

# TECHNOTE

## 6

### Monitor and maintain milking machine function

It is important to remain vigilant throughout lactation to ensure that machines are operating well and are being used correctly. Machines that are not functioning optimally can contribute to new intramammary infections, either directly or indirectly (O'Shea 1987, Mein *et al* 2004), by:

- spreading bacteria from teat to teat and from cow to cow;
- reducing teat health and natural defence mechanisms of the teat canal;
- causing impact of bacteria-laden droplets into the teat canal, especially towards the end of milking; or
- reducing the degree or frequency of udder evacuation.

Milking machine equipment has been designed to harvest milk efficiently and maintain healthy teats. Teats are attached to milking machines for 50-100 hours per lactation. An understanding of how machine milking affects teats gives an appreciation of the importance of maintaining equipment. Components of a milking machine are described in the Figure below.

#### What happens during machine milking

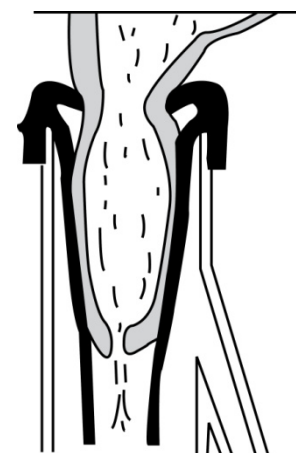
During the milk-flow phase of pulsation, the teat is drawn into the liner and stretched lengthwise and the teat barrel conforms to the internal diameter of the liner. The vacuum in the mouthpiece cavity of the liner keeps the liner in position.

Stretching of the teat walls, and movement of milk in response to the pressure difference between the teat sinus and open liner of the teat cup, causes the teat canal to open and milk to flow out of the teat (see first Figure in margin). The teat end is constantly exposed to the vacuum, and fluid accumulates in blood vessels and tissues in this region of the teat.

Closure of the liner compresses the teat. At the onset of the 'compression' phase of each pulsation cycle, the collapsing liner places most of its compressive force on the teat end and little load is placed on the teat barrel (see second Figure in margin). The massage phase reduces teat end congestion by distributing fluid, drawn into the teat end under vacuum, upwards through the teat tissue.

Definitions of the components of milking machines are given in ISO 3918: 2007 Milking machine installations – Vocabulary.

#### When the liner is open



Machine milking creates a pressure difference that causes milk to flow, and the teat canal to open.

Each cluster has a small vent that admits air into the claw bowl during milking. This air admission is especially important at the end of milking, to allow vacuum to equalise with atmospheric pressure, when the milk line is pinched shut or closed during cup removal. If this vent is blocked, the vacuum in the claw does not equalise, increasing the risk of teat impacts during cup removal.

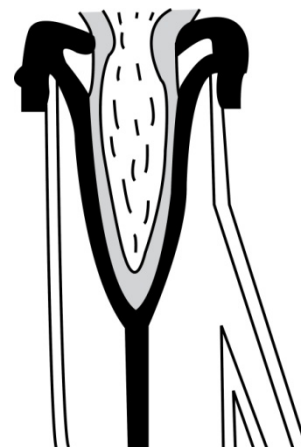
Optimal milking machine operation for mastitis control aims to:

- stop bacteria entering the teat canal during milking by minimising impacts caused by liner slip, rough cup removal or vigorous machine stripping and large cyclic variations; and
- keep teat skin and teat canals healthy by ensuring correct vacuum, pulsation, liner action and milking techniques.

Field experience shows that mastitis problems are often resolved by fixing simple problems such as unsuspected high vacuum, pulsator or liner problems, or by clearing blocked air vents. Furthermore, teat condition usually is improved by more careful attention to minimizing over-milking.

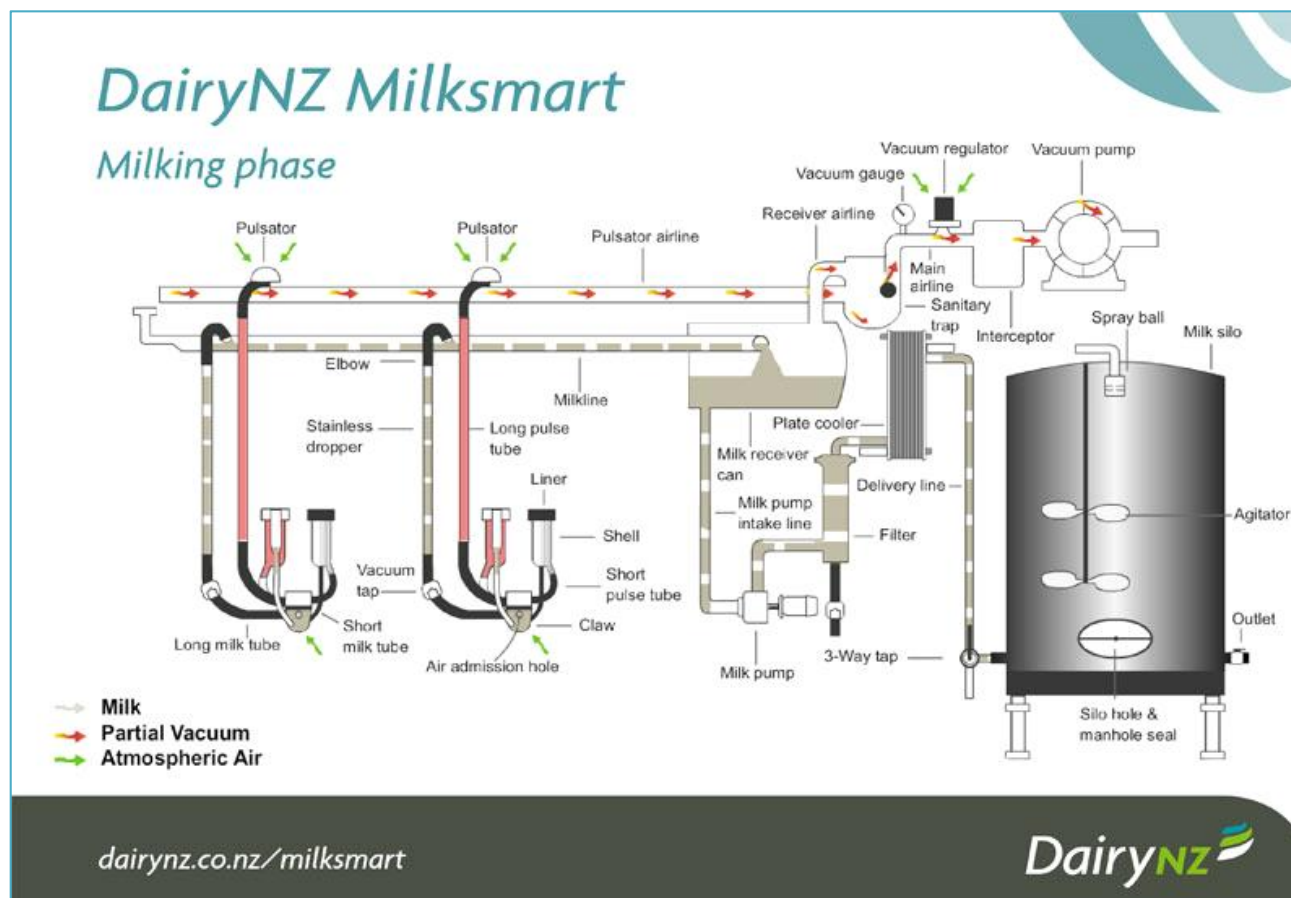
A regular, detailed and comprehensive analysis of milking machine function is necessary to define and correct problems.

When the liner is closed



Pulsation provides a massaging action to keep the teat healthy.

Components of a milking system (© Milksmart, 2012).



# 6.1

## Use the daily, weekly and monthly guides to check machine function.

Inadequate routine maintenance of mechanical components and rubberware will, in time, cause the milking machine to function poorly, leading to a greater risk of mastitis. Regular, systematic checks (see Table below) will aid early detection of problems, encourage preventive maintenance and enable basic trouble-shooting (Mein 1997).

### Recommended daily, weekly and monthly checks of milking machine function

Daily checks <sup>1</sup>	Weekly checks <sup>1</sup>	Monthly checks <sup>2</sup>
Check air admission holes (vents).	Check for twisted liners.	Check regulator function.
Check the vacuum gauge.	Check rubberware for damage.	Check for perished and damaged rubberware.
Listen to the pulsators.	Check filters on pulsators or on filtered air supply lines.	Measure completeness of milking and milking times.
Watch milk entering the receiver can to ensure minimal slugging.	Count cup squawks and slips requiring correction by milker.	
Check teats as cups come off.		
Note cow behaviour.		

<sup>1</sup>These tasks should be assigned to members of the regular milking team.

<sup>2</sup> These tasks should be the responsibility of the herd manager.

### Milking-time tests

The daily, weekly and monthly checks of milking machine function include five milking-time tests that monitor teat condition, cow behaviour, average milking time, completeness of milking, and frequency of slipping or falling teat cups. A detailed description of each milking time test is given below.

#### 1. Machine function and teat condition

Ideally, teats should be as soft and supple just after milking as before milking. Teat tissue undergoes both short-term and long-term changes in response to the forces experienced during milking. Generally, changes in the teats due to machine milking are most obvious at the teat end.

Teats which are slightly swollen or hard (due to congestion or oedema) or slightly blue or purple in colour (cyanotic) after milking result from machine-induced circulatory impairment. Usually, teats are thicker (with fluid) after milking with wide-bore liners, or at high vacuum level (Hamann *et al* 1994).

Cyanosis or oedema around the teat apex or lower barrel often indicate some type of pulsation failure such as an insufficient collapse phase of

#### Confidence – High

The most common reason for milking machine problems is inadequate routine maintenance of mechanical components and rubberware.

#### Research priority – High

Further development of practical milking time tests and guidelines would be helpful. Training for veterinarians and technicians is essential. Development and evaluation of automated warning systems for faults and service requirements are recommended.

Determining the residual milk volume that presents a (direct) risk factor for mastitis is warranted.

Technote 9.1 describes how to assess teat skin and teat ends.

pulsation, short teatcup liners or liners with insufficient tension. Cyanosis or oedema around the upper barrel of the teat may be due to liners with hard mouthpiece lips or high mouthpiece vacuum (Hillerton *et al* 1998, Ramussen 1997) or to over milking or prolonged milking.

The act of milking aggravates all types of teat lesions. Machine milking is the main cause of hyperkeratosis (teat canal or orifice), radial cracking, petechial haemorrhages (tiny blood-blisters) near the teat end, and may exacerbate teat chapping. Infections that establish within teat lesions may present as 'black spot' at the external teat orifice.

Common machine faults include:

- excessive vacuum,
- over milking,
- liners mounted at unnecessarily high tension,
- pulsation failure,
- short teatcup liners,
- insufficient collapse phase of pulsation.

Oedema and small haemorrhages at the teat end heal quickly, but can be important early warning signs of a machine problem and an increasing mastitis risk. Regular checks of vacuum level, pulsators and liner suitability will help avoid teat damage. Over milking for a period of five minutes on four consecutive milkings is sufficient to cause tissue damage (Hamann *et al* 1994). Over milking, excessive vacuum and failure of pulsation greatly increase the likelihood of tissue changes in the teat.

## **2. Machine function and cow behaviour**

Signs of discomfort or nervousness when cups are put on or taken off should also alert milking staff to the possibility of problems with milking machine function (Hillerton *et al* 1998). The frequency of stepping or kicking (the KiSt response) indicates levels of comfort/discomfort while the milking unit is on the cow.

Guidelines for observing cow behaviour:

- One observer can watch the rear legs of up to four cows at any one time, provided that he or she stands out of the way but close to the stalls or bails.
- A step means lifting a hoof clear of the floor. This involves a significant and deliberate shift in weight for the cow, thus it is easy to observe and record.
- A kick means that a hoof is aimed at a person or at the milking cluster (including any deliberate attempts by the cow to remove the cluster by pressing on it with her hoof).
- Observations should be recorded together with a time stamp so that data can be grouped and analysed as kicks/steps (the 'KiSt response') during specified events such as:
  - When cows are in the stall waiting to be milked. (Discomfort at this point may suggest environmental factors such as flies or poor design of the stalls).
  - When operators are preparing the udder, attaching or re-attaching units, or at post-milking disinfection. (Discomfort may indicate a problem of interactions between the operator and a cow, or the milking machine and cow).

Use of a chart enables objective assessment of cow behaviour at different stages during milking. See Technote 13 for more information.

- During the first two minutes of milking and the last two minutes of milking. (Discomfort during these periods suggests machine effects).

These data can be analysed as the proportion of cows exhibiting 0 or 1, 2-4, 5-10, or >10 'KiSt' responses at different periods of milking.

A video camera can be used *in lieu* of direct observations. If a video camera can be set up to record 1-2 hours of milking, the video can provide an effective means of demonstrating and analysing behavioural responses with minimal interruption to the normal milking routine.

The sensitivity of teats to being touched can be assessed by manual palpation just after milking (Hillerton *et al* 1998). However, results in commercial herds will depend to a large extent on whether cows are accustomed to being touched after milking.

### 3. Milking time guide

Field studies in France (Billon 1993) and the United States (Stewart *et al* 1993, Thomas *et al* 1993) all show remarkably consistent regressions for the relationship between the average milking time and the average milk yield per cow per milking.

A crude way to assess machine function is to measure the average time taken to milk a sample of cows, where average cow milk yields are estimated from vat yield divided by the number of cow-milkings in the vat.

For herds operating without automatic cup removers (ACR) or operating with ACR at 200 mL/min, 80% of cows in a typical Australian or New Zealand herd should milk out within a particular time, related to the average yield. These yields and milking times are summarised in the Table below.

#### Guidelines for milking times for cows of different production levels

Average milk yield at a single milking	Time in which 80% of cows should have completed milking
10 L/milking	6.3 minutes
12 L/milking	7.2 minutes
14 L/milking	8.0 minutes
16 L/milking	8.8 minutes
18 L/milking	9.5 minutes
20 L/milking	10.2 minutes

Under these circumstances the expected strip yields, after cluster removal, should be 100 mL or less per gland. For herds with higher ACR settings, e.g. 400 mL/min, larger strip yields and/or shorter milking times will be observed.

Research in Australia and NZ has shown that taking the cups off at a pre-determined Maximum Milk-Out Time (MaxT) saves time without affecting milk production, quality, mastitis or milk cell counts (Clarke *et al* 2008; Jago *et al* 2010 a, b).

A herd's MaxT depends on the average milk production per cow per milking. So if MaxT is applied at 80%, then the slowest 20% of cows would have their milkings truncated by removing clusters after 6.3 min.

Technote 5.7 describes the effects of under and over milking and how to achieve shorter milking times in herds.

#### 4. Completeness of milking

Qualitative and semi-quantitative guidelines for defining and assessing completeness of milk-out of individual quarters are given in the Table below (from Mein *et al* 2010). The qualitative guidelines are a practical alternative for use in herds where hand-stripping would cause unacceptable disruption to the operators' milking routine – or unacceptable risk from kicking by cows that are unaccustomed to having their teats handled after milking.

The semi-quantitative assessment provides guidelines for selective hand-stripping, in combination with the qualitative assessment, to improve the reliability of diagnosis. Guidelines for assessment of udder strip yields by machine stripping are also included. Although machine stripping may provide a more reliable and repeatable measurement method, its use is limited to milking systems where milk meters are permanently installed.

See “How completely should we aim to empty cows’ udders at milking time?” Mein *et al* 2010, for more information - see Key Papers list.

Technote 5.7 discusses the effect of incomplete milking (poor milkout) on mastitis and yields.

#### Guidelines for assessing and recording completeness of milk-out

Record milk-out as:	Qualitative assessment	Semi-quantitative (hand-stripping of individual quarter)	Machine-stripping (based on whole udder)
G (Good)	Quarter is visibly wrinkled	5 or fewer easy strips (equating to <50 mL per quarter)	Less than 500 mL per udder
P (Poor)	Quarter appears slightly plump, possibly indicating unharvested milk	10 or more easy strips (equating to more than about 100 mL per quarter)	More than 500 mL per udder
U (Uneven)	One particular quarter appears plumper and less wrinkled, relative to the other quarters		One particular quarter appears plumper and less wrinkled, relative to other the quarters

Inconsistent strip yields in rear versus front quarters, or between quarters on the right side versus left side, usually indicate a problem of poor cluster positioning and/or cluster weight balance.

The most common causes of incomplete milking are:

- poor type or condition of the liner;
- clusters that do not hang evenly on the udder because the connecting hoses are too long, too short, twisted, or poorly aligned in relation to the cow;
- cup crawl caused by e.g. clusters that are too light when a wide bore liner is used or the vacuum is set too high.
- high or low milking vacuum levels; and
- a mismatch between the claw inlet and the short milk tube causing partial closure of the short milk tube where this tube joins the claw.

#### 5. Frequency of slipping or falling teat cups

A comprehensive summary (O’Shea 1987) of research herd data suggested that generalised vacuum fluctuations per se did not increase new infection rates but new infections were greatly increased by liner slips. Curiously, the effect of liner slips on mastitis incidence has never been established in large-scale field trials. However, the economic

importance of liner slips can be inferred from field studies with deflector shields fitted into the liner or with one-way valves fitted between the short milk tube and claw.

Field experiments with deflector shields in Britain and Australia (Griffin *et al* 1980) and in Norway (Binde *et al* 1989) indicated an overall reduction in new infection rate of about 10-15%. It is likely that these devices prevented all or most of the effects of liner slip on new infection rates.

The effect of a 'high' versus a 'low' slip liner on new infection rate was assessed in the United States using a 160-cow research herd under conditions of natural exposure and post-milking teat disinfection (Baxter *et al* 1992). Slips were recorded whenever a vacuum drop of 10 kPa or more occurred within a time of 0.25 seconds or less. The 'high slip' liner averaged 7.6 major slips per cow-milking, compared with 3.1 for the 'low slip' liner. New infection rates were 0.49 per 100 cow-days for high slip compared with 0.27 for the low slip liner. Interestingly, this works out to about one new infection per 2,500 liner slips for both the high and low slip liners. Not surprisingly, the new infection rate was higher in cows with one or more quarters already infected (1,500-1,850 slips per new infection) compared with previously uninfected cows (more than 6,000 slips per new infection).

Such results indicate that slipping teatcup liners might contribute 10-15% of the new intramammary infections on an 'average' farm. The effect could be well above this average on some farms depending on individual herd factors such as: the prevalence of subclinical infections and quality of milking management, and machine factors such as: type of liner, bore of short milk tubes and claw volume.

The incidence of slipping or falling teat cups can be assessed by careful observation. As a guideline, Mein and Reid (1996) suggested that slips or falls requiring correction by the milker(s) should be fewer than 10, and preferably fewer than 5, per 100 cow-milkings. Liner slips or falls early in milking often result from:

- poor cluster alignment (including uneven weight distribution in the cluster),
- low vacuum,
- poor liner condition,
- liner type e.g. in relation to cluster weight,
- blocked cluster air admission holes.

### **Documentation of monthly checks of machine function**

Results of the monthly checks should be recorded so trends can be assessed regularly. A standard place, such as an exercise book, wall calendar, pocket book or electronic file may be used.

The monthly checks will help detect subtle changes due to wear and age in rubberware and equipment. For example, checking the effective reserve of the vacuum pump and regulator function can be achieved by keeping a monthly record of the vacuum with one, or two, milking units open. This is a simple method to test for possible deterioration in the reserve vacuum pump capacity (due to pump wear, air leaks, or regulator performance).

## 6.2

**Call a milking machine technician if you observe any abnormalities in the milking machine during your daily, weekly or monthly checks.**

## 6.3

**Change liners at regular intervals.**

Teatcup liners are made of natural or synthetic (usually nitrile) rubber, or silicone. They are shaped to:

- provide an airtight seal at both ends of the shell;
- provide a mouthpiece and barrel of a size that will fit on a range of teat shapes and sizes;
- minimize liner slips and cluster fall-off;
- allow for a quick and complete milk out, while minimising teat congestion, discomfort and injury; and
- clean easily.

Liners are designed to flex and squeeze the teat during each pulsation. When fitted into a correctly matched teatcup, the liner should be stretched 5-16% more than its original length. Some liners have two or more 'tension notches' at their base. This enables them to fit a number of teat cups of slightly different lengths.

Over-stretched liners may provide good milking characteristics but are more likely to cause teat damage (Hillerton *et al* 2003).

As soon as they start working, liners gradually lose tension, absorb fat, and hold bacteria. Liners deteriorate under tension, and when exposed to sun, heat, chemicals and ozone (e.g. near motors). The rate that they deteriorate depends on materials from which they are made, their storage, cleaning, and use.

As an extreme example, some liners have passed their 'use-by-date' when they are put on the first cow due to poor storage e.g. when new liners are replaced just prior to drying off, and are left under tension through the dry period. Perished liners reduce the speed and completeness of milking, increase teat end damage, and increase the spread of mastitis bacteria.

The recommended life of rubber liners is 2,500 cow milkings, or 5 months, whichever comes first. For silicone liners it is 5,000 cow-milkings – but despite their longer life, they are more susceptible to tearing and puncturing than rubber liners, and more likely to split if cows step on them.

The recommended interval for liner replacement is often shorter than people expect! Daily, weekly and monthly checks of milking times, milking completeness, teat end condition, and cup squawks and slippage will help to identify problems.

**Choose liners that are compatible with shells, claw inlets,**

Technote 25 describes regular testing and servicing of milking machines by qualified technicians.

### Confidence – High

Extensive field experience has shown that old liners reduce the speed and completeness of milking, and reduce milk quality.

### Research priority – High

Farmers and advisers need more objective criteria to determine the optimum time to replace liners.

Most manufacturers recommend that rubber liners are used for 2,500 cow milkings (5,000 cow-milkings for silicone liners) and then changed.

SmartSAMM Liner Ready Reckoner allows farmers to calculate the life of rubber liners in their herd.

"If you notice a difference when you renew liners, then the old ones were on too long."  
– Graeme Mein



## *jetters and teats*

The initial search for a compatible liner (Fox *et al* 2009) can be simplified by considering the following aspects:

**Preferably, choose liners that are part of a manufacturer's chart of recommended matching combinations.**

This strategy minimizes potential compatibility problems and warranty issues.

### ***Ensure that liners fit the shell***

- Ensure that liners do not leak when placed in the shell, that they cannot be twisted easily, and that the liner barrel is stretched by between 5% and about 16% of its original length when mounted in the shell.
- Is the liner mouthpiece distorted when it is mounted in the shell? Check by ensuring that the size and shape mouthpiece lip does not change substantially as the liner is mounted into the shell.
- Does the connection point at the bottom of the shell hold firmly, without air leaks or easy twisting of the liner in the shell? Additionally, hold the liner up to the light and look through it to ensure that the shell at the connection point does not noticeably constrict the internal diameter of the short milk tube.

### ***Ensure that liners fit the claw nipples***

- Check the internal diameter of the short milk tube (SMT) against the external diameter of the claw inlet. As a rough guide, liners are compatible with claw nipples if the bore of the SMT is 2-3 mm narrower than the external diameter of the nipple.
- Although the SMT will stretch somewhat, the more it has to stretch, the more prone the rubber is to 'stress cracking' and to split if a cow kicks or steps on the cluster. Furthermore, an overstretched SMT may restrict the size of the milk pathway from the SMT into the claw as illustrated in the Figure.
- Check manufacturer's tables for the SMT recommended for the teat cup.

### ***Ensure that liners are compatible with the jetters***

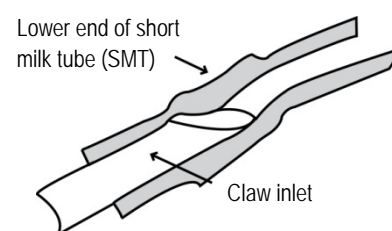
- Try before you buy. The liner needs to stay in or on the jetter during the wash cycle without substantial leaking of air so the CIP (cleaning in place) system can operate effectively.
- Watch out for mouthpiece distortion if the liner mouthpiece does not match the jetter correctly.

### ***Ensure that liners match the average teat size for a given herd***

This is the most important issue and it should be given top priority. As a general rule, it is wise to select liners that favour the younger cows rather than the older ones. It is self-defeating to use, for example, large bore liners to get faster milking of old cows if that is going to cause teat stress or discomfort for the younger cows.

- **Liner bore.** As a general guide, medium bore liners (i.e. liners having a mid-barrel bore of 21.5-24.5 mm, measured 75mm below the mouthpiece lip) are suitable for average teat diameters of about 23.5 mm, which is typical for most NZ herds.

### ***Restriction to milk flow that can occur at the claw inlet***



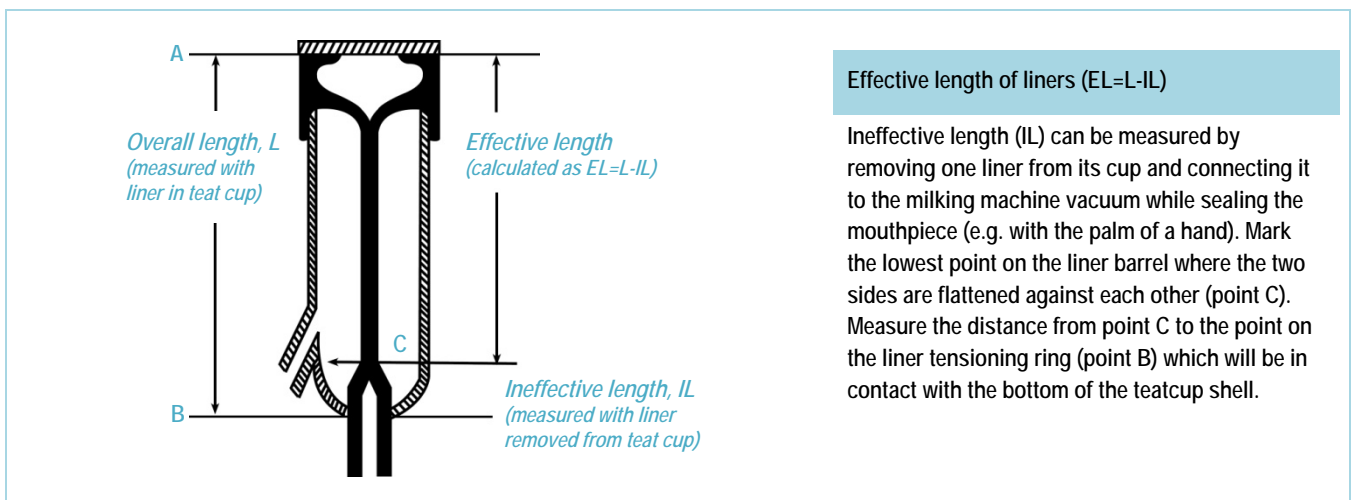
Note: the milk flow path from the teatcup into the claw is partially restricted at the point where the flexible SMT is connected to the rigid claw inlet.

- Effective length of a liner when mounted in its shell.**  
 Research in the 1970s showed that pulsation often failed on cows with long teats. Long teats were pulled so deeply into some liners that the teat-ends failed to get sufficient squeeze and the incidence of mastitis increased. The dairy industry responded to that discovery by producing liners with longer effective length to avoid this problem of pulsation failure.

Nowadays, liner effective length has ceased to be an important practical issue because dairy breeding and selection programs have resulted in shorter teats for NZ cows. Although it is rare to see teats that are more than 75 mm long now, it is still useful to know how to calculate the effective length of a given liner (see Figure below).

Assuming that 95% of teats are not more than 75mm in length, then a minimum effective length of about 135mm would be adequate for most liners and herds.

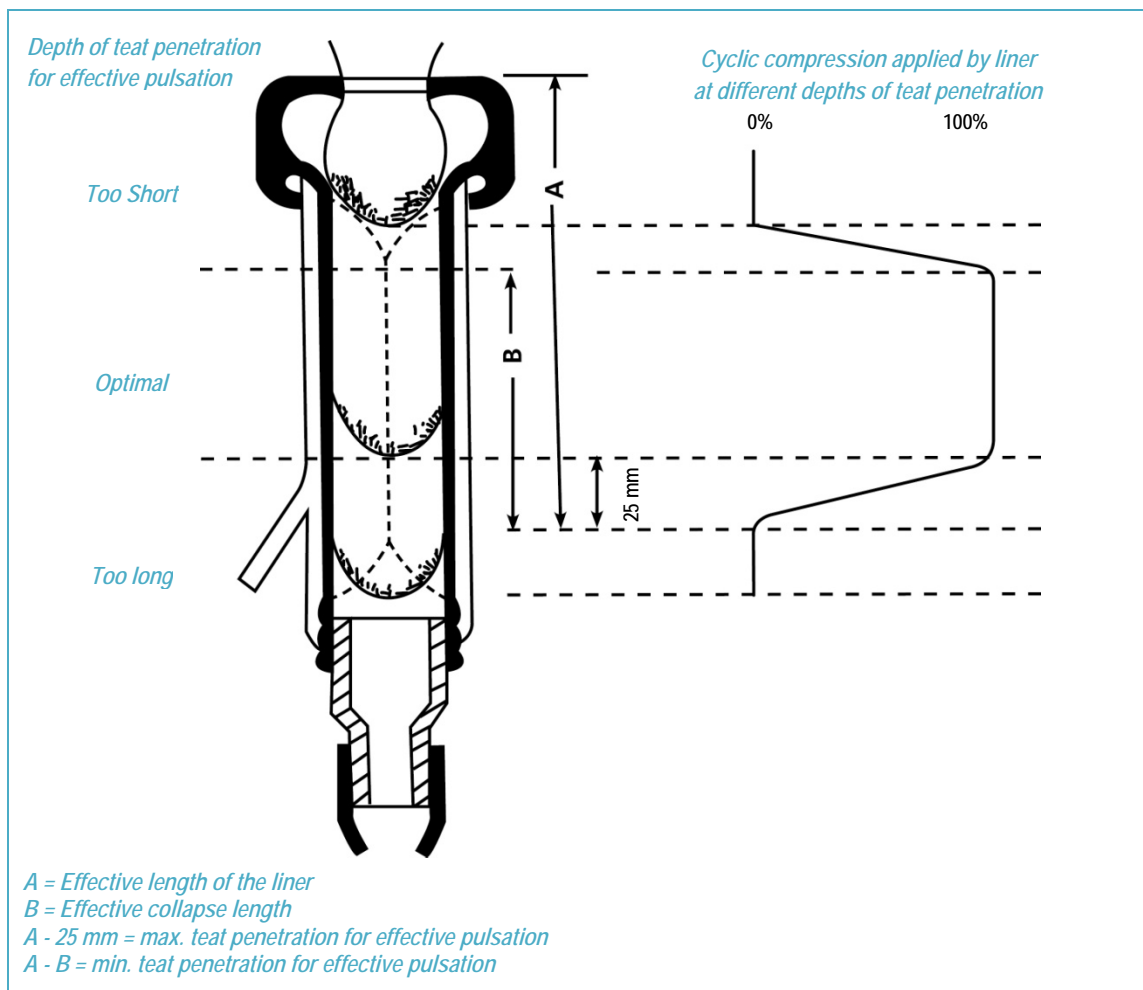
#### Measurement of the effective length of a teatcup liner.



- Mouthpiece ineffective length.** If the mouthpiece or lip cavity is too deep, very short teats often do not get adequate support from the liner barrel when it is open, or a proper squeeze from the closed liner. Such teats get insufficient relief from the milking vacuum and the cows do not like it! As a guide, this depth should not normally exceed 25 mm.

The effects, on the degree of compression applied by the closed liner, are illustrated in the Figure below. These estimates of the relative liner or cyclic compression are based on unpublished measurements by G. Mein. Very short teats get little or no squeeze, especially if the mouthpiece cavity is too deep. Some long teats also get little or no squeeze because the liner cannot collapse beneath the teat-end.

*Degree, or lack thereof, of compression applied by a closed liner around teats that penetrate to different depths within a liner. Effective pulsation occurs when the teat end remains in the 'Optimal' region.*



### **Final selection of the 'right' liner**

Final selection is always better done out in the farm dairy. Check the milking performance of liners on your 'short list' using the five key milking-time observations described in this Technote.

### **Acknowledgements**

DairyNZ and NMAC (NZ National Mastitis Advisory Committee) acknowledge the huge contribution of Dairy Australia's Countdown Downunder as the original source material from which SmartSAMB Technotes are derived, being updated and adapted for NZ dairy farming in 2011.

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