Evaluation of Milking Systems in Terms of New Mastitis Risk,

Performance

Authors

E.J. O'Callaghan, B.E., M.Eng.Sc., Ph.D.
D.E. Gleeson, N.C.A., Diploma in Dairy Husbandry, M.Sc.

Teagasc acknowledges with gratitude the support of Structural Funds in the financing of this research project.

Project No. 4505

Agriculture and Food Development Authority

Teagasc,
19 Sandymount Avenue,
Ballsbridge,
Dublin 4.
November, 2000

CONTENTS

1. SUMMARY

- Measurements of milking vacuum recorded on a flow simulator can provide guidelines for optimum design of milking units.

- Increasing the bore of the short milk tube above the recommended diameter or claw volume above 150ml does not improve milking efficiency.

- Increasing the long milk-tube bore from 13.5mm to 16mm increased the level of milking vacuum.

- The milking vacuum was highest with wide-bore tapered liners and simultaneous pulsation.

- The minimum vacuum was increased with narrow-bore liners and alternate pulsation.

- The milk yield with wide-bore tapered liners in heavy 3-kg clusters and using simultaneous pulsation was 5% higher than with light clusters (1.65 kg) with alternate pulsation.

- The milk yield depressions obtained with light clusters were similar in short and long term experiments and increased with the magnitude of the milk yield per milking.

- The teat condition scores were not affected by the magnitude of vacuum fluctuations.

2. INTRODUCTION

In efficient milking systems the losses in vacuum during milk-flow between the teat-end and the milk receiver are minimised and the maximum amount of milk is extracted with minimal levels of liner slippage and with minimal stress to the cow. Generally milking machines in commercial use are evaluated based on data obtained from dry testing or tests conducted with only air flowing through the machine. Vacuum losses in milking systems are measured during wet tests using milk flow simulators in a laboratory with air and liquid flowing through the machine. The test conditions in ISO standards (1996) for milking machines require that manufacturers establish the maximum flowrate of water during a simulated milking with an artificial teat to give a maximum fluctuation of 15 kPa measured over a complete pulsation cycle. Tests at Moorepark showed that the flow capacity should be based on level of vacuum at the teat-end when the liner was open (milking vacuum) rather than the magnitude of the vacuum fluctuation at the teat-end. The ISO committee responsible for drafting milking machine standards was informed of these results.

Technical data on milking machines should include both flow capacity of the milking unit obtained from a flow simulator for a range of water flowrates and also data on the biological responses of the milking unit expressed in terms of machine yield, milking time, strip yield, incidence of liner slips during milking and teat tissue condition. It is possible to have a milking machine working according to ISO standards and giving poor milking performance. O'Callaghan (1989) evaluated a range of commercial clusters in terms of milk yield, milking time and cluster stability. Gleeson et al. (1999 (a-f), 2000, (a-d) evaluated the effects of milking machine conditions on teat tissue reaction, cell count, and milking characteristics. In this report the effect of the design features of milking units on vacuum at the teat-end during milk flow simulation tests are shown. The effect of having high and low levels of vacuum fluctuations at the teat-end on milk yield, teat tissue condition and cell count was also measured.

3.DESIGN AND DEVELOPMENT OF AN ELECTRONIC MILK-FLOW SIMULATOR

O'Callaghan (1997a, 1998, 1999) showed that vacuum measurements made over complete pulsation cycles do not give a true picture of the vacuum at the teat when the liner is open, The level of vacuum at the teat-end mainly influences the peak milk flow rate and milking time. Most commercial vacuum recorders that are used for milking-time test indicate the vacuum variations over a full pulsation cycles. For optimum design of milking units the mean vacuum level at the teat-end when the liner is open should be high. The objective of the present study was to develop a flow simulator for the measurement of flow capacity of milking units and to provide recordings of vacuum during the open and closed phases of the pulsation chamber waveform.

The flow simulator consisted of four artificial teats each separately connected to four reservoirs. The level in each of these reservoirs was maintained constant. Flow into these reservoirs is supplied by a tank, which is mounted above the reservoir.

The vacuum levels in the pulsation chamber, teat end, claw and system vacuum level was measured using four gauge pressure transducers. This information is presented for a complete liner movement cycle, and for the open and closed phases within each cycle.

3.1 Effect of claw volume and size of milk tubes on vacuum at the teat-end and in the claw

The magnitude of the vacuum is affected by the resistance of the components between the teat-end and the milk pipeline, by liner design and by pulsation effects. With an optimum design of milking unit the losses in vacuum from the apex of the teat to the milk pipeline should be low. The objective of the present study was to determine the effect of the diameter of the long and the short milk tube and the volume of the claw on the vacuum at the apex of a artificial teat during simulated flow conditions with a range of pulsation settings.

All tests were performed on a flow simulator. The openings in artificial teats were placed in the plane of collapse of the liners and the flow of water ceased when the liner collapsed. Vacuum measurements were made at the apex of one artificial teat, at the top of the claw between the milk entry nipples, in the pulsation chamber and in the milkline. Tests were carried out on a cluster fitted with wide bore tapered liners with three water flows 4, 6, 8 litres/min; a pulsation rate of 60 cycles/min; two short milk tube (S.M.T) internal diameters 8.5 and 13.5 mm; two long milk tube (L.M.T) internal diameters 16 and 13.5 mm; two claw volumes 150 and 420 ml and two pulsation phases simultaneous-1 and alternate-2. Each claw was fitted with a 2.4 metre length of milk tube connected to a 48.5mm milk pipeline. A milk lift of 1.4 metres and a system vacuum level of 50 kPa were used.

Increasing the diameter of the S.M.T had minimal effect on the mean vacuum recorded with the liner in the open position (Table 1) or the vacuum recorded over a complete pulsation cycle (Table 2). For the three water flows, the vacuum with the liner open was approximately 5 kPa higher with simultaneous pulsation than with alternate pulsation, this difference was not apparent from the recordings of vacuum over a complete pulsation cycle. It is probably more realistic to express the flow capacity of a complete milking unit in terms of vacuum measured both over the complete pulsation cycle and when the liner is in the open position. Increasing claw volume reduced vacuum with the liner open with simultaneous pulsation. A significant increase in vacuum both with the liner open and over a complete pulsation cycle occurred when the L.M.T was increased from 13.5 to 16 mm.

Table 1: Effect of the diameter of the S.M.T., L.M.T., and claw volume on vacuum at the teat-end with the liner in the open position

	Flow	**0**		**4**		**6**		**8**		
SMT	**Pulsation**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**s.e.**
(mm)										
8.5		48.0	47.9	44.5	39.5	42.1	36.0	39.0	32.2	0.2
13.5		48.0	48.1	43.9	39.7	41.2	36.0	37.8	32.6	0.2
Claw Vol	Pulsation	1	2	1	2	1	2	1	2	s.e.
(ml)										
150		48.5	48.0	45.7	40.2	43.6	36.6	41.0	33.0	0.2
420		47.5	47.8	42.7	39.2	39.7	35.7	36.0	31.7	0.2
LMT	Pulsation	1	2	1	2	1	2	1	2	s.e.
(mm)										
13.5		48.0	48.0	43.4	38.0	39.8	33.8	35.5	29.3	0.2
16.0		48.0	47.0	45.0	41.2	43.5	38.2	41.4	35.4	0.2

Table 2: Effect of the diameter of the S.M.T., L.M.T., and claw volume on vacuum at the teat-end over a complete pulsation cycle

	Flow	**0**		**4**		**6**		**8**		
SMT (mm)	**Pulsation**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**s.e.**
8.5		47.8	47.8	38.1	39.1	34.8	33.3	31.6	31.1	0.2
13.5		47.7	47.8	38.9	39.7	35.5	36.0	31.9	32.5	0.2
Claw Vol (ml)	Pulsation	1	2	1	2	1	2	1	2	s.e.
150		47.9	47.9	38.5	39.7	35.5	35.9	32.6	32.3	0.2
420		47.5	47.7	38.4	39.2	34.7	35.4	31.0	31.4	0.2
LMT (mm)	Pulsation	1	2	1	2	1	2	1	2	s.e.
13.5		47.5	47.7	37.2	38.0	33.1	33.5	28.9	28.9	0.2
16.0		48.0	47.9	39.7	40.8	37.2	37.8	34.6	34.9	0.2

3.2 Measurements of vacuum at the teat-end and in the claw with six commercial clusters

Vacuum measurements were made with six cluster types (Table 3). The wide bore liner had an upper barrel bore of 31.5mm and was tapered to 20mm at the lower end of the barrel. Cluster 1 was a typical cluster used on most Irish dairy farms .The layout of the clusters and long milk tube during the simulation tests were similar to that in a commercial herringbone or side-by-side parlours that are fitted with mid-level milking machines (Fig.1). The mean vacuum in the milk pipeline was set at 50 kPa at zero flow.

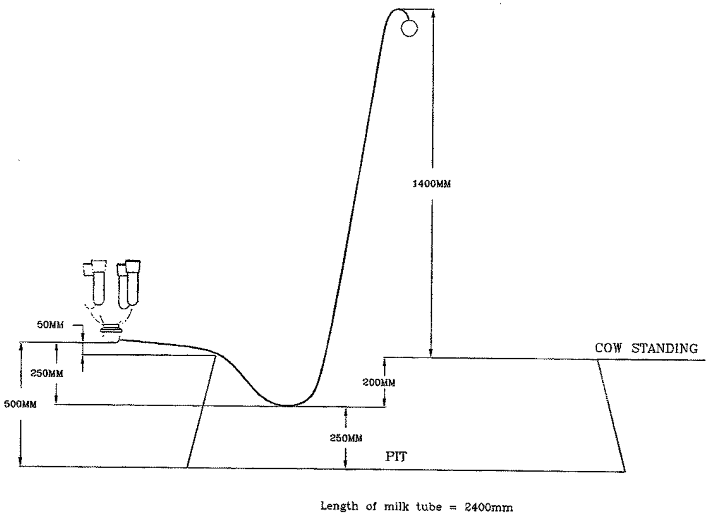


Figure 1. Diagrammatic representation of simulator for mid-level milking systems

Table 3: Details of clusters and settings for simulation tests in a mid-level milking system

Class	Levels	Values
Flow	4	0,4,6,8 L
Rate	1	60 cycles/min.
Ratio	3	60,64,68 %
Phase	2	1 = Simultaneous 2 = Alternate
LMT	2	16.0, 13.5
Cluster	6	1,2,3,4,5,6

Cluster	Liner	Claw Vol.	SMT diam.	Bore (upper)	Bore (lower)
1	Wide bore	150	8.5	31.5	20.0
2	Wide bore	150	13.5	31.5	20.0
3	Wide bore	420	13.5	31.5	20.0
4	Wide bore	420	8.5	31.5	20.0
5	Narrow bore	323	11.1	22.0	19.5
6	Narrow bore	275	12.0	25.0	21.0

System vacuum -50kPa

As expected the vacuum when the liner was open was reduced with increases in water flowrate. (Table 4). An increase in the diameter of the short milk tube from 8.5 mm to 13.5 mm for cluster 1 had a minimal effect on the liner vacuum. With simultaneous pulsation and a wide bore tapered liner increasing the claw volume reduced the liner vacuum for three water flows. Liner vacuum is affected by water-flow and the measurement can be a useful indicator of flow capacity of a milking unit in association with other measurements.

Table 4: Vacuum at the teat-end with the liner in the open position

	Flow Lm	**0**		**4**		**6**		**8**	
Cluster	**Pulsation**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1		48.5	48.2	46.3	39.8	44.3	36.0	41.8	32.6
2		48.4	48.3	45.0	40.5	42.9	36.6	40.0	33.5
3		47.4	48.0	42.7	39.2	39.5	35.5	35.6	31.7
4		47.5	47.6	42.8	39.2	39.9	35.9	36.1	31.7
5		46.2	47.0	38.7	38.3	37.1	34.1	34.1	31.9
6		47.2	47.0	42.9	39.3	40.2	35.9	37.7	32.5

Again the mean and minimum vacuum was reduced with increases in water flowrate. The differences in mean vacuum measured over complete pulsation cycles (Table 5) were small in practical terms for the six clusters with either simultaneous or alternate pulsation, the minimum vacuum was lowest with a wide bore taper liner used in cluster 1 (Table 6). Alternate pulsation gave higher minimum vacuum than simultaneous pulsation for the six clusters.

Measurements of minimum vacuum over a full cycle differ considerably with cluster type and also are influenced by water-flowrate. With the wide bore tapered liner, an increase in the diameter of either the short milk tube (SMT) or the claw volume increased the minimum vacuum.

Table 5: Mean vacuum at the teat-end measured over a full cycle

	Flow l/m	**0**		**4**		**6**		**8**	
Cluster	**Pulsation**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1		47.9	48.0	37.9	39.2	35.0	35.1	32.3	31.6
2		48.0	47.8	39.0	40.2	36.0	36.6	32.9	33.5
3		47.4	47.8	38.7	39.1	34.9	35.4	30.9	31.7
4		47.6	47.6	38.2	39.1	34.6	35.4	30.9	31.1
5		47.0	47.0	38.5	38.5	35.3	34.2	32.0	31.3
6		47.4	46.9	38.6	39.2	35.6	35.7	32.7	32.3

Table 6: Minimum vacuum in full cycle

	Flow l/m	**0**		**4**		**6**		**8**	
Cluster	**Pulsation**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1		38.0	44.0	14.4	25.5	12.2	19.3	10.4	14.6
2		39.1	43.9	22.5	36.5	18.9	32.5	15.5	28.9
3		41.1	45.0	27.6	36.0	23.0	32.0	19.1	27.9
4		41.7	44.9	22.2	33.2	17.9	26.9	15.2	19.6
5		43.3	43.7	30.4	34.5	25.2	27.7	21.8	23.1
6		41.4	44.0	27.8	36.4	24.4	32.5	20.9	28.2

The vacuum fluctuation or the difference between the maximum and the minimum over a complete pulsation cycle are presented in Table 7. Rating of clusters for flow capacity based on a vacuum fluctuation is of limited value. The wide bore tapered liners developed at Moorepark (cluster1) gave the highest level of liner vacuum and induced low level of vacuum when the liner closed. This low vacuum at the teat-end when the liner is closed does not cause increases in the incidence of liner slippage. Recording the flow capacity based on the magnitude of the vacuum fluctuation as suggested in the ISO standards (1996) is not practical. A more appropriate criteria for flow capacity is to record the vacuum with the liner in the open position. Mean teat-end vacuum and claw vacuum was similar for the six clusters.

Table 7: Vacuum fluctuation in a full cycle

	Flow l/m	0		4		6		8	
Cluster	Pulsation	1	2	1	2	1	2	1	2
1		13.0	6.5	37.3	21.4	37.0	25.6	37.8	28.2
2		11.1	6.2	28.2	10.0	29.0	11.5	29.0	13.0
3		8.7	4.5	18.9	8.2	19.8	8.6	19.7	10.1
4		8.3	4.5	24.2	11.5	25.4	14.9	24.2	19.1
5		6.2	5.3	15.7	8.9	18.4	12.9	19.8	15.0
6		8.6	5.2	18.1	7.9	18.4	8.9	19.4	10.3

4. EFFECT OF TWO MILKING PRINCIPLES ON MILKING CHARACTERISTICS OF DAIRY COWS

In Ireland cows are milked with milking machines that are fitted with heavy clusters (3.0-3.2 kgs) and wide-bore tapered liners. OíCallaghan (1989) showed that maximum milk yield and minimum numbers of liner slips could be achieved with this principle of milking. This system gave high levels of milking efficiency and a large fluctuation in vacuum. An alternative milking principle widely used on European and U.S.A farms uses a light cluster and narrow bore liners. With this system, the milking vacuum is lower ,and the fluctuation in vacuum is small. The objective of this study was to compare the two alternate milking principles over a six-week period.

Treatment 1 used a heavy cluster weight of 3.2kg with a claw volume 150ml,wide bore liners (31.9mm), and simultaneous pulsation. Treatment 2 consisted of a light cluster of 1.65 kg with a claw volume of 275ml,narrow bore liners (25.0 mm) and alternate pulsation. The clusters were removed automatically when the flow reached 0.2kg/min. Treatment 1 gave 5.9% higher daily milk yield than Treatment 2. Similar differences were recorded in short-term trials carried out at Moorepark (1999) on these milking systems. Total yields of fat, protein and lactose were higher with treatment 1 due to the higher milk yield, this difference was not significant.

5. EFFECT OF HIGH AND LOW LEVELS OF VACUUM FLUCTUATIONS ON TEAT TISSUE CONDITION, MILK YIELD AND CELL COUNT

In simulation studies, wide-bore tapered liner and simultaneous pulsation gave the highest level of milking vacuum, and the lowest level of vacuum when the liner was in the closed position. With narrow bore liners and alternate pulsation the opposite effect occurs.

The effect of these vacuum conditions on teat condition score, cell count and milk yield was compared over a full lactation for two treatment clusters. Treatment 1 consisted of a heavy cluster weight of 3.2kg with a claw volume 150ml,wide bore liners (31.9mm), and simultaneous pulsation. Treatment 2 consisted of a light cluster of 1.65kg with a claw volume of 275ml,narrowñbore liners (25.0 mm) and alternate pulsation. The clusters were removed automatically when the flow reached 0.2 kgs/min.

The milk yields were 5.2% and 0.5% higher at the AM and PM milkings, respectively, with Treatment 1 than with Treatment 2 (Table 8). The depression in milk yield with light clusters is dependent on the magnitude of the milk yield per cow per milking. This is shown in Figure 2. The teat condition scores were similar for the two Treatments over the complete lactation (Table 9).

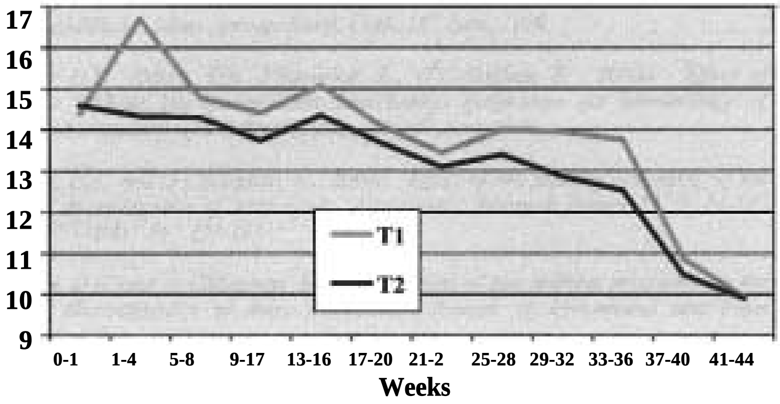
Table 8: Effect of milking system on lactation milk yields (kg)

	T1	T2	T1 - T2	% Yield Difference
Total AM yield	3,619	3,430	189	5.2
Total PM yield	1,846	1,837	9	0.5
Total lactation yield	5,465	5,267	198	3.6

Table 9: Mean teat-end scores for two milking systems over a full lactation

Days calved	30	60	90	120	150	180	210	240	270	300
T1	0.89	1.28	1.48	1.56	1.73	1.70	1.80	1.94	1.66	1.60
T2	0.87	1.26	1.52	1.55	1.66	1.67	1.85	1.93	1.74	1.73

Figure 2 AM Milk Yields with High and Low Vacuum Fluctuations



6. REFERENCES

Gleeson, D. E., Dillon, P. and Rath. M. 1999a. The effect of breed cow type on bovine teat-end Hyperkeratosis Development during lactation. (Abstract). Irish Journal of Agricultural and Food Research,**38** : 272.

Gleeson, D. E. and O'Callaghan, E. 1999b. Effect of system vacuum level on bovine teat-tissue reaction and milking characteristics. Proceedings, Annual Meeting of National Mastitis Council, inc. Arlington, Virginia 14th-17th February, **38** :209- 210.

Gleeson, D. E., O'Callaghan, E. and Rath. M. 1999c. Effect of milking plant vacuum setting on bovine teat-tissue reaction and milking characteristics. Agricultural Research Forum, 25th-26th March (IGAPA), **38** :43- 44.

Gleeson, D. E., O'Callaghan, E. and Rath. M. 1999d. Effect of vacuum level on bovine teat-tissue reaction and milking characteristics. (Abstract). Irish Journal of Agricultural and Food Research, **38** : 271-272.

Gleeson, D. E., Dillon, P. and Rath. M. 1999e. The effect of Dairy cow type on bovine teat-end Hyperkeratosis development during lactation. Agricultural research forum, 25th-26th March (IGAPA), 38 : 45-46.

Gleeson, D.E. and O' Callaghan, E. 1999f. Effect of pulsation setting on teat-tissue reaction and milking characteristics. International Conference on Mastitis and Machine Milking. Silver Springs Hotel, Cork, 18th June, 1999.

Gleeson, D.E., Kilroy, D.E. Fitzpatrick, E., O'Callaghan, E. 2000a. Effect of Machine Milking on Bovine Teat SinusInjury. Symposium on Immunology of Ruminant Mammary Gland. Stresa, Italy, 11-14th June, 2000.

Gleeson, D.E. and O' Callaghan, E. 2000b. Effect of two milking principles on the milking characteristics of dairy cows. Agricultural Research Forum, UCD, 14-15th March (IGAPA), 26:193-194

Gleeson, D.E. and O' Callaghan, E. 2000c. Effect of two milking principles on the milking characteristics of dairy cows. Irish Journal of Agricultural and Food Research. (Abstract) (in press).

Gleeson, D.E. and O' Callaghan, E. 2000d. Effect of high and low levels of vacuum fluctuations on teat tissue condition, milk yield and cell count. IMQCS conference Portlaoise, 14th January, 2000.

ISO 6690, 1996. Milking machine installations - construction and performance. International Standards Organization,Geneva, Switzerland.

O'Callaghan, E.J. 1989. Measurement of cluster stability and its relationship to liner design and physical settings of the milking machine. Ph.D. Thesis, National University of Ireland, Dublin.

O'Callaghan, E.J.1997. Comparison of testing systems for evaluating milking units. International Conference on machine milking and mastitis. 23rd May, 1997. Teagasc. ISBN 1 901138, **151**:31-55.

O'Callaghan, E.J.1997a. Milking machines ñ design and efficiency. Todayís Farm, 7:5, Jan-Feb, pp.39-41.

O'Callaghan, E.J. and Gleeson, D.E. 1999. Measurement of vacuum stability in milking units during simulated milking. (Abstract).Irish Journal of Agricultural and Food Research, **38**:2, 272.

O'Callaghan, E.J. and Gleeson, D.E. 1999. Measurement of vacuum stability in milking units during simulated milking. In: National Mastitis Council, 38th annual Meeting, Arlington, Virginia, 14th-17th February, Arlington, Virginia, USA, pp.206-208.

NOTES