



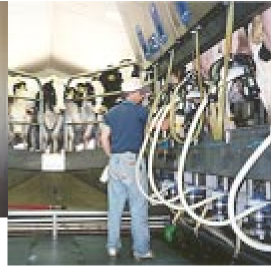

GREEN CERTIFICATE CURRICULUM

DPP INDEX

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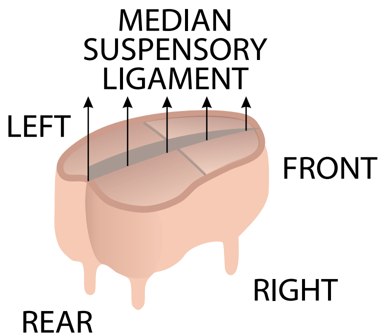
Anatomy of the Mammary Gland

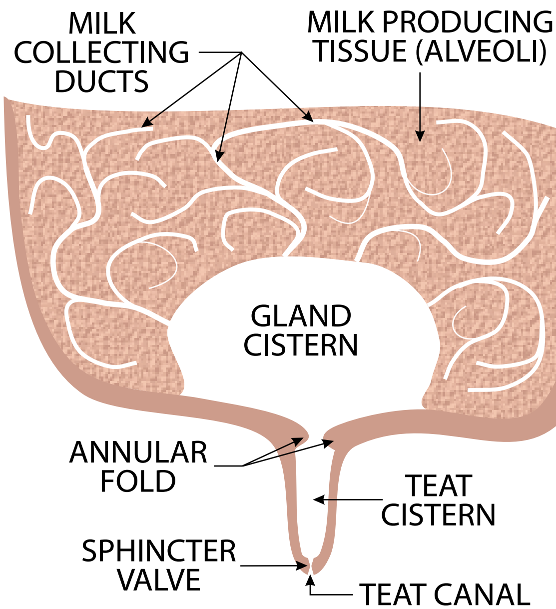


The cow's mammary gland (udder) consists of 4 distinct quarters, separated and enclosed by supporting connective tissue (see figure on left). The fact that the quarters are separate means that:

- the quality and quantity of milk produced by each quarter can vary, and;
- if one quarter becomes infected with **mastitis**, the bacteria cannot pass within the mammary gland from one quarter to another.

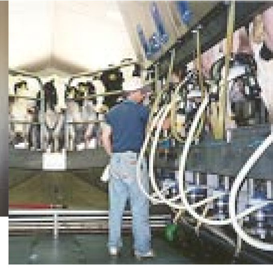
Parts of the mammary gland important in milk production are shown in the figure below:

- the actual milk producing tissue of the gland is composed of *alveoli*, tiny (0.1 - 0.3 mm in diameter) spherical groups of cells which extract nutrients from the bloodstream to produce fat, protein, lactose and the other organic components secreted in milk. A thin outer layer of muscular tissue squeezes milk out of the alveoli when stimulated by **oxytocin**;
- a network of *milk collection ducts* receive the milk produced by the alveoli, carrying it to the *gland cistern*;
- milk in the gland cistern flows into the *teat cistern* through the *annular fold* which can restrict flow, particularly near the end of milking;
- during suckling or milking, milk flows from the gland through the *teat canal*;
- the *sphincter* valve is a ring of muscular tissue which closes the teat canal.









Milk Secretion and the Letdown Reflex

Milk is produced by mammary gland **alveoli**. Immediately after milking, the rate of milk secretion into the **milk collection ducts** is very rapid. But, as the **gland cistern** fills, back pressure is exerted on the alveoli, which (among other reasons) causes their rate of milk secretion to decline. This is why increased milking frequency results in higher daily production – alveoli back pressure is released more often.

At milking time, approximately 60% of the milk in the mammary gland is found in the **alveoli**, 20% in the **milk collection ducts** and 20% in the **gland cistern**. When the cow is stimulated, the hormone *oxytocin* is released by the brain into the bloodstream. When it reaches the mammary gland, oxytocin causes the muscular tissue surrounding the **alveoli** to contract, squeezing their milk out into the **milk collection ducts**, the **gland cistern** and the **teat cistern**. The milk 'letdown' effect of oxytocin begins 20 to 60 seconds after initial stimulation and normally lasts for 6 to 8 minutes. Therefore, it is important to attach the milking machine approximately one minute after initial stimulation. Although a second pulse of oxytocin may be released, it will be less effective than the first.

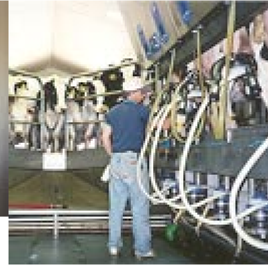
Stimuli which initiate the milk letdown reflex include:

- physical contact with the mammary gland, from either a suckling calf or a milker cleaning the teats;
- the sight of a calf;
- the sound of the milking machine.

Inadequate physical stimulation of the teats, delayed attachment of teat cups or faulty equipment may fail to take full advantage of the letdown reflex. Pain, fear or other stress may inhibit letdown through the release of adrenaline which restricts mammary blood flow and blocks the action of oxytocin.

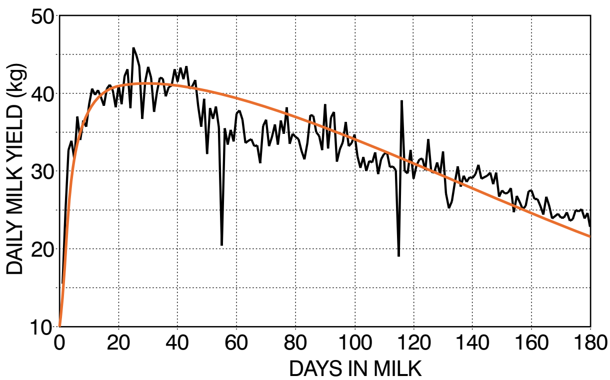






Production & Persistency

As her lactation progresses, the cow's milk production will vary considerably, but most cows will follow a predictable pattern. The graph below shows an example of daily milk production for the first 6 months of a cow's lactation. For this particular cow, production rises quickly after calving, reaches a peak at 20-30 days in milk (DIM) then declines steadily after that.



Example lactation curve. Milk production is measured in either kg or litres.
1 litre = 1.02857 kg.

Rate of decline after peak is referred to as *persistency*, expressed as percentage decline in production from one month to the next. For example, for the cow whose production is shown on the left, production at 4 months (120 days) was about 30 kg/day. A month earlier (90 days) it was about 33 kg/day. Persistency was therefore about 30 ÷ 33 = 91%.

The table below gives average peak yields, DIM at peak and post-peak persistencies for Western Canadian Holsteins.

	--------------------------- 305-DAY PRODUCTION LEVEL ---------------------------							
	OVER ALL	5000 -5999	6000 -6999	7000 -7999	8000 -8999	9000 -9999	10000 -10999	11000 -11999
PEAK MILK KG :								
LACT 1	29.6	23.4	26.0	28.7	31.7	34.8	37.7	41.0
LACT 2	38.7	29.2	32.2	34.9	37.5	40.5	43.5	47.0
LACT 3+	42.0	30.1	33.4	36.2	39.2	42.0	45.1	48.0
DIM AT PEAK :								
LACT 1	56	39	44	48	57	64	69	76
LACT 2	35	27	27	28	32	35	38	41
LACT 3+	37	27	31	31	32	36	38	41
PERSISTENCY (66-305 DIM) :								
LACT 1	96.5	95.5	95.8	96.1	96.4	96.7	97.0	97.1
LACT 2	93.8	92.4	92.7	92.9	93.4	93.6	93.9	94.1
LACT 3+	93.5	91.8	91.9	92.3	92.7	93.1	93.3	93.7

The Milking System

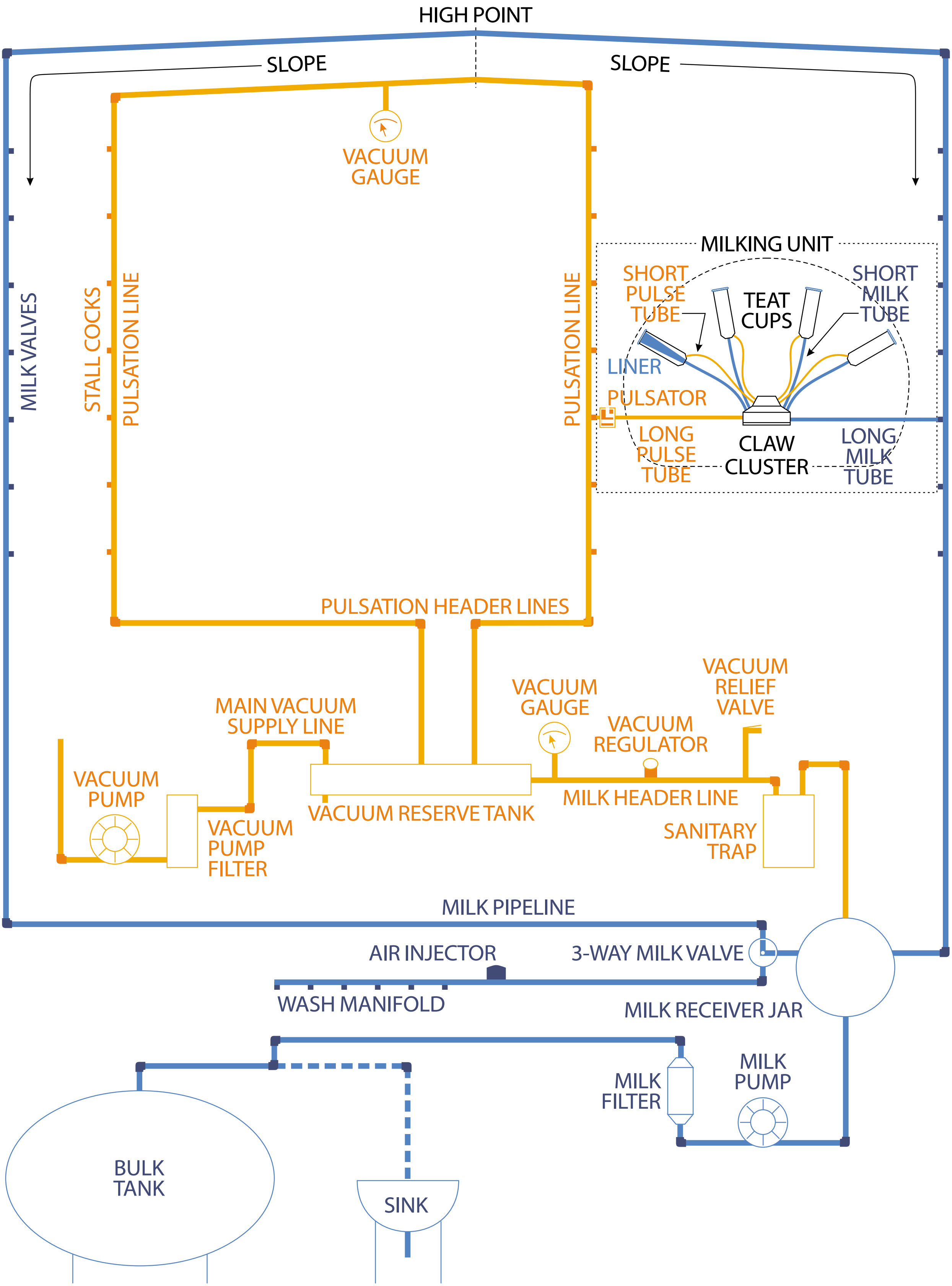
Figure 1 illustrates the configuration of a typical milking system. Key components include:

- **vacuum pump** - creates a partial **vacuum** in the system by removing part of the air;
- **vacuum pump filter** - prevents particulate matter from entering the vacuum pump;
- **vacuum reserve tank** (also called the vacuum balance, vacuum buffer or distribution tank) - distributes vacuum to the **pulsation header** and **milk header** lines and buffers the vacuum level when small amounts of air enter the system (e.g. when a **cluster** falls off an udder);
- pulsation header lines - distribute vacuum to the pulsation lines;
- pulsation lines - distribute vacuum to the milking units;
- stall cocks - connectors between the long vacuum tubes of the milking units and the pulsation lines;
- **pulsator** - controls the massaging action of the **teat cup liner** by alternately applying **vacuum** or admitting air at **atmospheric pressure** to the pulsation chamber between the teat cup liner and shell;
- **long vacuum tube** - carries pulsator impulses (vacuum or air at atmospheric pressure) from pulsator to **claw**;
- **short vacuum tube** - carries pulsator impulses from **claw** to **teat cup**;
- **teat cup** - consisting of metal or hard plastic teat cup shell and flexible rubber or synthetic **teat cup liner** - the space between these 2 parts is the **pulsation chamber**;
- **claw** - distributes pulsator impulses from the **long vacuum tube** to each of the 4 **short vacuum tubes** and transfers milk from the 4 **short milk tubes** to the **long milk tube**;
- **cluster** - the assembly including **claw**, **teat cups**, **short** and **long vacuum tubes** and **short** and **long milk tubes**;

... continued

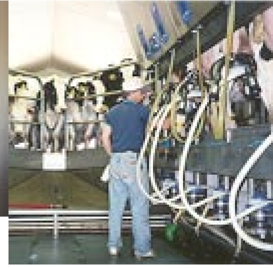
The Milking System
(continued)

- milking unit - the assembly including **cluster**, **long vacuum tube**, **long milk tube** and **pulsator**;
- **milk header line** - provides **vacuum** to the milk side of the system;
- **vacuum regulator** (also called the vacuum controller) - prevents the system vacuum level from rising excessively by admitting air into the system when the **vacuum** reaches a preset upper limit;
- **vacuum relief valve** - a safety valve which prevents system vacuum from rising excessively in case of a malfunction of the **vacuum regulator**;
- **vacuum gauge** - measures system vacuum;
- **sanitary trap** - separates the 'air-only' side of the milking system from the milk side, preventing the transfer of liquids (milk, cleaning solutions) into the vacuum system;
- **milk receiver jar** - collection point for milk flowing from the milking units through the **milk pipeline**.
- **milk transfer pump** - moves milk from the **milk receiver jar** to the **bulk tank**.


HIGH POINT
SLOPE
SLOPE
VACUUM GAUGE
MILK VALVES
STALL COCKS
PULSATION LINE
PULSATION LINE
MILKING UNIT
SHORT PULSE TUBE
TEAT CUPS
SHORT MILK TUBE
LINER
PULSATOR
LONG PULSE TUBE
CLAW CLUSTER
LONG MILK TUBE
PULSATION HEADER LINES
VACUUM GAUGE
VACUUM RELIEF VALVE
MAIN VACUUM SUPPLY LINE
VACUUM REGULATOR
VACUUM PUMP
VACUUM PUMP FILTER
VACUUM RESERVE TANK
MILK HEADER LINE
SANITARY TRAP
MILK PIPELINE
AIR INJECTOR
3-WAY MILK VALVE
WASH MANIFOLD
MILK RECEIVER JAR
MILK FILTER
MILK PUMP
BULK TANK
SINK

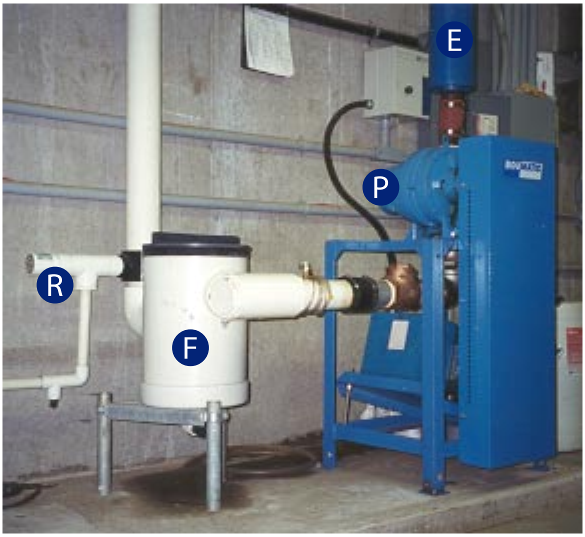






Vacuum Pump

The purpose of the vacuum pump is to remove air from the milking system. The *filter* (interceptor) prevents solid or liquid material from being drawn from the system into the pump. The amount of air removed by the pump determines the **vacuum** level measured by the system's **vacuum gauge**(s). For example, if **atmospheric pressure** is 100 **kPa** and the vacuum pump removes half of the air in the system, the vacuum gauge should read 50 kPa.



Vacuum pump (P), exhaust (E), filter (F) and relief valve (R).

Air must be removed at least as fast as it is let in during milking in order to keep the vacuum level constant. When air enters faster than the pump can remove it, vacuum level will drop and milking efficiency will be reduced. Pump capacity should always be greater than the maximum rate at which air can enter the system. This allows excess vacuum to be relieved by the **vacuum regulator** (controller).

Vacuum pump capacity is expressed as the rate at which air can be removed from the system, measured in cubic feet per minute (CFM) or litres per minute (L/min). Depending on the pump manufacturer, one of two different rating standards are used:

- the ASME (American Society of Mechanical Engineers) Standard measures pump CFM capacity at normal **atmospheric pressure**;
- the New Zealand Standard measures pump CFM capacity at a pressure of 15 **inches of mercury** – approximately ½ of **atmospheric pressure**.

...continued

Vacuum Pump
(continued)

Therefore, 1 CFM ASME Standard = 2 CFM New Zealand Standard and a pump with a rated capacity of 100 CFM ASME will have an equivalent New Zealand Standard capacity of 50 CFM. One CFM is equivalent to 28.3 L/min.

The capacity of the pump required for a particular milking system depends on the number of **milking units** used since this affects the amount of air introduced into the system during milking. Commonly guidelines are as follows:

For stall barns with pipelines and swing parlours:

Milking units	Pump Capacity CFM ASME
2	36
4	42
6	52
8	66
10	80

For parlours with milking units at each stall:

Milking units	Pump Capacity CFM ASME
6	48
8	56
12	78
16	100
20	112
24	120

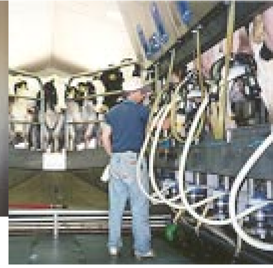
Several other system variables also affect required pump capacity. These include:

- the size of milk and vacuum lines;
- the number and sizes of auxiliary milking equipment such as **weigh jars** and **milk meters**;
- the amount of air leakage into the system.

While these guidelines will help to estimate required vacuum pump capacity, the critical factor is *reserve air capacity*. With the system completely set up and ready to milk, reserve air capacity should be 3 to 5 CFM ASME per milking unit.







Vacuum and Pulsation Lines

Adequate sizing of and proper installation of vacuum and pulsation lines is critical in supplying adequate and stable vacuum to the **claw** and **teat cup**.

The *main vacuum supply line* runs from the **vacuum pump** to the **vacuum reserve tank**. The *milk header line* runs through the **sanitary trap** to the **milk receiver jar**. The size of both of these lines must be equal to or greater than that of the pump intake port. The following guidelines may also be used, given the vacuum pump capacity and the total length of vacuum line from pump to milk receiver jar:

Vacuum Pump Capacity (**CFM ASME**)	Approx length of vacuum line (ft)[a]				
	10	20	40	60	80
	minimum internal diameter (in)				
50	2	2	2	3	3
70	3	3	3	3	3
100	3	3	3	3	3
150	4	4	4	4	4

[a] vacuum line length includes allowance for vacuum reserve tank, sanitary trap and 8 elbows.

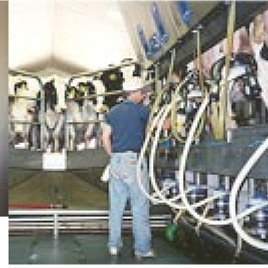
Pulsation header lines run from the **vacuum reserve tank** to the *pulsation lines* which supply vacuum through the **pulsators** to the **pulsation chambers** of the **teat cups**. Guidelines for sizing both pulsation header and pulsation lines are as follows:

- 1 to 14 pulsators – 2 inch inside diameter;
- 15 or more pulsators – 3 inch inside diameter.

In most new installations, vacuum and pulsator lines are PVC. If not properly glued, PVC junctions may leak and, therefore, need to be periodically checked.







Vacuum Reserve Tank

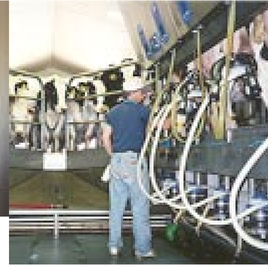
The vacuum reserve tank is commonly referred to as a balance, buffer or distribution tank. Its main function is as an distribution manifold between the **vacuum pump** and the system's plumbing. It also provides a reserve of vacuum to help buffer or cushion sudden air admissions into the system (e.g., **cluster** fall-off). A tank size of 5 gallons per milking unit is common.

Vacuum reserve tank showing main vacuum supply line (V), milk header line (M) and pulsation header lines (P).

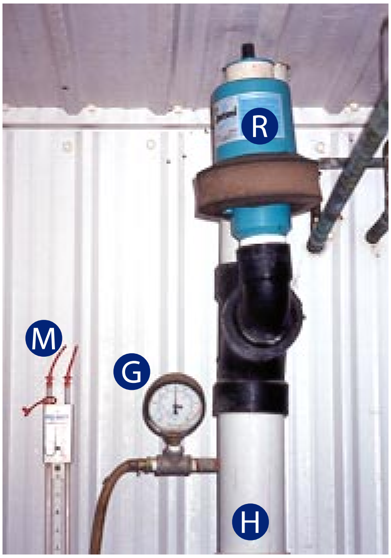
For parlour milking systems, the vacuum reserve tank should be located as near to the **milking units** as possible, usually directly above the **milk receiver jar** and **sanitary trap**. This location results in the most stable vacuum levels for systems which may experience high air loss volumes over short periods of time. For tie stall systems, the tank is usually located near the **vacuum pump**.







Vacuum Regulator (Controller)



Vacuum regulator (R), vacuum guage (G), mercury manometer (M) and milk header line(H).

The vacuum regulator admits air into the system when its vacuum level exceeds the maximum setting. The regulator cannot compensate for inadequate **vacuum pump** capacity – it cannot raise system vacuum level when it falls below the minimum setting. Therefore, the **vacuum pump** must always be capable of raising system vacuum level above the maximum setting in order for the regulator to do its job.

The CFM rating of the regulator must exceed the capacity of the vacuum pump – 125% at 50 **kPa** is recommended. If the regulator is unable to admit air at the maximum rate at which the **vacuum pump** removes it, system vacuum can rise to levels which may cause **teat damage**.

The regulator must also be sensitive enough to prevent vacuum fluctuations greater than 1.7 **kPa** in the **milk header line**. For this reason, the newer diaphragm regulators are preferred over the older weighted or spring-controlled types.

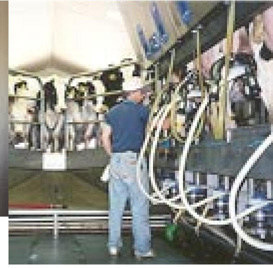
Acceptable **teat-end vacuum** level is in the 36-42 kPa range. To achieve this target, the regulator must initially be set to achieve **pulsation line** vacuum levels as follows:

Lowline system	42 to 46 **kPa**
Centre-mount weigh jar system	46 to 49 kPa
Highline system	47 to 51 kPa

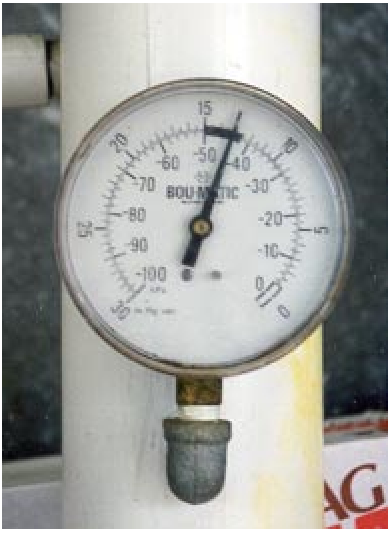
The regulator setting should be adjusted after checking **teat-end vacuum** levels during peak milk flow for 8-10 cows.







Vacuum Gauge



A dial-type vacuum gauge. The outer scale measures **in Hg**; the inner scale indicates **kPa** below **atmospheric pressure**.

The vacuum gauge measures system vacuum at the level of the **milk header line**, the **pulsation header lines** and the **pulsation lines**. Common guidelines for system vacuum level at this level are as follows:

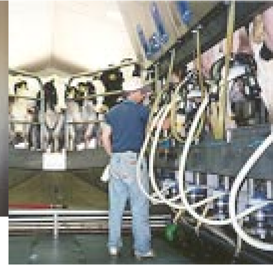
Lowline system	42 to 46 **kPa**
Centre-mount weigh jar system	46 to 49 kPa
Highline system	47 to 51 kPa

Vacuum levels at other points in the system will vary due to constricted air flow and the presence of milk on the 'wet' side of the system. The ultimate objective is to achieve a **teat-end vacuum** level in the 36-42 **kPa** range.

Two gauges should be installed in every system – one should be visible from the point where the vacuum pump is started at the beginning of milking; the other should be visible during the milking routine. If the two gauges indicate different values, they should both be recalibrated against a **mercury manometer**.

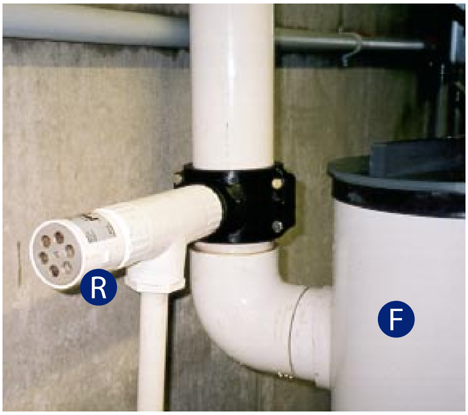






Vacuum Relief Valve

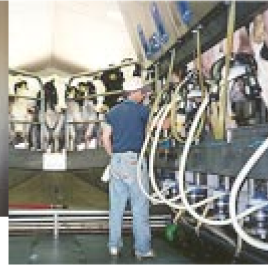
The vacuum relief valve prevents system vacuum from rising excessively should the **vacuum regulator** fail. It is normally set to limit system vacuum to approximately 5 **kPa** above normal. The relief valve should be installed in close proximity to the regulator.



Vacuum relief valve (R) and vacuum filter (F).



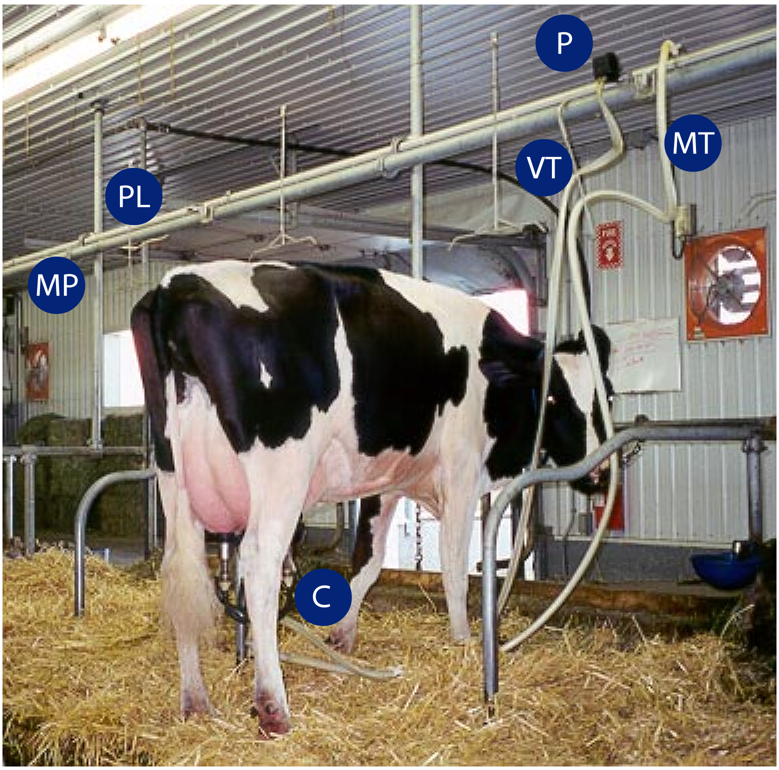




Milk Pipeline

The glass or stainless steel milk pipeline serves 2 functions:

- it carries milk from its connections with the **long milk tubes** of the milking units to the milk receiver jar;
- it supplies vacuum to the teat end through the **long milk tube**, **claw**, **short milk tube** and **teat cup liner**.



Tie stall highline system showing milk pipeline (MP), pulsation line (PL), pulsator (P), long milk tube (MT), long vacuum tube (VT) and cluster (C).

Tie stall barns normally employ a highline system where the milk pipeline runs about 1.8 to 2.1 metres above floor level, requiring a system vacuum level of 47 to 51 **kPa**. In a lowline parlour installation, the pipeline is normally installed as low as possible, preferably below udder level, requiring a lower system vacuum level (42-46 **kPa**).

Milk pipelines are installed as a **closed loop**, sloping in 2 directions (slopes) from a high point toward the **milk receiver jar**. Minimum slopes are 1 inch drop per 10 feet of length for welded pipe and 1½ inches per 10 feet for coupled pipe. With these slopes, pipelines should be self-draining to prevent the retention of milk or cleaning liquids.

Assuming line slope is adequate, appropriate milk pipeline size depends on the number of **milking units** per slope and herd production level. Guidelines are as follows:

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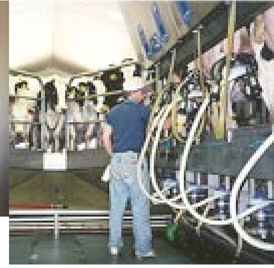

Glossary of Terms

atmospheric pressure: the force per unit of area exerted by the atmosphere on all objects. The official international unit of pressure is the kiloPascal (kPa) which is related to other units as follows:

100 kPa = 1 atmosphere = 1.01 bar
= 750.2 millimetres of mercury (mm Hg)
= 29.53 inches of mercury (in Hg)
= 15 pounds per square inch (psi or lb/in^2)

Because the depth of the atmosphere varies with altitude, so does atmospheric pressure. For example:

Location	Altitude metres	Atmospheric Pressure kiloPascals
Vancouver	3	102
Abbotsford	54	101
Winnipeg	239	99
Saskatoon	501	95
Red Deer	905	91
Calgary	1077	89

DHI: Dairy Herd Improvement. A program in which the milk production, milk component levels and somatic cell counts of individual cows are recorded 10 or 12 times per year. Results are used for both herd management and for estimation of the genetic values of individual cows, their ancestors and their progeny.

flooding: occurs when a column of milk completely fills any tube or line between the **teat cup** and the **milk receiver jar**. Flooding slows milk movement and, if air is being admitted to the system behind the milk column, vacuum level will be lowered.

Glossary of Terms (continued)

limping: the difference between **pulsation ratios** on the two sides of an **alternate pulsator**. For example, if one side is at a 60:40 pulsation ratio while the other is at 62:38, there is 2% limping.

mercury manometer: a pressure guage consisting of a column of mercury sealed at one end whose height is dependent on the pressure (or vacuum) exerted on the open end.

vacuum: absence of air or, more generally, absence of matter. Vacuum pressure is measured relative to **atmospheric pressure**. In a perfect vacuum, where all air has been removed, the vacuum pressure will be about 100 kPa, depending on **altitude**. The partial vacuum required in a milking system will have a vacuum pressure of about 50 kPa. Ideal teat end vacuum pressure is 37-40 kPa.

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