds. In very high-producing herds, or for unusually fast-milking herds, the calculations should be based on a mean peak flowrate of 5 L/min per cow, as shown in Table 2. Note that using equation 1 will not produce the same numbers as those in tables 1 and 2 because the tables have taken into account the effects of unit attach rate using the method developed by Stewart (1993).

EVALUATING EXISTING SYSTEMS

It is important to understand that the newly published equipment standards and design guidelines are meant to apply to newly built systems. These guidelines are meant to be conservative as new systems installed today should be designed to accommodate higher producing cows for the useful life of the system which should be 20 years from today. For example, the attach rate of 10 seconds per unit used for these design tables is faster than most milkers apply milking units. The recommended technique in accordance with the physiology of milk ejection consists of washing and drying the teats, fore-stripping and then immediately attaching the teatcups will result in an attach rate of 20 to 30 seconds per unit. This method will result in better labor efficiency and reduced peak milk flow in the milkline than washing all udders and then returning to attach all units.

When evaluating an existing system the emphasis should be placed entirely on the performance of the system. Existing systems should be evaluated by recording the vacuum changes in the receiver and at the first milkline inlet for at least two complete turns (from cups on one batch to cups off the second batch). The design guidelines can be used to determine whether milking performance might be improved by increasing the milkline slope, or ensuring more consistent slope, or by changing to a larger milkline. If a system passes the performance test there is no reason to make changes. If the system does not pass this test, improvements should be made in the following order of importance:

1. Improve operator technique to reduce the amount of air admission during unit attachment and normal milking. This measure will have little of no cost and will significantly improve the vacuum stability in most systems.
2. Reconfigure the milkline. Increase the slope of the milkline especially near the receiver. If clearance is a problem, slope the line so that the minimum slope is near the high point of the system and slope increases toward the receiver. Slope should be maximum in the last sections of the line where most bends and fittings are located as these account for much of the restriction to milk flow. System performance can also be improved by minimizing the number of bends and fittings in the milkline.
3. If steps 1 and 2 and been done correctly and the system still does not pass the performance test, the size of the milkline can be increased. If the milkline diameter is increased, the system cleaning flow dynamics must be adjusted correctly.

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Table 1. Maximum number of milking units per slope to maintain stratified flow for parlours with units attached every 10 seconds per slope and an average peak milk flowrate of 4 litres per minute per cow. NOTE: ID = internal diameter of milkline. The calculations indicate an unlimited number of units for some combinations. These are identified by parentheses, e.g. (23), in the tables. The figures in parentheses show the maximum number of milking units per slope for these design combinations if units were attached at intervals of 5 seconds per slope. Combinations with an unlimited number of units per slope for a 5 second per slope attach rate are indicated by (--).

a) Careful operators and looped milklines (50 l/min transient air admission per slope).

		Slope		
ID	0.5%	1.0%	1.5%	2.0%
48 mm	4	6	8	9
60 mm	7	11	15	20
73 mm	14	26	(25)	(31)
98 mm	(32)	(--)	(--)	(--)

b) Careful operators and dead-ended milkline, or typical operators and looped milklines (100 l/min transient air admission per slope).

		Slope		
ID	0.5%	1.0%	1.5%	2.0%
48 mm	2	4	6	7
60 mm	6	9	12	16
73 mm	11	21	(23)	(28)
98 mm	(30)	(60)	(--)	(--)

Table 2. Maximum number of milking units per slope to maintain stratified flow for parlours with units attached every 10 seconds per slope and an average peak milk flowrate of 5 litres per minute per cow.

a) Careful operators and looped milklines (50 l/min transient air admission per slope).

		Slope		
ID	0.5%	1.0%	1.5%	2.0%
48 mm	3	4	6	7
60 mm	6	9	11	15
73 mm	10	19	(20)	(23)
98 mm	(25)	(48)	(--)	(--)

b) Careful operators and dead-ended milkline, or typical operators and looped milklines (100 l/min transient air admission per slope).

		Slope		
ID	0.5%	1.0%	1.5%	2.0%
48 mm	2	3	4	5
60 mm	4	7	10	12
73 mm	9	16	25	(21)
98 mm	(23)	(43)	(--)	(--)