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SOME RECENT RESEARCH ON MILKING MACHINE DESIGN

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SUMMARY

The claims made for the low-line system of milking in preference to the high-line system were examined in relation to speed of milking, milk quality, mastitis incidence and economies in machine installation and design of dairy sheds.

Results from a series of experiments and other data suggested that the case for the low-line rather than the high-line system was not conclusive.

IN RECENT YEARS much publicity has been given to the low-line milking plant, on the grounds that it offers advantages over the more conventional high-line system (Whittlestone, 1966, 1967; Fell, 1968). Much of the evidence to support the claims rests on experiments involving several variables, so that the exact effect of the difference in pipe-line height could not be identified. In some cases the characteristics measured were not those with which the farmer is directly concerned, such as the maximum rate of milk flow, while in others the end point of milking has been determined by means which are not available to the practising farmer.

It is possible to argue theoretically that the low-line system will give faster milking as it will provide a higher milking vacuum, but this is not sufficient evidence on which to base a major redesign of milking plant installations.

This paper describes the results of some experimental work to test the arguments put forward, under carefully controlled conditions. While the investigation is not yet complete, it does indicate that the case is by no means "cut and dried".

The claims made for the low-line system are briefly the following:

(1) Faster milking.

(2) Improved milk quality owing to the development of lower levels of lipolytic rancidity.

(3) Less variability in milking vacuum, with consequent possibilities of lower mastitis incidence.

(4) Easier installation and more economical shed design.

SPEED OF MILKING

The best measure of "speed" of milking, and the one with which the farmer is most directly concerned, is the time the cups are on the cow.

Two separate trials were conducted over periods of two weeks and four weeks in mid-lactation to test the effect of height of milk line entry on the milking characteristics of a group of cows.

In each trial the cows were milked into a flow-recording unit which allowed an accurate recording of the milk-flow curve at each milking. All other factors were constant, except that the entry to the recorder cylinder was at udder height in one case, and at 137 cm (54 in.) above udder height in the other. While this does not represent the maximum difference which occurs in practice, it was the maximum which could be accommodated within the experimental dairy. It is hoped to be able to conduct further trials where the height difference is greater.

The cows were prepared by using an adequate stimulus, and milked with soft moulded teat cups using a standard Ruakura pulsation, with a slow squeeze. When the milk flow rate had fallen to 0.45 kg (1.0 lb) per minute, as indicated by the Ruakura milk flow indicator, a weight of 1.6 kg (3.5 lb) was applied for machine stripping and the point on the curve marked. When the indicator had cleared, indicating a flow rate below 0.22 kg (0.5 lb) per minute, the teat cups were removed and the recording marked for the end of milking.

The times measured were thus comparable with those which would apply in a practical dairy where a good milking indicator is used.

RESULTS

Table 1 shows the results of the second trial, which was conducted for four interchanged weekly periods. The results of the first trial involving a different group of cows, which was conducted for only two weeks, were virtually identical but were not statistically significant owing to the limited data.

The difference in milk weight, although significant, was confounded with time, and was reversed for the first two periods of the trial. The difference in milking time was very small and non-significant, and, even if real, was probably due to the difference in milk weight. The results indicate that milking time is not influenced by a difference in

TABLE 1: MILK CHARACTERISTICS WITH HIGH- AND LOW-LINE SYSTEMS
Data for average 9 cows, 28 milkings per treatment.

	Milking System		
	High-line	*Low-line*	*Difference*
Weight (kg)	4.59	4.75	+ 0.16**
Time (min)	4.10	4.19	— 0.09
Weight/Time (kg/min)	1.12	1.13	+ 0.01
Maximum rate (kg/min)	2.35	2.48	+ 0.13*
Machine stripping:			
Weight (kg)	0.84	0.70	+ 0.14*
Time (min)	1.53	1.44	+ 0.09
Weight/Time (kg/min)	0.55	0.49	— 0.06**

*$P < 0.05$; **$P < 0.01$

height of this order. In the same way, the average flow rate was not influenced.

The maximum rate of milk flow showed an increase in favour of the low-line, but this was offset by reduced flow rate during the machine stripping period.

The results in general indicate that, although the increased vacuum level applying in the low-level system can give rise to a higher maximum flow rate, this is offset by a higher degree of teat cup crawling, and consequently lower rate of machine stripping. The result is that there is no effective difference in milking time.

One interesting observation is that teat cup crawling, a feature which is usually associated with damage and discomfort, seemed more pronounced with the low-level system.

COMPARISON WITH SURVEY RESULTS

The results of a field study (Jackson & Murray, 1968) examining the throughput of dairy sheds support these experimental findings. In that survey there was relatively little difference between the high- and low-line doubled-up systems (44 and 47 cows/man/hr, respectively), but the major difference in throughput resulted from the use of doubled or single herringbone systems (high-line; 44 and 56 cows/man/hr, respectively).

This confusion between "low-line" systems, and "doubling-up" is an aspect of the problem which has not been fully appreciated in many investigations, but is in fact an entirely separate issue.

LIPOLYTIC RANCIDITY

It is claimed that the lifting of the milk in the milk dropper by means of the air admission at the claw causes serious quality faults in the milk.

In the present trials, the milk of each cow was sampled for two milkings during each weekly period. The average free fatty acid (FFA) levels, as stearic acid, are given in Table 2.

TABLE 2: EFFECT OF PIPE-LINE HEIGHT ON FREE FATTY ACID LEVEL

	Trial 1, Nov. 1966	*Trial 2, May 1967*	
	Stearic Acid (mg/100 ml milk)	*Stearic Acid (mg/100 ml milk)*	*Stearic Acid (mg/100 mg b/fat)*
High	12.07	14.75	0.480
Low	10.00	10.75	0.333
Difference	2.07	4.05	0.147
% Increase	20.7%	37.9%**	44%**

**$P < 0.01$

In Trial 1, the differences were not significant owing to the variability of the FFA values, but in Trial 2 the differences were highly significant. The results are very similar to those obtained by Gholson *et al.* (1966) under similar conditions. It is interesting that, with two samples in each treatment with a group of 13 cows, it was not possible to demonstrate a significant difference in Trial 1, owing to the variability between cows, and from day to day. This suggests that little reliance can be placed on results based on small numbers of samples.

LIPOLYSIS IN OTHER PARTS OF THE PLANT

While the evidence indicates that the raising of the milk in the dropper can cause an increase of over 40% in FFA value, it must be considered in relation to the degree of damage which occurs elsewhere in the plant. There will be little gained in changing the configuration of the plant to avoid a small quality loss, if in so doing a substantially greater one is introduced elsewhere.

It has been suggested (Whittlestone, 1967) that the use of the flow-controlled centrifugal pump system, commonly used with low-line installations, produces a low level of rancidity, and is thus superior to the more conventional two-chambered releaser, or the diaphragm pump. In particular, this latter has been criticized on the grounds that while running continuously it will frequently pump air, which it is claimed greatly increases the level of rancidity.

To test some of these points, the three systems were set up in the experimental dairy so that they could be interchanged daily and levels of FFA measured. In the case of the two pumps, it was possible to operate them simultaneously from the same tank full of milk, with the same control sample.

RESULTS

The results of preliminary trials are presented in Table 3. In A, samples taken from delivery pipes of equal length are compared with samples taken from the common intake pipe. In each case the pumps ran full so that no air was pumped. The centrifugal pump delivered through the restriction normally used with a plate-cooler.

TABLE 3: EFFECT OF MILK RELEASING SYSTEM ON FREE FATTY ACID LEVEL

	Stearic Acid (mg/100 ml b/fat)
A. Average of 3 trials — milk from 10 cows:	
Control before pumping	0.239*
Centrifugal and restriction	0.466
Diaphragm (no air)	0.426
B. Three milkings each treatment — approx. 20 cows (Average flow rate = 1.36 kg/min):	
Releaser	0.483
Centrifugal and restriction	0.503
Diaphragm (plus air)	0.469

*$P < 0.05$

The difference between the pumps was not significant, but that between each pump and the control was significant at the 5% level.

In B, the FFA levels for three milkings with each system are compared. In this case the group of 20 cows in late lactation was milked through the system and the milk was then sampled from the holding vat. Duplicate samples were taken in each case. The average milking rate was very low indeed, being approximately 1.36 kg (3.0 lb) per minute throughout the milking. The centrifugal pump was flow-controlled, so that it operated only when the receiver tank was full, and then only until the milk level reached the lower control level.

In the case of the diaphragm pump, the pumping rate was set in excess of 15.9 kg (35 lb) per minute continuously, so that for practically the whole milking the pump was pumping air through the milk. This, theoretically, would impose the most extreme conditions, in terms of butterfat damage.

The results, although the differences were not significant statistically, do not support the view that the centrifugal pump is superior, as all treatments produced a similar result. Furthermore, the diaphragm pump, while running in a completely "starved" condition, did not appear markedly worse than when running full. This is quite contrary to the theory put forward concerning the importance of air in lipolysis (Whittlestone, 1967), and suggests that the basic hypotheses may be incorrect.

The gain in the FFA level owing to pumping or releasing is also interesting in that it represents an increase of nearly 100%, which is nearly 2½ times that contributed by the dropper system and air admission in the trial described earlier. This suggests that other aspects of milking plant design are of more importance in determining the level of hydrolytic rancidity, than the mere placing of the milk line.

Quite apart from this, however, there does not appear to be any satisfactory evidence yet to show that the matter is of any economic significance to the industry at the present stage.

VACUUM DIFFERENCES WITHIN THE PLANT

In the present day large milking plants, the air flow levels are very high, particularly in the air line, and, when combined with the very long lengths of pipe-lines, can cause major differences in vacuum level between one part of the plant and another during operation.

In particular, there have been instances in the field where a low vacuum level in the air line has apparently led to milking difficulties.

Since the placing of the milk line can be a factor also in determining the milking vacuum, it was felt worth while to test the behaviour of the high- and low-line systems under conditions of vacuum imbalance which might be encountered in the field.

Tests were carried out using the high- and low-level systems described earlier, but this time with:

(1) Air line vacuum level 12.7 cm (5 in.) Hg below the milk line vacuum level.

(2) A slowly applied vacuum stroke in the pulsation, as opposed to the normal rapid application of vacuum.

TABLE 4: EFFECT OF A REDUCED AIR LINE VACUUM LEVEL, PIPE-LINE HEIGHT AND PULSATION SHAPE ON MILKING CHARACTERISTICS

	Weight (kg)		*Time (min)*		*Weight/Time (kg/min)*		*Max. Rate (kg/min)*	
	High	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*
Normal pulsation: Air line — 38 cm Hg vac. Milk line — 38 cm Hg vac.	5.89	5.72	4.60	4.39	1.28	1.30	2.35	2.70
Choked vacuum phase: Air line — 38 cm Hg vac. Milk line — 38 cm Hg vac.	5.53	5.81	4.68	4.65	1.18	1.25	2.18	2.27
Normal pulsation: Air line — 25 cm Hg vac. Milk line — 38 cm Hg vac.	5.98	6.14	4.81	4.72	1.24	1.30	2.17	2.34
Choked vacuum phase: Air line — 25 cm Hg vac. Milk line — 38 cm Hg vac.	5.33	5.72	5.30	6.13	1.01	0.93	1.96	1.76

The results of the tests are given in Table 4. The figures are the average for 3 or in some cases 4 days on each treatment for a group of 12 cows.

It can be seen that provided the pulsation waveform is normal, and the vacuum stroke is rapid, a differential of 12.7 cm (5 in.) Hg between air line and milk line has little effect. It is also apparent that the choking of the pulsation alone has only a minor effect in each case.

When, however, both these situations occur together, there is a violent effect on the rate of milking, and this is particularly pronounced in the case of the low-level system. The result was, in fact, so marked in some cows that whole quarters remained unmilked, and milking was generally very uneven.

This result suggests that the low-line system, maintaining a high average teat cup vacuum, may well be more prone to faults in milking arising from vacuum imbalance and variations in pulsation waveform, both of which have been considered of little importance. The effect on the evenness of milking indicates at least that more than average care should be taken in low-line installations to ensure a high level of air line vacuum and rapid rise in the vacuum stroke of the pulsation.

VACUUM VARIATIONS DURING MILKING

It is claimed that the high-line system causes a greater degree of variability in vacuum at the teat cup and that this could be a contributing cause of mastitis. Unfortunately, the evidence is largely circumstantial, and as yet no direct evidence has been brought forward to support the contention.

While the vacuum level at the claw piece may be rather more variable with the high-line system in some instances, this is not a matter of direct concern, since it is the vacuum level inside the inflation which affects the teat, and this is largely determined by the movement of the inflation under the influence of the pulsation. The milk in the claw tube acts as a buffer in screening out the fluctuations in the claw. Again, the length of the dropper system in relation to the rate of pulsation will determine the extent of the major vacuum fluctuations in the claw, and there is no guarantee that any one low-line system is going to be better than any high-line system.

The relationship between vacuum variation generally and mastitis is itself only poorly understood. While there is field evidence associating low reserve air levels with mastitis incidence, this does little more than point the way to further research. The only clear experimental evidence implicating vacuum variation is the work of Cowhig and Nyhan (1967) which relates to a specific type of variation involving both the air line and the milk line.

Therefore, at this stage it is not possible to be specific as to which kind of variations are permitted and which are not. It may be that certain types of variation in relation to the pulsation waveform are in fact advantageous and to make major changes in plant design without sound evidence would seem to be unjustifiable.

If it can be shown that vacuum variation within the teat cup is of some significance in regard to mastitis infection, it would be more logical at first to attempt to overcome the difficulty by improving the design of existing systems. One such improvement has already been tried which holds considerable promise in other directions as well. A claw has been made which incorporates a no-return valve in each claw tube so that back-flow from the claw cannot take place. This has the effect of further screening the vacuum fluctuations in the plant from the cow, and at the same time reduces the risk of cross-infection to a very low level.

INSTALLATION AND LAYOUT

Vacuum Supply Line

The vacuum supply line to the plant between the vacuum tank and the milk receiver is very important to the vacuum control system. As seen in Fig. 1, it carries all the air flow from the plant in a normal installation. In the configuration shown, which is most common, it offers a common resistive path for the air flow from the air and milk lines, so that variations in vacuum occurring in either line are impressed on the other. As mentioned earlier, the only evidence (Cowhig and Nyhan, 1967) relating vacuum variation to mastitis, concerns variations involving both the air and milk systems simultaneously, as would be the case with a common resistive path shown. It would seem to be an advantage, on present evidence at least, to minimize this common coupling as much as possible.

In the high-line system, this is readily possible since the vacuum tank and milk receiver are usually close together, and if necessary a large diameter pipe can be used without undue cost. In the low-line system on the other hand,

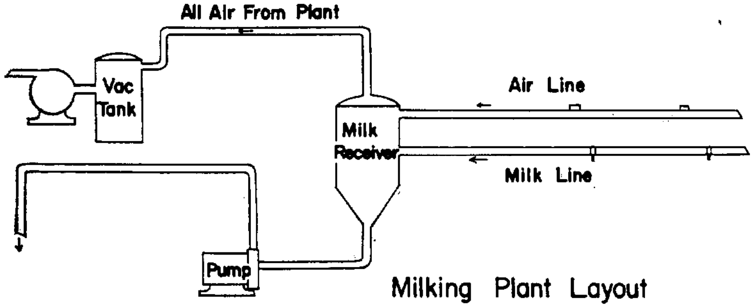

FIG. 1: *The pipe-line between milk receiver and vacuum tank forms a common resistive path for all air flow from the plant. Variations common to both pipe-lines are more pronounced when this pipe-line is long, as is the case with most low-line systems.*

the milk receiver is commonly placed in the herringbone pit, and a considerable length of piping separates it from the vacuum tank, usually with several right-angle bends.

INSTALLATION

The installation of the low-line system also presents problems not encountered in the high-line system. The pipe-lines are installed along the concrete pit wall, generally under the pit ledge. This makes attachment difficult, and does not allow flexibility of alignment which is a feature of the overhead mounting. At the same time, the limited space between pipe-lines and floor and the frequent need to install the pump system in the pit leads to added complications in installation and unnecessary complication of the piping system.

All of these things add to the cost of the system, and may impair its efficiency, unless considerable care is taken.

CLEANING

The low level placing of the pipe-line also presents difficulties in cleaning. The pipe-lines, pulsators and sight glasses are in a position where they are externally contaminated by dung, urine and wash water. At the same time, being below the pit ledge, they are not readily accessible and thus are rarely cleaned. It is inevitable that some of the liquid contaminants will seep into the seals and even the slightest air leak will cause it to gain entry to the pipe-lines.

The overhead mounting presents a relatively dry and clean location much more suited to the successful operation of pulsators and other equipment.

Draining of the pipe-line system also presents problems in the low-level installation, particularly where the milk receiver and pump are mounted in the pit.

The claim that the low-level installation in a doubled-up herringbone reduces the cost of the shed is hardly justified, in that in most instances an additional 1.8 m (6 ft) of shed length is needed to accommodate the milk pump in the pit. The high-line system avoids this, and, where doubling-up is considered advisable, will result in genuine savings in space.

CONCLUSION

The case for the low-line rather than the high-line system does not seem to be proved at all conclusively. Many of the claims made for its superiority appear to be of doubtful validity, and some of them are demonstrably incorrect. More detailed research work is clearly necessary before all the issues can be fully decided, but in the meantime there seems to be little to gain and perhaps much to lose by stampeding the industry into this system.

Clearly more information is required about vacuum variation and mastitis infection. Good facilities for this work exist at Ruakura and the techniques for investigation are at hand. More effort should be put into this field of investigation since it could afford an immediate gain, and at the same time provide some factual guide to the milking machine designer.

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