Milking System Design for Large Herds

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Milking system design has changed dramatically in recent years. Large parlors of up to 100 milking units have been primarily responsible for these advances in design. The U.S. leads the world in the design of highly efficient, modern and attractive facilities.

The industry has advanced with sophisticated component design, however, fundamental systems design has lagged in development. For example, most system cleaning designs have evolved from field experience and only recently have basic cleaning parameters been investigated.

Vacuum pumps: One area of controversy that has existed for many years is that of the required vacuum pump capacity. Guidelines are often promulgated without experimental evidence of performance. The required pump capacity is clearly governed by the amount of air usage at the specified operating vacuum for milking and/or washing. Usage requirements (10) are shown in Table 1.

Smith et al. (9) determined washing usage on 11 farms in California to range from 2.3 to 7.8 scfm, while average air usage during milking was .2 to 1.15 cfm. Spencer (8) determined milking vacuum requirements which included generous allowances for operator usage and by-pass air for regulators having substantial requirements, Figure 1.

Pipe size: Pipe sizing is well developed from a design standpoint but the available data is not utilized as much as is desirable. Vacuum head loss tables are available to precisely determine size based upon air flow, pipe diameter, length and number of fittings. Table 2 lists those losses from which calculations can be done for either analysis or design purposes. A vacuum head loss ranging from 0.25 to 0.5” Hg is recommended, while a reasonable maximum of 0.75” Hg is suggested. Table 3 lists the equivalent lengths of straight pipe to include in head loss determinations. Table 4 is derived from tables 2 and 3 which gives a quick, easy reference to pipe size.

Our observations indicate that the pipe size from the regulator to the balance tank is often too small. Any piping system should be designed for full pump capacity from the regulator to the pump since this is the area of greatest air flow. It is also suggested that full pump capacity should be accommodated to the receiver assembly, since this may also be the regulator location.

Milk pipes: Recent research indicates that milk pipe size recommendations are in serious need of review. Milk pipe size is a dichotomy of design in milking and washing requirements. Most authorities agree that stratified flow is desired during milking, while plug or slug flow is necessary to clean during the wash cycle, see flow patterns Figure 2. Measuring slug flow can be determined by monitoring milkline vacuum. A vacuum drop of 0.6” Hg from mean milking vacuum is a reliable indicator of slug formation (4).

Spencer and Bray (12) determined that the carrying capacity of 3 inch milk lines exceed those of the 3A recommendations for milking. Length of pipeline has little effect upon carrying capacity (7) while the unit attachment rate has a significant bearing upon the required diameter (2). Pipeline slope has a significant affect upon pipeline carrying capacity (5) as does transient air admission. The effect of slope can be noted in table 6.

Vacuum level: Operating vacuum recommendations are also in need of review. Manufacturers are often reluctant to specify an operating vacuum since no precise data are available. Our studies indicate that there is an interaction of liners and vacuum, therefore liners should be optimized to operating vacuum. Liner slip rate increases as vacuum is lowered from 15” Hg. It is interesting to note that the recommendation in Florida for vacuum setting is 15” Hg, “No more, No less” (1). Our guide to setting system vacuum is shown in table 5.

It is not uncommon to hear that vacuum should be set at the teat end. Consider that the vacuum at the teat end is cow dependant, that is, vacuum varies at the teat end depending upon milking rate. There are other variables such as height of pipeline, hose length and size, air vent rate (11) and type of automatic detacher. The best that can be done is to set system vacuum and the vacuum at the teat end has to fall where this combination of factors dictate. Vacuum fluctuation is an even more complex issue since milk and air are in two phase flow from the milking unit to the milk pipe. Many variable variations develop due to this phenomena. Thus, vacuum settings based upon teat end vacuum are difficult, at best.

Cleaning: No design is complete without considering the cleaning performance of a milking system. It is generally accepted that slug flow is required during the wash cycle so that the wash solution reaches all milk contact surfaces. The required air flow depends upon pipe diameter, ranging from 30 to 55 cfm on a 3-inch line (6). A larger pump capacity above the maximum suggested will not improve cleaning performance. A crucial factor in proper slug maintenance is the air injector timing. As a guide, dividing the length of line to be cleaned by 25 will give the approximate time of air injector open time. The air injector should remain open until just before the slug reaches the receiver. Excessive air volumes admitted by the air injector may break down the slug after its’ original formation. Slug velocities range from 23 to 32 ft/s.

Air injectors are often installed on the unit wash lines. This may force jetter cups off the liner mouthpieces and result in inadequate cleaning. In our experience, the air injector mounted in the milk room on the wash supply pipe to the main milk pipe yields the best results. A continuous air bleed to the unit washers will usually provide adequate turbulence up to 12 units (Double 12 parlor) and reduce the total wash solution volume. Parlors that are larger than a double-12 may require a wash pump to supply enough water to the units and achieve an even distribution of water among units. An electronic recorder to monitor slug passage or a visible pipe section mounted in the milkline prior to receiver entry will aid in determining washing performance.

The future: In the future it is desirable to improve systems design using known engineering principles. More research, especially with regard to cleaning, is needed in order to account for the wide variety of systems. Potential exists to greatly improve energy use for vacuum systems. Research at Cornell University (3) has shown that adjustable speed/dual vacuum systems can reduce energy use by 50% or more. Research has already shown that the re-use of detergents is possible.

In Europe, large diameter milk pipes (8”) are in use without receiver assemblies. They are cleaned with internal spray rails. We have only begun to use the marvels of electronic data capture. On-line conductivity measurements, fat, protein, and somatic cell counts are possible. Perhaps a pregnancy specific protein could determine pregnancy status. The use of robots may be economically feasible as conditions change. The use of shielding to protect fragile components will no doubt increase. Under-the-platform piping to clear the operator area and protect electronic meters will probably increase in popularity. The rate of change that has characterized the last decade is likely to accelerate.

Table 1: Vacuum usage of events during milking.*

Event	Cfm usage, ASME
Remove unit	.0 to 4.1
Put on unit	.1 to 8.0
Machine strip	.1 to 3.8
Liner slip	4.0 to 8.0
Unit fall off	20.0 to 50.0

* From (10).

Table 2: Vacuum drop per 100 feet of PVC pipe(inHg).*

Cfm, ASME	2 inch	3 inch	4 inch
30	.25	.04	—
40	.41	.06	—
50	.60	.08	—
60	.75	.12	—
70	1.03	.15	—
80	1.14	.19	.06
90	1.43	.24	.07
100	1.71	.29	.08
150	—	.61	.16
200	—	1.10	.26
250	—	—	.39
300	—	—	.54
350	—	—	.71
400	—	—	.91

* At 15 inHg. vacuum head.
From Spencer, S. B. and G. A. Mein. 1991. ASAE paper #913509

Table 3: Equivalent lengths of straight pipe (in feet) for various pipe fittings and pipe diameters.

	Nominal pipe size, inches Fitting (ID,in.)	2	3	4
Elbows:				
	45° standard	1.5	2.5	3
	90° med. radius	3	4	6
	90° short radius	6	10	12

T-pieces:			
Through flow	3	4	6
Side flow	7	9	15
Sweep, side flow	3.5	5	7
Expansion, contraction and tanks:			
Receiver, trap	10.5	14	22
Contraction — tank to pipe	3.5	5	7
Expansion — pipe to tank	7	9	15

Table 4: Recommended minimum pipe sizes (in inches) for the main airline of milking systems (11).

Vacuum pump capacity Cfm-ASME	(Length of main airline, in feet)				
	20	40	60	80	100
	Nominal pipe diameter, inches				
50	2	2	3	3	3
60	2	3	3	3	3
70	3	3	3	3	3
100	3	3	3	3	3
150	3	4	4	4	4
200	4	4	4	4	4
250	4	4	4	6	6
300	4	6	6	6	6
350	6	6	6	6	6
400	6	6	6	6	6

Table 5: Suggested operating system vacuum (10).

Type of system	Inches of mercury
High line	14.0 to 15.0
Low line	13.0 to 14.0
Mid line	13.5 to 14.5

Note: Operating vacuum may depend upon liner collapse resistance characteristics. It is suggested that liners with low resistance to collapse be used at the lower end of the ranges above, while high resistance to collapse liners be used at the high end of the range. Low resistance liners are defined as requiring less than 4"Hg differential to liner wall touch point while high resistance liners are greater than 4" Hg pressure differential to liner wall touch point.

Table 6: Effect of slope and transient air admission on number of units per slope (4).*

	Number of units per slope			
	Slope			
Milkline size	0.5%	1.0%	1.5%	2.0%
2 inch	2	3	4	
5 2.5 inch 4	6	10		
3 inch	6	10	16	24

(*: Based upon an average maximum flow rate of 12 lbs. per minute and transient air admission of 3.5 scfm.)

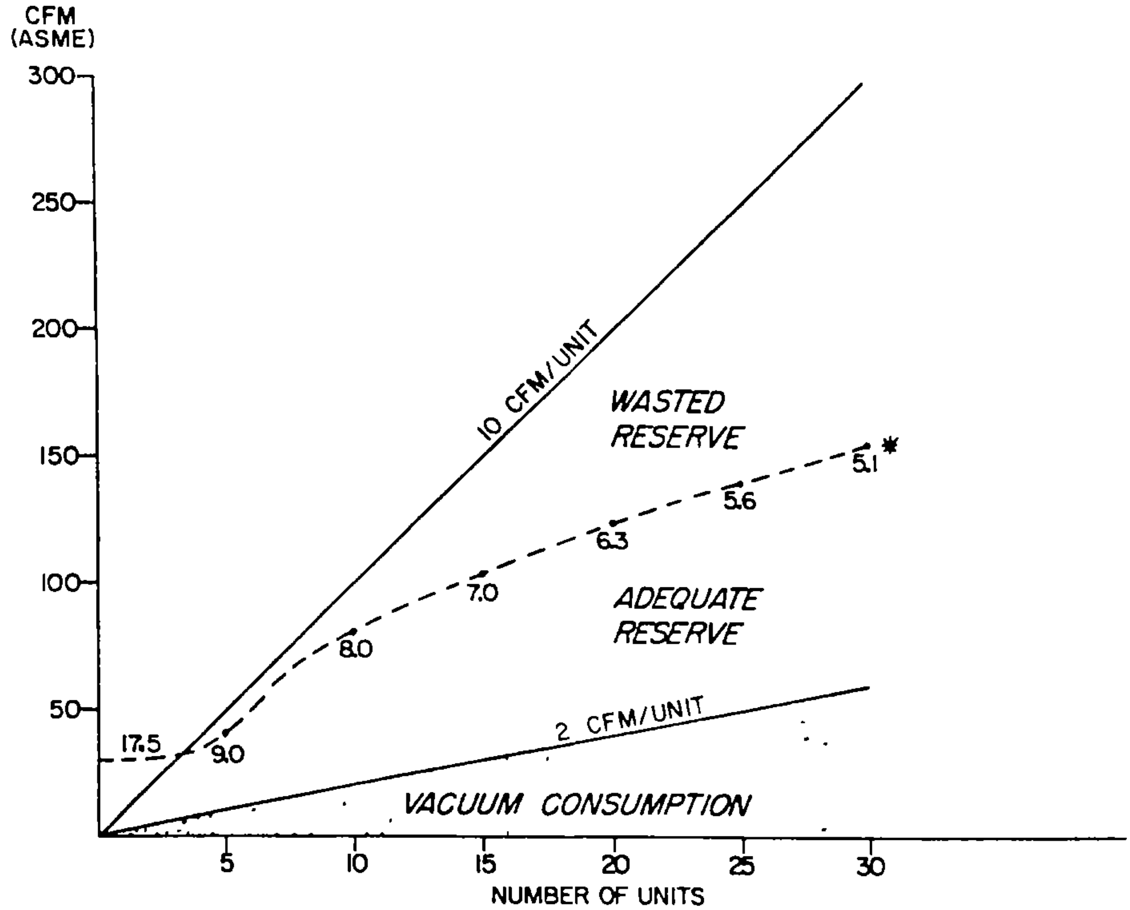

FIGURE 1 – VACUUM RESERVE AND UNIT CONSUMPTION

* VALUES ARE CFM/UNIT

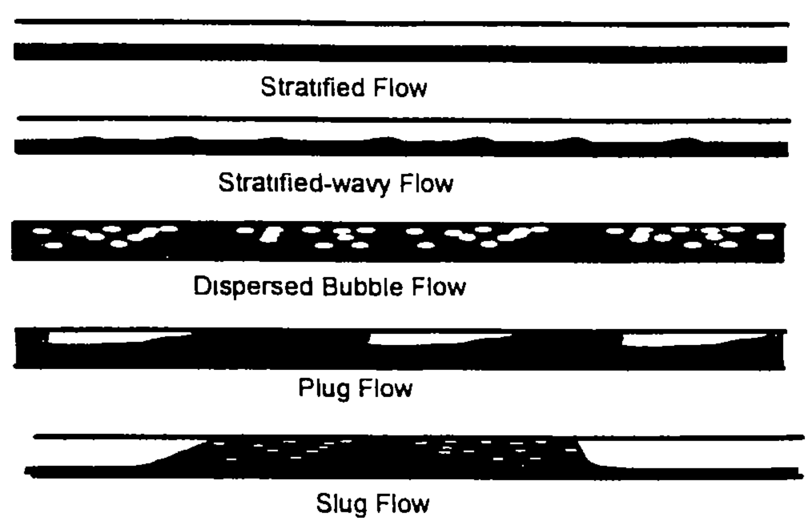

Figure 2 Gas-Liquid Two Phase Flow Patterns

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