New Standards for Sizing Milklines

Douglas J. Reinemann and Graeme A. Mein

In November 1994, a new standard for construction and performance of milking systems was approved and published by the American Society of Agricultural Engineers (ASAE S518). It includes major changes in the recommended number of milking units for milklines. These changes are based on research conducted at the University of Wisconsin–Madison Milking Research and Instruction Laboratory.

New performance standard

The new standards specify a minimum performance criterion rather than a particular number of milking units on a milkline. The performance standard for acceptable vacuum stability in the milkline is not more than a 0.6″ Hg (2 kPa) drop in milkline vacuum below the receiver vacuum during normal milking conditions.

This performance standard is based on the condition known as stratified flow. This means that milk should flow in the lower part of the pipeline with a clear continuous space above it. This allows a large volume of air to pass over during the milking process. Slug flow occurs whenever slugs of milk fill the entire cross-section of the milkline (figure 1). Occasional slugs in the milkline are almost unavoidable when a large volume of air is admitted; for example, when a milking unit falls off.

A milking unit fall-off is not considered a condition of normal milking. Unit fall-off should be a rare event in a reasonably maintained and operated milking system. Normal, slug-free conditions should occur for at least 95% of the herd’s milking time and an occasional slug should not be regarded as evidence of a system failure.

The new performance standard assures that the milkline will not slug under normal operating conditions, including unit attachment, detachment and liner slips. Slug flow conditions almost always induce transient drops in milkline vacuum greater than 0.6″ Hg. Under stratified flow conditions, milkline vacuum almost usually remains stable within 0.6″ Hg of the receiver vacuum.

A milkline slug produces a small and momentary drop in claw vacuum beyond the normal fluctuations. A momentary vacuum drop is not likely to adversely affect milking performance or increase the risk of mastitis.

Figure 1. Cross-section of milkline showing stratified and slug flow.

Frequent slugging in the milkline may result in a lower mean claw vacuum—an effect on milking performance and milk quality similar to that of raising the milkline height by a foot. Frequent slugs can slow milking and cause more liner slips, or produce a marginal increase in the acid degree values in milk.

Design guidelines for new systems

While the new standard’s emphasis has shifted from a design specification to a performance standard, there is still a need for design guidelines for new systems. Examples of such guidelines are shown in tables 1, 2 and 3.

The four most important design criteria for determining the minimum number of milking units on a milkline are: 1) diameter and slope of the milkline; 2) admission of air into the milking system; 3) peak milking rates of cows; 4) and the rate of unit attachment. The significance of each is discussed in the following section.

Diameter

Increasing the pipeline diameter has the greatest single effect on carrying capacity. As shown in tables 1, 2 and 3, doubling the milking diameter increases the effective milk-carrying capacity of a milkline by at least nine times.

Slope

Gravity and air flow over the milk’s surface create milk flow. Increasing milkline slope boosts the influence of gravity and reduces the risk of slug flow by reducing the average fill depth for any given milk flowrate. As shown in the 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 reduce the line’s milk-carrying capacity. Flat spots influence the likelihood of milkline slugging more than the
overall average slope. The effective milk-carrying capacity is also reduced by excessive bends and other fittings in the line which increase frictional losses. This can be compensated for by increasing the slope of a milkline in the region of bends and fittings, especially near the receiver where both the milk and air flow rates are highest.

**Air admission**

The velocity of the air moving over milk is the main cause of slugging in milklines. The highest air flow rate and air velocity occur when intermittent or “transient” air is admitted during attachment and detachment of units, liner slips and unit fall-offs. A design guideline of 7 cfm (200 L/min) for intermittent air flow is a reasonable allowance for liner slip and unit attachment for operators who take care to limit air admission while attaching milking units to the cow. For operators who do not follow good unit attachment practices, this allowance should be doubled.

Milking operators play an important role in helping to maintain vacuum stability by taking care to limit the amount of air admitted when they attach or detach milking units. When the milkline is looped, the transient airflow rate per slope can be halved because air can flow to the receiver through both arms of the loop according to the easiest flow path. Significant benefits thus result from the reduction in the air flow rate per slope when milklines are looped.

**Peak milking rates of cows**

The average peak milking rate per cow and the average rate of attaching milking units to individual cows are the two main factors that determine the maximum predicted milk flow rate in the milkline. Average peak flow rate for high-producing herds in the U.S. are currently about 9 lb./min (4 L/min) per cow. A design value of 12 lb./min (5.5 L/min) per cow has been used to develop tables 1, 2 and 3. This figure has been derived from field measurements and represents the fastest milking 5% of cows in the U.S. This higher figure was used to ensure that milking systems installed now will be adequate for milking high-producing herds into the next century. The average peak flow rate of cows in any herd can be measured in several ways (see sidebar on page 3).

**Attachment interval**

The time between unit attachments plays a secondary role in determining the expected peak milk flow rate in the milkline. To further simplify the calculations and provide the most conservative estimates, tables 1 and 2 assume that all units are attached at the same instant. If the unit attachment interval is taken into account, the allowable number of units per slope only for the 3-inch line at the highest slopes, and for the 4-inch line will increase slightly.

---

**Table 1. Maximum number of units per slope for looped milklines in milking parlors with careful operators.**

<table>
<thead>
<tr>
<th>Nominal line size</th>
<th>Slope</th>
<th>0.8%</th>
<th>1.0%</th>
<th>1.2%</th>
<th>1.5%</th>
<th>2.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 mm (2 in)</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>60 mm (2.5 in)</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>73 mm (3 in)</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>98 mm (4 in)</td>
<td>27</td>
<td>30</td>
<td>34</td>
<td>38</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** A slope of 0.8% is equivalent to 1-inch drop in 10 feet. A slope of 1.2% is equivalent to 1½-inch drop in 10 feet. Milkline slopes greater than 1.6% (2" per 10 feet) are not recommended unless the cow platform is sloped in the same direction as the milkline.

---

**Table 2. Maximum number of units per slope for looped milklines in milking parlors with typical operators.**

<table>
<thead>
<tr>
<th>Nominal line size</th>
<th>Slope</th>
<th>0.8%</th>
<th>1.0%</th>
<th>1.2%</th>
<th>1.5%</th>
<th>2.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 mm (2 in)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>60 mm (2.5 in)</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>73 mm (3 in)</td>
<td>9</td>
<td>10</td>
<td>12</td>
<td>13</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>98 mm (4 in)</td>
<td>24</td>
<td>27</td>
<td>31</td>
<td>36</td>
<td>41</td>
<td></td>
</tr>
</tbody>
</table>

---

**Table 3. Maximum number of units per slope for looped milklines in round-the-barn pipeline systems.**

<table>
<thead>
<tr>
<th>Nominal line size</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8%</td>
<td>1.0%</td>
</tr>
<tr>
<td>48 mm (2 in)</td>
<td>2</td>
</tr>
<tr>
<td>60 mm (2.5 in)</td>
<td>6</td>
</tr>
<tr>
<td>73 mm (3 in)</td>
<td>(9)</td>
</tr>
</tbody>
</table>

**NOTE:** Figures in parentheses indicate an unlimited number of units for an attaching rate of 30 seconds per unit for stanchion barns. If more than one operator is attaching units on the same slope, the attachment rate may be quicker. The figures in parentheses then apply. They indicate the upper limit for number of units for an attaching rate of 10 seconds per unit.
Evaluating existing systems

The new performance standards are meant to apply to new systems. They are therefore meant to be conservative, as systems installed today should be designed to accommodate higher producing cows for the useful life of the system. For example, tables 1 and 2 assume that units are attached instantaneously in parlors and that all cows will be at peak milk flow rate at the same time. Recommended techniques when a pre-dip is used will result in an attachment interval of 15 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. If milkline carrying capacity is questioned, the first step in evaluating the system is to measure vacuum stability in the milkline and in the receiver during normal milking. This test should also be performed as a commissioning test of a new milking system.

The measurement in the milkline should be made by a direct connection to the first inlet on the milkline which is at least 3 feet (1 meter) from the receiver on the slope that is more heavily loaded. Ideally, the milkline and receiver measurements should be made simultaneously. This dynamic test should be run at least two complete turns in a milking parlor or during the time required to milk two cows with each milking unit on a round-the-barn pipeline system. Pay special attention to tests performed during unit attachment and removal. It is preferable to perform several tests of 15 to 30 seconds duration each rather than a single test of several minutes duration. Several short tests will help to identify the specific events which caused vacuum fluctuation.

The ASAE performance standard states that the milkline vacuum should not fall more than 0.6” Hg (2 kPa) below the vacuum level in the receiver during normal milking. Figure 2 shows an example vacuum recording made on a properly functioning system during milking, as units are being attached and detached. Most vacuum recorders will indicate the maximum and minimum vacuum recorded over the test interval. The vacuum fluctuation is taken as the maximum vacuum minus the minimum vacuum.

In the recording illustrated in figure 2, both milkline and receiver vacuum fluctuations are less than 0.6” Hg (2 kPa). The difference between the milkline vacuum fluctuation and the receiver vacuum fluctuation is the contribution to vacuum fluctuation caused by the milkline. If the difference in milkline and receiver fluctuations exceeds 0.6” Hg (2 kPa) it is likely that a slug has occurred. The vacuum fluctuation in the receiver in figure 2 is less than 0.6” Hg indicating that the effective reserve and regulator response are sufficient to cope with the amount of air admitted by the operators. The difference between the milkline and receiver fluctuations is also less than 0.6” Hg indicating that the milkline did not slug.

Estimating the average peak milking rate of cows in a herd

The average peak flow rate of cows in any herd can be estimated in one or more of the following ways.

1) The average peak flow rate is closely correlated (r = 0.81) with the average milking rate (pounds of milk per cow divided by her milking time in minutes) of a representative group of cows according to the regression:

\[
\text{Average peak} = 0.4 + 1.5 \frac{\text{average milk yield per milking flow rate (lb/min)}}{\text{average milking time per cow}}
\]

2) Average peak flow rate is highly correlated (r = 0.92) with the average pounds of milk per cow obtained from a representative group of cows in the first two minutes of milking according to the regression:

\[
\text{Average peak} = 1.1 + 1.2 \left(\frac{\text{average yield in first 2 min}}{\text{flow rate (lb/min)}}\right)
\]

3) Average peak flow rate is highly correlated (r = 0.89) with the average pounds of milk per cow obtained from a representative group of cows in their second minute of milking:

\[
\text{Average peak} = \frac{\text{average (yield at 2 min minus yield at 1 min)}}{\text{flow rate (lb/min)}}
\]

An example recording made on a system with milkline slugging is shown in figure 3. The vacuum fluctuation in the receiver is less than 0.6” Hg indicating a properly functioning regulator and vacuum pump. The difference between milkline and receiver vacuum fluctuations is greater than 0.6” Hg, however, indicating the presence of a slug in the milkline.

An example recording from a system with poor vacuum regulation and/or excessive air admission is shown in figure 4. Both receiver and milkline vacuum drop by more than 0.6” Hg (2 kPa) when air is admitted (probably...
The difference between the milkline and receiver vacuum fluctuations is not, however, greater than 0.6” Hg. This vacuum fluctuation is not caused by milkline slugging and can be reduced only by reducing the amount of transient air admission or by improving the effectiveness of vacuum regulation.

If the milking system passes this performance test there is no reason to make changes. If the vacuum recordings indicate that slugging may be occurring, improvements should be made in the following order:

1. Improve operator technique to reduce the amount of air admitted during milking unit attachment, detachment and normal milking. This costs little or nothing and significantly improve the vacuum stability in most systems.

2. 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. Performance can also be improved by minimizing the number of bends and fittings in the milkline.

3. If steps 1 and 2 have been carried out correctly and the system still does not pass the performance test, increase the size of the milkline. If the milkline diameter is increased, adjust the water volume and air injector settings to ensure that the system can be cleaned.

Figure 2. Vacuum recording for a properly functioning milking system.

Figure 3. Example vacuum recording with a slugging milkline.

Figure 4. Example vacuum recording with no slugging and poor regulator response and/or excessive air admission.

I-04-97-IM-50