TECHNOTE

25 Test, service and up-grade milking machines

Virtually all infections enter the udder through the teat end. In typical Australian dairy herds, use of milking equipment is estimated to lead to about 20-25% of mastitis infections. Potential mastitis problems are likely to increase as the average milk production per cow continues to increase.

Numerous studies, mostly involving artificial challenge with high concentration of mastitis pathogens, have helped to elucidate the main milking-related mechanisms of spread of mastitis infections. These are:

- spreading organisms via contaminated liner surfaces, milker's hands and teat lesions;
- assisting the passage of organisms into the teat canal via impacts and possibly via reverse pressure gradients;
- decreasing the effectiveness of the teat canal as a barrier due to teat damage and loss of keratin lining of teat canal; and
- less frequent or less complete emptying of the udder.

25.1 Fully test and service your milking machine at least once per year.

Most surveys of milking machine efficiency indicate a wide variety of faults. These usually result from gradual changes in performance because of continued use, wear and age.

Extensive field experience indicates that the efficiency and function of milking machine components influence mastitis prevalence, mainly by their effects on the new mastitis infection rate.

Regular testing, service and maintenance of milking equipment is essential to maintain good mechanical performance, to improve the speed and completeness of milking, and to improve mastitis control.

Routine monitoring of key indicators at milking-time (such as teat condition, cow behaviour, milking-time and completeness of milking and occurrence of teatcup slips and falls) will provide an early alert to problems emerging in the milking system.

Confidence – High

Potential mastitis problems are likely to increase (especially as the average milk production per cow continues to increase) if milking machines are not regularly tested, serviced and maintained.

Research priority – Low

Technote 6 describes how to monitor and maintain milking machine function and monitor key indicators.

Confidence – Moderate

Much new scientific and technical information has been published in the 1990s. Fully certified technicians are more likely to know about the recent information, and they are more likely to know how to apply this knowledge to testing, servicing and trouble-shooting.

A complete AMMTA test should be conducted:

- As an acceptance test for a new milking system (before the final payment!).
- After major service work or major upgrade on an existing installation.
- At least once per year for all systems (or after each 1,500–2,000 hours of operation).

The following quick series of dry tests should be performed after each 500-1,000 hours of operation as part of a regular testing and maintenance contract:

- Vacuum level in receiver with no units open.
- Equilibrium vacuum level in receiver with 1 or 2 units open to admit air.
- Initial 'undershoot' or 'overshoot' in receiver vacuum when one unit is open end and then closed (this is a simple test for a dirty or sticking regulator).
- Effective Reserve and Manual Reserve.
- Vacuum recordings of pulsation characteristics (all pulsators tested, with teatcup plugs in each milking unit as it is tested).

25.2 Use a milking machine technician who tests to AMMTA standards.

Dry tests should be performed and reported by technicians who hold a current AMMTA testing certificate, a National Milk Harvesting Centre certificate or an acceptable equivalent. The National Milk Harvesting Centre also provides certification for technicians who have demonstrated proficiency in Countdown Performance Tests.

Don't rely only on an annual service. Other, more frequent test procedures are outlined below. Immediate additional testing and service is recommended if any of the following are observed:

- cows appear to milk slowly or incompletely;
- teatcups slip or fall frequently;
- teat condition is poor; or
- cows appear nervous or uncomfortable.

Types of milking machine tests

Milking machine tests have been classified into five types by the International Dairy Federation Expert Committee A32: physical measurements, dry tests, wet tests, milking-time tests, and cleaning-time tests.

Physical measurements

Physical measurements describe the dimensions of the installation and its components. These measurements are done without the machine running. Examples of these measurements include length, diameter and slope of pipelines, and the weight and volume of components such as clusters. Such physical measurements should be performed as a standard part of the initial acceptance test for any new installation, or after a major upgrade of an existing installation, to ensure compliance with the contract of sale or service.

Dry tests

Dry tests are conducted with the machine running but not milking, and with only air flowing through the machine. This type of test has been described loosely, but incorrectly, as "static testing". Examples of dry tests include vacuum levels and vacuum fluctuations in various parts of the system, vacuum pump and reserve capacity, and testing of pulsators. The standard Australian Milking Machine Trade Association (AMMTA) test procedure is a comprehensive series of dry tests plus some physical measurements.

Wet tests

Wet tests are performed with the machine running without milking the cows, but having both air and liquid (water, milk, or artificial milk) flowing through the machine. Equipment manufacturers or testing authorities in a laboratory typically perform wet tests. Examples of wet tests include vacuum level and fluctuations in pipelines and clusters, vacuum drop across components, tests of the threshold milk flow rate for automatic detachers, and measurement of liquid discharge rate from a releaser milk pump.

Some wet tests are suitable for field use and are valuable diagnostic tools for trouble-shooting (International Dairy Federation 1999). The choice of a particular wet test procedure, and the frequency of on-farm testing, depends on the problem to be resolved. One of the most useful wet test procedures involves an artificial udder which is connected to one or more milking units (one at a time) to help diagnose problems of slow milking or frequent cup falling, and to optimise the system vacuum settings (Stewart et al 1996).

Milking-time tests

Milking-time tests describe measurements or observations made while milking cows. The results of milking-time tests are the best and most direct indicator of the performance of any milking system (Mein 1992). Measurement of milk flow-rates, or measurement of vacuum in the milkline, receiver, claw, short milk tube, and the liner mouthpiece are examples of these tests.

Three of the most practical and useful milking-time test measurements are:

- mean vacuum and vacuum fluctuations in the milkline.
- mean vacuum and vacuum fluctuations in or near the receiver (not necessary if the milkline vacuum recording indicates vacuum changes less than 2 kPa); and
- mean vacuum in the claw during peak milk flow for a representative sample of cows.

Five of the most practical and useful milking-time observations for evaluating performance of milking units are:

- average milking time per cow (relative to the average yield per cow per milking);
- frequency of liner slips and cup falls requiring corrective action by the milker;
- amount of 'available' milk left in the quarters of an udder when cups are removed (that is, a frequency distribution of strip yield for individual quarters in a representative sample of cows);
- teat condition score immediately before and after milking; and
- cow behaviour:
  - are cows nervous and uncomfortable when teatcups are attached or removed?
  - are teats unusually sensitive to touch after milking?

Cleaning-time tests

Cleaning-time tests are carried out during the cleaning of the milking machine or bulk tank. Examples of these tests include: temperature, chemical concentration, water quality, water and air-flow velocities, and cleaning cycle times. Such tests should be conducted:

- when a new cleaning system is installed; and
- whenever cleaning problems occur or milk test results indicate poor quality.

The series of practical vacuum measurements should be conducted:

- Within one month after the first milking in a new milking system (after cows and operators have settled into a regular milking routine).
- After any major service work or system upgrade.
- If the dairy manager complains of problems of slow or incomplete milking, frequent liner slippage or cups falling, poor teat condition or cow behaviour.

Technote 6.1 describes the five milking-time observations in detail.

The table in revised Technote 9 page 14 (February 2003) summarises changes in teat condition that may be seen when milking machines or liners are not performing optimally.

The 'Liners' FAQ sheet (February 2003) describes how to tell if the liners need changing.

To systematically assess milking-time observations, use the guides and record sheets from the Mastitis Investigation Pack in the revised Technote 13 (February 2003).

25.3 Insist that the technician provides and explains a full written report.

Dry test reports

A list of recommendations is given on the summary page of all AMMTA test report forms under three main headings: 'Milking Machine Performance Test Measurements', 'Condition and/or Suitability of Main Components' and 'Safety'. For those advisers less familiar with the AMMTA Milking Machine Test Report Form, some tips for using the information are as follows:

Page 1 of the Milking Machine Test Report Form

- Check how long it has been since the last test was done. If it was more than three months ago, consider asking for a re-test.
- Taking into account the milkline size and average slope in relation to the number of milking units, ensure the milkline capacity is likely to meet current guidelines by comparing the figures recorded with the tables in Technote 25 page 11.
- Read the 'Milking Machine Test Summary and Recommendations' section carefully. Pay particular attention to the technician's comments on: pulsation system, vacuum levels, effective reserve and cluster.
- Recommendations under the heading 'Condition and/or Suitability of Major Components' should be an objective description of faults due to continued use, wear and age. Pay particular attention to the technician's comments on: regulator, liners, rubberware, claw tubes and air filters.
- Check for any recommendations about safety.

The Farm Injury Regular Surveillance Tools on the Monash University Accident Research Centre website at www.general.monash.edu.au/muarc

Although it is seldom a mastitis problem, safety is a serious issue for human life and health. A study by the Dairy Research and Development Corporation showed that in the past 10 years in Victoria alone, more work-related deaths occurred in agriculture than in any other industry group (Day 1997). Dairy plant was listed as one of the most common causes of non-fatal injuries. These are mainly loss of fingers or hair and scalp injuries resulting from unguarded vacuum pumps or milk pumps.

Page 2 of the Milking Machine Test Report Form

- Look at the Working Vacuum (section 3a) and compare this with the sumamry guidelines on the next page.
- Look at the Effective Reserve (section 5) and compare with AMMTA specifications given in the right hand column.
- Look at the Regulation efficiency % (section 7a) and compare with AMMTA minimum specification of 90% given in the right hand column.
- Look at the Claw Air Admission (section 9d) and compare the value per unit with AMMTA guideline (but remember that this is no more than an average estimate per claw - some claw vents could be blocked, others could be oversized).

Page 3 of the Milking Machine Test Report Form

Go through the Pulsation Chamber Vacuum Recordings data systematically with a biro or highlighter, marking any values that are outside the specifications given in Technote 25, page 5. Start with the most important columns – 'D%' and 'D(sec)', then check the next most important column, namely the 'Ratio (A + B %)'. The Pulsation 'Rate (CPM)' and 'B%' seldom exceed the specified limits in modern milking systems. 'C%' is a useful indicator of common problems such as air leaks into pulse tubes (causing an unusually short C-phase) or partially blocked air ports (causing an unusually long C-phase).

Countdown performance test reports

Countdown has developed a module for experienced milking machine technicians who wish to apply for the Countdown Downunder certificate of 'Performance testing of milking machines'. The performance tests incorporate elements of

Summary of guidelines for a milking machine dry test

Pulsation system

- Pulsator characteristics:
  - Rate shall be within +/- 3 cycles per min of installer's values.
  - Ratio shall be within +/- 5 units of percentage.
  - B-phase shall be not less than 30% (and not more than 4 kPa vacuum change).
  - D-phase shall be not less than 15% and not less than 150 milliseconds.

Vacuum levels

- The ISO 5707 Standard does not specify any particular system vacuum levels. However, the recommended mean Working Vacuum at the receiver should be within the range:
  - 47-50 kPa for a high-level milkline system.
  - 45-48 kPa for a mid-level milkline (not more than 1.25 m above cow platform).
  - 42-46 kPa for a low-level milkline (mounted below the cow platform).
- Vacuum gauge: Must be accurate within +/- 2 kPa of the true reading.
- Main airline(s): Not more than 3 kPa (and preferably less than 2 kPa) vacuum difference between the vacuum pump and receiver, and no more than 1 kPa vacuum difference between receiver and the regulator (or its sensor).
- Effective Reserve is a basic reserve of 800 litres/minute plus an incremental reserve of:
  - 20 litres/minute per unit for up to 40 units.
  - 10 litres/minute per unit for each unit above 40 units.

  For example, a minimum effective reserve for a 50-unit rotary = 800 + (20 x 40) + (10 x 10) = 1,700 litres/minute. In addition, the Effective Reserve shall be at least 90% of the Manual Reserve. This is called the Regulation Efficiency. It implies that the Regulation Loss shall be not more than 10%.

Cluster

- Long milk tube has a minimum bore of 12.5 mm and a maximum bore of 16 mm for mid- or high-level milklines.
- Cluster air vent plus leakage gives a total air admission of 6-12 litres/minute per unit.
- Maximum air leakage of 2 litres/minute per unit.
- Maximum air leakage through any vacuum shut-off valve when closed = 2 litres/minute.

Air leakage

- Not more than 5% of vacuum pump capacity into the airline system.
- Not more than 10 + 2n litres/minute into the milkline system (where n = the number of milking units).

Pulsator airline(s)

- The mean vacuum difference between the receiver and the most distal part of the pulsator airline shall not be more than 2 kPa.
- Cyclic vacuum fluctuations in the pulsator airline(s) shall not exceed 4 kPa. This limit is implied by the specification for pulsation phase-B.

the milking machine tests described on pages 2 and 3 (with the exception of the cleaning-time tests) and they are useful for evaluating the performance of Australian milking machines.

Information about the Countdown Downunder certificate of 'Performance testing of milking machines' can be obtained from www.countdown.org.au

Sheet F of the Countdown Downunder Mastitis Investigation Pack can be used to summarise the Countdown performance tests of milking machines. Assessments are made in four areas:

- ensuring compatibility of cluster components;
- checking the effectiveness of vacuum regulation;
- measuring the claw vacuum; and
- measuring vacuum stability in the milkline and receiver.

Revised Technote 13 (February 2003) page 25 shows an example of Sheet F from a farm mastitis investigation.

Ensuring compatibility of cluster components

Uneven weight distribution between the four quarters of an udder is one of the most common causes of incomplete milking, uneven milk-out, and liner slips. Ideally, the milking unit should hang squarely on the udder so that about 25% of the total cluster weight is applied to each quarter throughout milking. This rarely occurs in practice. The uniformity of distribution of the effective weight of any cluster between the four teatcups can be evaluated with a simple device that suspends the milking unit in the approximate position as if on a cow's udder. The effects of twisting or pulling of the milk hose can be demonstrated with this device which consists of a square of plywood with slots cut at the four corners to hold the top of each teatcup securely. In its simplest form, the device is suspended at its center of gravity by a cord so that it is free to rotate, twist or tilt, thereby indicating non-uniform weight distribution.

Observations about cluster alignment at milking can be recorded on Sheet K of the Mastitis Investigation Pack in revised Technote 13 (February 2003).

Careful measurement of air admission into individual clusters has great practical value. In a typical conventional dry test, only the average air admission rate per cluster is estimated. In the worst-case scenario, however, a good average result could be achieved if half the air vents were blocked and the other half were admitting twice the recommended amount of air. Blocked or partially blocked air vents reduce claw vacuum level, increase claw vacuum fluctuations, increase cluster flooding and liner slip, and increase milking time per cow. Excessive air admission (more than 12 litres/minute) also tends to reduce claw vacuum level, usually increases claw vacuum fluctuations and, in addition, tends to cause more milk frothing and lipolysis.

REVIEW AND PLANNING

Checking the effectiveness of vacuum regulation

Effective vacuum regulation is described by the milkline vacuum and tests for unit fall-off, regulator undershoot and regulator overshoot (see diagram below). These four characteristics can be assessed in a single series of measurements. Four consecutive recordings are made with an electronic vacuum recorder or digital vacuum gauge that can display the maximum, average and minimum vacuum levels. The recorder or gauge is connected into the milkline via any convenient milkline inlet. The connection point for 'worst-case' evaluation is the milkline inlet furthest from the receiver.

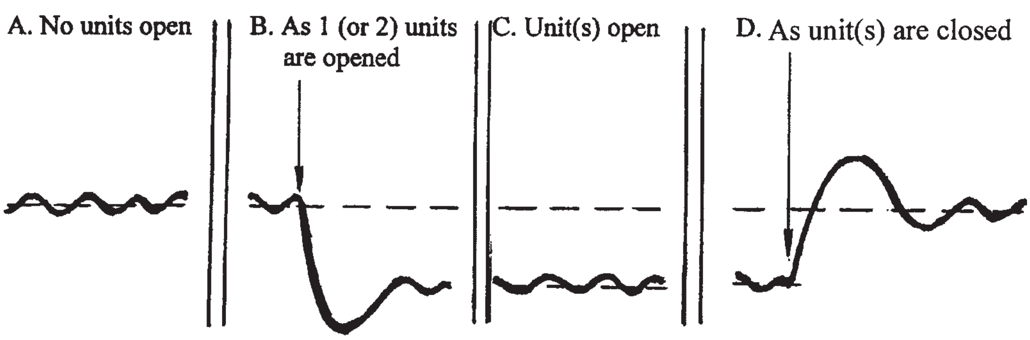
Measurements are made before, during and after a milking unit is opened and closed to simulate cluster falling as shown in the four vacuum records below. In sheds with more than 32 units, two units are opened and closed to simulate the likelihood for higher demand in larger dairies.

The unit fall-off test is an indication of the adequacy of the Effective Reserve. An overshoot or an undershoot of 2 kPa or more in the regulated vacuum level may indicate a dirty, sticking, or slow-responding regulator.

If Regulation Efficiency recorded during the AMMTA dry test was less than 90%, the simplest way to determine the likely cause is to measure the vacuum change at or near the regulator sensing point in conjunction with the measurement of Effective Reserve. If the system is properly plumbed, the regulator should sense at least two-thirds of the vacuum drop of 2 kPa that was applied at the central test point for measurement of Effective Reserve. Therefore, a vacuum drop of 1.3 kPa or more should be measurable at the regulator sensing point when the vacuum at the central test point is dropped by 2 kPa.

If the vacuum change at the regulator is less than 1.3 kPa, then the plumbing is not adequate for the pump capacity, or the system has too much pump capacity, or the regulator is located too far from the sanitary trap. If the vacuum change at the regulator is more than 1.3 kPa, then low regulation efficiency is due to an inefficient regulator (dirty, faulty, or poorly designed), or the regulator is incorrectly matched to the size of the pump.

Measuring the efficiency of vacuum regulation



Milkline vacuum	= Average A
Unit fall-off test	= Average A minus Average C (less than 2 kPa desirable)
Undershoot	= Minimum C minus Minimum B (less than 2 kPa desirable)
Overshoot	= Maximum D minus Maximum A (less than 2 kPa desirable)

Revised Technote 13 (February 2003) gives tips for how to collect data efficiently during milking-time tests and observations.

To be able to interpret the results of any performance test, it is important to know the response rate of the vacuum recording system being used.

Measuring the claw vacuum

Claw vacuum can be measured during milking OR with a flow simulator with the milking system running but not milking. With a flow simulator, the average claw vacuum can be measured before milking in 3-5 clusters with the flow rate set at 5 litres/minute. This wet test is an acceptable substitute for measuring the mean claw vacuum on 6-10 real cows during milking. It is a better measurement in some ways because the simulator flow rate is known and is highly repeatable.

For either method of measurement, the aim is to achieve a mean claw vacuum within the range 36-42 kPa during the peak flow period of milking.

Because most cows will be milking at their peak flow rate when measured 90 seconds after clusters are attached, the average claw vacuum should be at its lowest equilibrium level at that time of milking. This expected drop in vacuum between the claw and milkline is the essential basis for setting the recommended ranges of Working Vacuum at the central test point. That is, to achieve a mean claw vacuum within the range 36-42 kPa, Working Vacuum should be set within the range of:

- 47-50 kPa for a highline system, due to an expected vacuum drop of 8-10 kPa
- 45-48 kPa for a midline system, due to an expected vacuum drop of 6-8 kPa
- 42-46 kPa for a lowline system, due to an expected vacuum drop of 4-6 kPa.

When the measurements are made during milking, differences between average claw vacuum at 30 seconds and 90 seconds usually indicate inadequate milk ejection at the time the teatcups were attached. It is likely that teatcups were attached to an individual cow too soon if this difference is greater than:

- about 3 kPa for a cow milked in a low-line system
- about 4 kPa in a mid-line system, or
- about 5 kPa in a high-line system.

Examples of the typical vacuum drop caused by separate components in the milking unit

Component of the milking unit	Typical values of the vacuum drop
Length and diameter of the long milk tube	At a flow rate of 5 litres/minute, vacuum drop = 1-2 kPa / metre of 16 mm milk tube = 2-3 kPa / metre of 14 mm milk tube
Height of milk lift to a high-level or mid-level milkline	Vacuum drop is about 3-3.5 kPa per metre of lift. Example: At a 'milk' flowrate of 5 litres/minute through a 2-metre long, 16 mm diameter long milk tube and a milkline 1.25 metres above the claw, the mean claw vacuum would equal (2 x 1.5) + (1.25 x 3.25) = 3 + 4 = 7 kPa lower than the milkline vacuum
A blocked air admission hole	Mean vacuum drop will be about 10 kPa per metre of lift at any given milk flow rate.
Herd Test meter	Additional vacuum drop for some types of milk meters commonly used for monthly herd testing is about 5-6 kPa at 5 litres/minute.

According to ISO 5707, devices such as a milk meter flow sensor, "shall not cause an additional vacuum drop of more than 5 kPa measured in the cluster at a milk flow rate of 5 litres/minute and an airflow of 8 litres/minute ...". Milk meters used at every milking must comply with this requirement. Those used periodically for milk recording should comply with this requirement, but this guideline is often difficult to meet because it includes, correctly, "any necessary connecting tubes" for the equipment. The intent is to maintain fast-milking conditions by minimising restrictions in the milk flow path.

Flow simulators can be used to show the average vacuum drop caused by ancillary components in the milking unit (see table opposite page).

No claims can be made for the accuracy of, or the implications of, claw vacuum fluctuations measured with flow simulators. The overriding effect of tiny air leaks past the artificial teats makes such measurements misleading, frustrating and unreliable.

Measuring vacuum stability in the milkline and receiver

A practical performance guideline is that the milkline vacuum should be stable with no transient vacuum drops below 2 kPa for at least 95% of the time. If vacuum changes in the milkline did not exceed 2 kPa, there is no real need to measure receiver vacuum. However, if milkline vacuum changes did exceed 2 kPa, then receiver vacuum should be measured to determine if milkline fluctuations were caused by slugging in the milkline or by inadequacy in the vacuum regulation system.

A practical performance guideline to the effectiveness of vacuum regulation is that receiver vacuum should be stable within 2 kPa during normal milking conditions.

Most vacuum recording systems include an electronic vacuum recorder in combination with a variety of tubes and fittings used to connect to the milking machine. The characteristics of the vacuum recording system and the measurement techniques used can affect the accuracy of any measurement of vacuum changes. The minimum sampling rates and response rates of an acceptable vacuum recording system are shown below.

Recommended minimum sample rate and response rate for vacuum recording systems

Type of test	Minimum Sample Rate (Hz)	Minimum Response Rate (kPa/s)
Dry tests or tests in dry parts of the milking machine	24	100
Wet or milking-time tests in the milkline, or claw	64	1,000
Wet or milking-time tests in the short milk tube	170	2,500
Milking-time test of vacuum changes during a liner slip	1,000	22,000

Summary of guidelines for a Countdown performance test

Compatible cluster components have been selected

- Liners fit their shells.
- Bore of the short milk tubes is compatible with the size of claw nipples.
- Liners seem appropriate for the average teat size in the herd.
- Cluster air admission is within guidelines.

Vacuum levels and differences meet standards and guidelines

- Unit fall-off test: Not more than 2 kPa drop in average vacuum in the milkline or receiver with one unit open to atmosphere (or two units are opened in if the milking systems has 32 units or more).
- Regulator undershoot: Not more than 2 kPa initial transient drop below the minimum equilibrium vacuum when one unit is opened (or two units are opened in systems with 32 units or more).
- Regulator overshoot: Not more than 2 kPa initial transient rise above the maximum equilibrium vacuum when one open unit is closed (or two open units are closed in systems with 32 units or more).
- Vacuum change at regulator: A drop of 1.3 kPa or more in vacuum at the regulator when the vacuum level in the receiver or at the Central Test Point is dropped by 2 kPa.

Mean claw vacuum meets the guidelines

- Mean claw vacuum should be within the range 36-42 kPa during the peak milk flowrate period for a representative group of group of cows (that is, when measured 90 seconds after teatcups are applied) or when measured with a flow simulator at a liquid flow rate of 5 litres/minute.

Vacuum stability in milkline and receiver meets the guidelines

- Not more than 2 kPa transient drop in milkline vacuum below the mean level in the receiver during normal milking. This implies stratified flow conditions for at least 95% of milking-time.
- Preferably, not more than 2 kPa variation in receiver vacuum during normal milking.

Sizing of milklines

The effective carrying capacity of milklines is increased by:

- increasing the slope of the milkline;
- looping the milkline; and
- increasing the milkline size.

The tables on the following page are adapted from the current International Standard guidelines (ISO 5707:1996). They have been selected and endorsed by the Australian Milking Machine Trade Association (AMMTA 1998) for use in Australian conditions. They show how the milkline design, diameter and slope affect the milkline carrying capacity in herds with different production volumes. The theoretical design criteria common to both tables are:

- milking units are attached every 10 seconds, and the average claw air admission rate is 10 litres/minute/unit; and
- when each unit is attached, the average amount of transient air admitted by the operator is 200 litres/minute in a dead-ended milkline, or 100 litres/minute into each loop of a looped milkline.

Carrying capacity for fast-milking herds producing 5,000 L or more per cow per lactation[a] (adapted from AMMTA 1998)

Milkline design	Nominal internal diameter (mm)	No. units for different milkline slopes			
		Slope 0.5% 5 mm/metre	Slope 1.0% 10 mm/metre	Slope 1.5% 15 mm/metre	Slope 2.0% 20 mm/metre
Dead-ended	48.5	1	2	3	4
	60	3	5	7	9
	73	6	11	17	25
	98	30	Unlimited (34)	Unlimited (58)	
Looped	48.5	2	3	4	5
	60	4	7	10	12
	73	9	16	25	Unlimited (21)
	98	Unlimited (22)	Unlimited (43)		

a This assumes an average peak milk flow of 5 litres/minute per cow.

Carrying capacity for slower-milking or lower producing herds[b] (adapted from AMMTA 1998)

Milkline design	Nominal internal diameter (mm)	No. units for different milkline slopes			
		Slope 0.5% 5 mm/metre	Slope 1.0% 10 mm/metre	Slope 1.5% 15 mm/metre	Slope 2.0% 20 mm/metre
Dead-ended	48.5	1	2	4	5
	60	3	6	9	11
	73	8	15	23	Unlimited (23)
	98	Unlimited (24)	Unlimited (45)		
Looped	48.5	2	4	6	7
	60	5	9	12	16
	73	11	21	Unlimited (23)	Unlimited (28)
	98	Unlimited (30)	Unlimited (60)		

b This assumes an average peak milk flow of 4 litres/minute per cow.

In some instances, the tables show that the calculated number of units is unlimited when units are attached at 10 second intervals. In these instances, the figure given in brackets shows the maximum number of units if milking units are attached to cows at intervals of only 5 seconds.

Changes in the assumptions in the tables, such as a higher average milk flow rate or higher transient air admission, will result in fewer numbers of units per slope.

25.4 Carry out all recommendations.

Make sure the qualified technician has grouped the recommendations for service or upgrading into categories such as urgent and immediate changes, important but not urgent improvements, and cosmetic or other improvements. If not, discuss with the technician or seek guidance from others, then set target dates for the service work or system upgrades.

All things being equal, the best use of a limited budget will come from fixing or upgrading those components that directly affect the forces applied to cows' teats. Therefore, the most cost-effective sequence for upgrading inadequate components is likely to be:

- fix or replace regulator, and move it to correct position, if necessary (to improve vacuum control, milking speed, liner slips and teat condition);
- fix or upgrade pulsation system (to improve reliability, milking speed, comfort and mastitis);
- upgrade liners and shells, if necessary (to improve speed and completeness of milking, liner slips, comfort, teat condition and mastitis);
- upgrade claws and long milk tubes if necessary (to reduce uneven milk-out, liner slips and cup fall by improving weight balance between quarters).
- upgrade milkline and receiver group (to increase milk flow and discharge capacity, and/or improve system cleaning performance); and
- upgrade vacuum pump and airlines (to improve air-flow, energy efficiency, and system cleaning performance).

However, this suggested sequence would need to be modified for individual systems. Clearly, the best way to set priorities for a sequential upgrade will be to determine the key mechanical factor (or factors) that limit the desired rate of improvement in the major problem area. The problem area may be the speed or completeness of milking, cow comfort or teat condition, cell counts or mastitis, or poor cleaning.

Key papers

AMMTA. Australian Milking Machine Technicians Association Specification Handbook, 1998.

Day L. On the track of dairy farm injuries. Dairy Research and Development Corporation Research Note 48, March 1997.

International Dairy Federation. Functional requirements for milk machines referring to the ISO standards 3918, 5707 and 6690. In: Bulletin to the International Dairy Federation No. 358. Brussels, Belgium, 2000.

ISO 5707:1996. Milking machine installations – construction and performance. Standards Association of Australia, Sydney, Australia, 1996.

Mein GA. Basic mechanics and testing of milking systems. In: Bramley AJ, Dodd FH, Mein GA, Bramley JA, editors. Machine milking and lactation, Chapter 7. Insight Books, Huntingdon, Vermont, United States, 1992:235-284.

Stewart S, Farnsworth R, Mein GA. et al. Field measurement of vacuum levels using a portable flow simulator. In: Proceedings of the 35th National Mastitis Council Annual Meeting, Nashville, Tennessee 1996:214-227.