

# EFFECT OF VARIATION OF VACUUM LEVEL ON MILKING RATE OF AUSTRALIAN ILLAWARRA SHORTHORN COWS

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## SUMMARY

Increasing the vacuum level from 10 in. to 16 in. increased the maximum milking rate and the overall milking rate. The increase in maximum rate was slightly greater for faster milking cows than for slower milkers.

Considerable variation in milking rates was found between cows. Faster milkers milked faster at 10 in. than did slower milkers at 16 in. Rates are compared with those reported by other workers for other breeds of cows.

Neither the amount of strippings nor stripping time appeared to be related directly to vacuum level.

The vacuum at the teat-cups approached the unit vacuum only towards the end of the milking period. The teat-cup vacuum during the period of fastest milking showed little difference with milking vacuum levels of 12, 14 and 16 in. for the fastest milking cows.

## I. INTRODUCTION

In recent years considerable attention has been paid to the rate of milking of dairy cows, and several investigators in England, the United States and New Zealand have considered the effect of milking at different levels of vacuum. Smith and Petersen (1946) and Baxter, Clarke, Dodd, and Foot (1950) found that the rate of milking increased with increased vacuum. Gregoire, Mochrie, Elliot, and Spielman (1954) also reported that rates of flow appeared to be increased with an increase in vacuum level. Stewart and Schultz (1958) obtained similar results with randomly selected slow-milking cows. However, Whittlestone and Verrall (1947) working in New Zealand did not find any significant difference in the average milking rates of cows milked at 10, 14½ and 19 in. vacuum.

In order to obtain data on the milking rates of dairy cows under Queensland conditions, experiments were made using Australian Illawarra Shorthorn (A.I.S.) cows. These trials were conducted on the Atherton Tableland, at an altitude of 2,600 ft above sea level.

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## II. EXPERIMENTAL PROCEDURE

### (a) Cows Selected

The cows used in these trials were from a pure-bred A.I.S. commercial dairy herd. They were selected arbitrarily from those giving a fairly good yield of milk at the afternoon milking. The stage of lactation varied from 2½ months to 6 months. On the first occasion recordings were obtained from 11 cows, and in the second series 12 cows were milked.

### (b) Milking Methods

Milking was carried out using a "Ridd" milking machine fitted with "Alfa Laval" teat cups and pulsator. The "Swedish" synthetic inflations which were used were new at the beginning of the trials. This set of cups and inflations was used only on the occasions of test recordings. The pulsation rate was kept constant at 54 per minute, and at this rate the pulsator had a squeeze to release ratio of 30 : 70. This ratio was measured along the atmospheric pressure ordinate of the graph drawn by a "Ruakura" vacuum recorder. The air reserve of the 3-unit milking machine was checked, and it was maintained above the recommended level of 10–11 cu. ft. per min machine requirement (Phillips 1952).

A standard procedure was followed in preparing cows for milking. The udder was washed with warm water, then two squirts of foremilk were removed from each teat. The teat-cups were put on one minute after the start of washing.

### (c) Recording

A record of the milking process was obtained using the apparatus described by Murray (1960). Milk entered the bucket through a milk-flow indicator. Machine stripping was commenced when the sight-glass was half-full, which indicated that the rate of milk flow had dropped to approximately 0.7 lb per min. The cups were removed when the operator considered that no milk remained in the udder or teat sinuses. All cows were hand-stripped to check on the efficiency of machine stripping.

Records of milking rates were obtained at the afternoon's milking on consecutive days at 16, 14, 12 and 10 in. vacuum. Before the test recordings and at the morning milkings, the cows were milked at 15 in. vacuum.

Table 1

RESULTS OF 23 RECORDINGS ON 13 COWS AT EACH OF FOUR LEVELS OF VACUUM

—	Total Weight of Milk (lb)				Total Milking Time (min)				Percentage Strippings				Stripping Time (min)				Maximum Rate (lb per min)				Overall Rate (lb per min)							
	10	12	14	16	10	12	14	16	10	12	14	16	10	12	14	16	10	12	14	16	10	12	14	16				
Cow—																												
1	13 $\frac{3}{4}$	16 $\frac{1}{2}$	13 $\frac{3}{4}$	17	4.0	4.5	3.4	4.1	11.0	15.3	21.8	8.8	0.9	1.2	1.2	0.8	4.7	5.0	6.0	6.2	3.4	3.7	4.0	4.1				
1	15 $\frac{3}{4}$	16 $\frac{1}{4}$	16	14	4.8	4.3	4.1	3.3	19.0	12.3	10.9	7.1	1.2	0.8	0.9	0.3	4.2	5.0	5.7	6.5	3.3	3.8	3.9	4.2				
2	15	15 $\frac{1}{4}$	16	16 $\frac{1}{2}$	4.3	3.8	3.9	3.6	6.7	9.8	7.8	4.5	0.5	0.7	0.7	0.4	4.7	5.2	4.7	5.7	3.5	4.0	4.1	4.6				
2	15 $\frac{1}{2}$	12 $\frac{1}{2}$	12 $\frac{3}{4}$	13	4.3	3.4	3.5	2.9	18.1	10.0	14.0	5.8	0.8	0.5	0.8	0.5	5.2	5.0	5.5	6.5	3.5	3.7	3.6	4.5				
3	14	16 $\frac{1}{2}$	14 $\frac{3}{4}$	18 $\frac{1}{2}$	5.1	4.8	3.9	4.3	8.9	6.1	10.1	13.5	0.7	0.4	0.7	1.0	3.2	3.7	4.7	6.0	2.7	3.4	3.8	4.3				
4	11	9 $\frac{1}{2}$	12	11 $\frac{1}{4}$	3.8	2.8	3.1	2.7	9.1	2.5	2.1	4.4	0.3	0.1	0.3	0.2	3.0	4.2	5.0	5.2	2.9	3.4	3.9	4.2				
5	15 $\frac{1}{2}$	15 $\frac{1}{2}$	16 $\frac{3}{4}$	15 $\frac{1}{4}$	5.4	4.7	4.1	3.9	13.1	8.1	1.6	1.6	1.0	0.7	0.3	0.2	3.5	4.5	5.2	5.5	2.8	3.3	4.1	3.9				
5	14	15 $\frac{1}{2}$	16 $\frac{3}{4}$	15 $\frac{1}{4}$	5.3	5.0	4.4	3.5	12.5	6.5	3.1	1.6	0.7	0.3	0.3	0.2	3.0	3.7	4.2	5.5	2.6	3.1	3.8	4.3				
6	15	17 $\frac{1}{2}$	16 $\frac{3}{4}$	17 $\frac{1}{4}$	4.9	5.0	4.0	3.9	11.7	8.6	10.4	7.2	0.6	0.6	0.6	0.6	4.5	4.2	5.0	5.0	3.1	3.5	4.2	4.4				
6	16	17	16 $\frac{1}{4}$	13 $\frac{1}{2}$	6.0	5.0	4.3	3.2	20.2	13.2	6.2	5.6	1.0	0.8	0.6	0.2	2.7	4.2	4.7	5.2	2.7	3.4	3.8	4.2				
7	15 $\frac{1}{2}$	16 $\frac{1}{2}$	17	15	5.2	4.8	4.9	4.3	9.7	13.5	11.7	13.3	0.7	0.6	0.8	1.0	4.0	3.7	4.2	5.0	3.0	3.4	3.5	3.5				
7	15 $\frac{1}{4}$	17	17 $\frac{1}{2}$	16 $\frac{1}{4}$	5.6	5.4	5.6	4.4	21.3	17.6	12.9	15.4	1.0	0.9	1.2	0.8	3.2	3.7	4.2	5.2	2.7	3.1	3.1	3.7				
8	12	12	12	14 $\frac{3}{4}$	5.1	4.2	4.2	4.3	10.4	14.5	18.8	13.5	0.5	0.7	1.0	0.9	2.7	3.2	3.7	5.0	2.4	2.9	2.9	3.4				
8	11	14 $\frac{1}{2}$	11 $\frac{1}{2}$	15	5.2	5.4	4.0	4.8	27.3	13.8	8.8	11.7	1.2	0.8	0.7	1.0	2.5	3.2	3.7	4.5	2.1	2.7	2.9	3.1				
9	13	11 $\frac{1}{2}$	12 $\frac{1}{2}$	13	5.4	4.3	3.9	4.2	21.2	15.3	20.0	15.4	1.0	0.6	0.9	0.9	2.7	3.0	4.0	4.5	2.4	2.7	3.2	3.1				
9	14	13 $\frac{3}{4}$	13 $\frac{1}{4}$	13 $\frac{1}{4}$	5.2	4.1	4.2	3.2	10.7	9.1	15.1	11.3	0.7	0.4	0.9	0.7	3.5	4.0	4.5	5.7	2.7	3.4	3.2	4.1				
10	12	12 $\frac{1}{4}$	10 $\frac{1}{2}$	10 $\frac{1}{2}$	4.8	3.9	3.8	2.8	4.2	4.2	10.3	4.8	0.2	0.4	0.8	0.3	3.0	3.7	4.0	5.0	2.5	3.1	3.2	3.8				
11	9 $\frac{3}{4}$	12	12 $\frac{1}{4}$	13	4.5	5.1	4.5	4.5	20.5	10.4	16.3	9.6	0.8	0.4	0.6	0.7	2.5	2.5	3.2	3.5	2.2	2.4	2.7	2.9				
11	10	12	15 $\frac{1}{4}$	11 $\frac{1}{2}$	5.8	5.4	5.5	4.2	20.0	6.3	18.0	4.3	0.9	0.4	1.3	0.2	2.0	2.5	3.5	3.5	1.7	2.2	2.8	2.7				
12	9 $\frac{1}{4}$	16	15	13 $\frac{3}{4}$	5.4	6.0	5.5	4.8	13.5	6.3	20.0	16.4	0.6	0.5	1.2	1.2	2.5	2.7	3.2	3.5	1.7	2.7	2.7	2.9				
12	12 $\frac{3}{4}$	14 $\frac{3}{4}$	15	12 $\frac{3}{4}$	7.0	5.8	5.8	4.3	17.6	15.4	10.0	3.9	1.1	1.0	0.9	0.4	2.0	3.0	3.0	3.7	1.8	2.5	2.6	3.0				
13	11 $\frac{1}{4}$	14 $\frac{1}{4}$	15 $\frac{3}{4}$	12 $\frac{3}{4}$	6.2	6.3	6.0	4.3	13.3	19.3	11.1	9.8	0.8	1.1	0.7	0.6	2.2	2.5	3.2	3.5	1.8	2.3	2.6	3.0				
13	14	14	13	14 $\frac{1}{2}$	7.5	6.2	5.0	4.6	16.1	16.1	11.5	6.9	1.0	1.1	0.8	0.4	2.0	2.5	3.2	4.0	1.9	2.3	2.6	3.2				
Average	13 $\frac{1}{4}$	14 $\frac{1}{2}$	14 $\frac{1}{2}$	14 $\frac{1}{4}$	5.25	4.79	4.42	3.92	14.6	11.1	11.9	8.5	0.79	0.65	0.80	0.59	3.20	3.69	4.27	4.93	2.67	3.09	3.36	3.70				

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#### (d) Data Obtained

Visual inspection of the milk flow curves showed differences in milking rates between cows and between the different treatments. So that these differences could be evaluated the following data were obtained:

Total weight of milk.

Total milking time.

Maximum milking rate over any half-minute.

Overall milking rate obtained from total yield divided by total time.

Strippings expressed as a percentage of total yield.

During these trials records were also obtained of the vacuum at the teat-cups during the milking process and at the beginning of machine stripping.

### III. RESULTS

The results for 23 recordings on 13 cows at each of the four levels of vacuum are shown in Table 1.

#### (a) Variation Between Cows

The figures obtained show that there was a wide variation between the milking rates of these cows under similar conditions. For example, the maximum milking rate at 16 in. varied from 3.5 to 6.5 lb per min, and at 10 in. from 2.0 to 5.2 lb per min.

The range of values for the overall rate showed similar variations, from 2.7 to 4.6 lb per min at 16 in., and from 1.7 to 3.5 lb per min at 10 in.

#### (b) Vacuum Level and Milking Rates

Decreasing the vacuum level from 16 in. to 10 in. caused a progressive decline in the maximum milking rate and the overall rate. The trends in milking rates for each individual cow were the same as for the averages of the 23 tests. The average results of these trends are shown graphically in Figure 1. It can be seen that the effect of vacuum level was slightly greater on maximum milking rate than on overall rate where machine stripping is included.

In Table 2, the average milking rates for 6 tests on faster milkers and 6 tests on slower milkers are shown for each vacuum level. The differences in milking rate between the faster and the slower milkers at any vacuum level were greater than the differences in milking rate at the 10 in. and 16 in. vacuum for each group. The faster milking cows milked more rapidly at 10 in. than the slower cows did at 16 in. The increase in maximum rate as the vacuum level increased was slightly greater for the faster than for the slower milking cows but the increase in overall rates was the same for both groups.

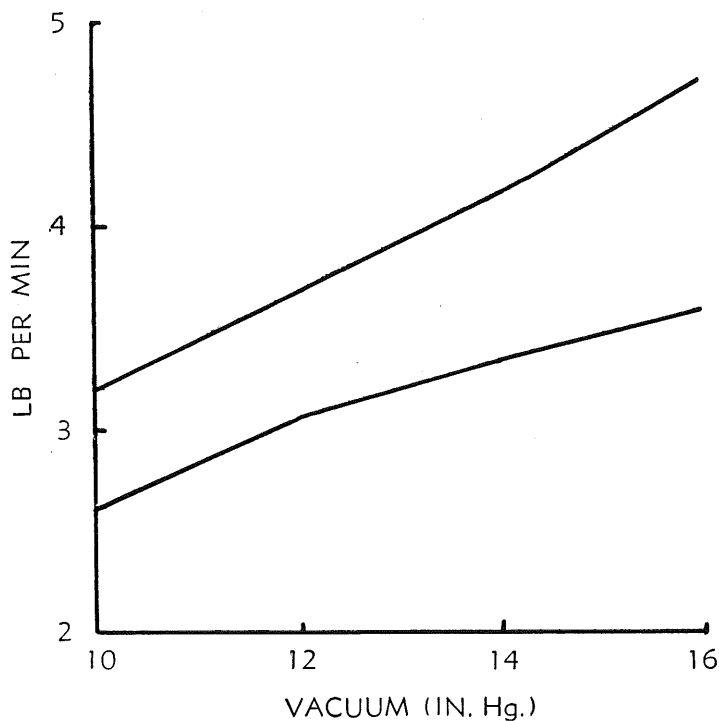


Fig. 1.—Average values for milking rates at four vacuum levels.

**Table 2**

AVERAGE MILKING RATES FOR 6 TESTS ON FAST MILKERS, AND 6 TESTS ON SLOW MILKERS AT FOUR VACUUM LEVELS

Vacuum Level (in. Hg)	Maximum Rate (lb/min)		Overall Rate (lb/min)	
	Fast Cows	Slow Cows	Fast Cows	Slow Cows
16 ..	6.0	3.6	4.3	3.0
14 ..	5.3	3.2	3.9	2.7
12 ..	4.7	2.6	3.7	2.4
10 ..	4.2	2.2	3.2	1.9

### (c) Yield of Strippings and Stripping Time

The amount of strippings expressed as a percentage of the total yield is shown in Table 1. The average percentage was 14.6 at 10 in., 11.1 at 12 in., 11.9 at 14 in. and 8.5 at 16 in. vacuum. There was no indication in these results of any increase in the amount of strippings at the higher vacuum levels. The largest average amount of strippings was found at the 10 in. level.

There was little difference in the times for machine stripping at the different vacuum levels. The average stripping time was least at the 16 in. vacuum when the smallest amount of strippings was obtained.

#### (d) Vacuum at Teat Assembly

During the trials a vacuum gauge was attached to the milk claw rubber as close as possible to the teat-cup. Vacuum readings at this point were recorded at intervals throughout the milking and just before the beginning of machine stripping. There was regular oscillation of 1–2 in. in the reading on this gauge, caused by the pulsation in the teat-cups.

The readings obtained in trials with 11 cows milked at four different vacuum levels are set out in Table 3. There was a tendency for the teat-cup vacuum to be lower with a faster rate of milk flow. The vacuum readings taken at the time of maximum rate of milk flow were the lowest throughout the milking. As the end-point of machine milking was approached, and the rate of milk flow decreased, the teat-cup vacuum rose slightly until just before machine stripping, when it was 1–3 in. lower than the vacuum being applied to the unit.

### IV. DISCUSSION

There were significant increases in the maximum milking rate with increasing vacuum, thus showing that the results obtained by Smith and Petersen (1946), Baxter *et al.* (1950), Gregoire *et al.* (1954) and Stewart and Schultz (1958) for various breeds applied also to A.I.S. cows in Queensland.

Stewart and Schultz reported that there was a greater increase in maximum rate between 10 in. and 12·5 in. than between 12·5 in. and 15 in. In contrast, the greatest increase occurred between 14 in. and 16 in. in this study.

Baxter *et al.* (1950) failed to obtain an increase in overall rate of flow as they increased the vacuum from 11 to 20 in., owing to the longer time necessary to remove the larger amounts of strippings at the higher vacuum levels. In these trials the overall rates increased with increasing vacuum and there was no indication of larger amounts of strippings at higher vacuum levels. A similar result was obtained by Stewart and Schultz (1958).

Several workers have reported wide variation in milking rates between cows when large numbers of animals of different breeds have been examined. Beck, Fryer, and Atkeson (1951) examined 102 cows of the Ayrshire, Guernsey, Holstein and Jersey breeds. At 15 in. vacuum, maximum milking rates varied from 3·4 to 12·8 lb per min. Stewart, Schultz, and Coker (1957), in an examination of 286 cows at 12·5 in., found an even greater range of values for maximum milking rate (1·3 to 14 lb per min), and Dodd (1953) quoted maximum rates varying from 1·00 to 10·40 lb per min. The variation between the small number of cows in the present trials was not as great as reported by the above workers. The actual milking rates tended to be lower than those quoted by the American workers but were comparable to the centre of the

**Table 3**

VACUUM READING AT TEAT-CUPS AT TIME OF FASTEST MILKING AND JUST BEFORE MACHINE STRIPPING

Cow	Milking Vacuum (in. Hg)											
	16 in.			14 in.			12 in.			10 in.		
	Max. Milking Rate (lb/min)	Teat-cup Vacuum at Time of Max. Rate	Teat-cup Vacuum at Stripping	Max. Milking Rate (lb/min)	Teat-cup Vacuum at Time of Max. Rate	Teat-cup Vacuum at Stripping	Max. Milking Rate (lb/min)	Teat-cup Vacuum at Time of Max. Rate	Teat-cup Vacuum at Stripping	Max. Milking Rate (lb/min)	Teat-cup Vacuum at Time of Max. Rate	Teat-cup Vacuum at Stripping
1	6.2	11	14	6.0	10	12	5.0	9	9	4.7	7	8
2	5.7	10	15	4.7	10	12	5.2	9	9	4.7	8	8.5
3	6.0	10	13	4.7	10.5	13	3.7	9	10	3.2	8	8.5
5	5.5	9	13	5.2	10.5	13	4.5	9	10	3.5	8.5	9
6	5.0	11	14	5.0	11	13	4.2	9	9	4.5	8.5	9
7	5.0	11	14	4.2	11	12	3.7	9	9	4.0	8.5	9
8	5.0	12	15	3.7	11	12	3.2	10	10	2.7	9	9
9	4.5	13	15	4.0	11	12	3.0	10	10	2.7	9	10
11	3.5	13	15	3.2	12	13	2.5	10	10	2.5	9	9
12	3.5	13	14	3.2	12	12	2.7	10	10	2.5	9	9
13	3.5	13	15	3.2	12	13	2.5	10	10	2.2	9	9

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range reported by Dodd. The mean value for maximum rate in these trials was 4.93 lb per min, compared with a mean of 4.96 lb found by Dodd. Whittlestone and Verrall (1947) reported an average value for the overall milking rate of 2.64 lb per min at 15 in. vacuum. The comparable figure in the present study was 3.70 lb per min at 16 in., showing that this batch of cows milked faster than those tested by Whittlestone and Verrall.

Smith and Petersen (1946) and Baxter *et al.* (1950) found larger amounts of strippings at higher vacuum levels, and concluded that this was due to teat-cup crawl at the higher vacuum. There was no evidence of this effect in the present work at the vacuum levels used. Gregoire *et al.* (1954) suggested that 13 in. vacuum appeared to give more efficient milking, since the mean stripping time and the mean amount of strippings were lower than for 10 in. and 17 in. groups, and Stewart and Schultz (1958) found less strippings at 12.5 in. than at 15 in., although the stripping time remained the same. The least amount of strippings was actually found at 16 in. in these trials, suggesting that more efficient milking was obtained at this higher vacuum level.

Baxter *et al.* (1950) and Stewart and Schultz (1958) noted that the faster milking cows had a greater increase in maximum rate of flow as the vacuum increased than did the slower milking cows. Similar results were noted in the present work although the increases in the overall rate were about the same for both groups of cows.

Generally there was no difficulty in milking at 10 in. vacuum, although there was a tendency with some cows for the teat-cups to fall off.

Observations made on the level of negative pressure near the teat-cups showed that, during milking, this vacuum was considerably lower than the line vacuum, and that only when the rate of milk flow became very low did the vacuum level become nearly equal to that of the unit. This finding is in line with the effect noted by Petersen (1944) on vacuum in the teat. He stated that when milk flows freely into the teat there is no detectable vacuum in the teat sinus, but that when teat-cup crawl has closed the passage between udder and teat, the vacuum within the teat becomes identical with that in the milk-line. In the present work the vacuum at the teat-cups was lower during the period of maximum milking rate for the faster milkers than for the slower milkers. For the faster milking cows there was little difference in teat-cup vacuum when milking was carried out at 16, 14 and 12 in. vacuum. The possibility of greater udder injury at higher vacuum levels would therefore apply only if the teat-cups were left on the cow after milk-flow ceases.

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## REFERENCES

- BAXTER, E. S., CLARKE, P. M., DODD, F. H., and FOOT, A. S. (1950).—Factors affecting the rate of machine milking. *J. Dairy Res.* 17: 117-27.
- BECK, G. H., FRYER, H. C., and ATKESON, F. W. (1951).—Variation in the response of dairy cows to a standard method of machine milking. *J. Dairy Sci.* 34: 589-605.
- DODD, F. H. (1953).—Normal variations in the rate of machine milking. *J. Dairy Res.* 20:301-18.
- GREGOIRE, A. T., MOCHRIE, R. D., ELLIOT, J. I., SPIELMAN, A. A., and BEALL, G. (1954).—Effect of vacuum level and milking duration on milk production, milking time, and rate of milk flow in mastitis-free first calf heifers. *J. Dairy Sci.* 37: 276-83.
- MURRAY, A. J. W. (1960).—Apparatus for recording milk flow curves of cows milked by machines. *Qd J. Agric. Sci.* 17: 147-53.
- PETERSEN, W. E. (1944).—Action of the mechanical milker in relation to completeness of milking and udder injury. *J. Dairy Sci.* 27: 433-40.
- PHILLIPS, D. S. M. (1952).—In "Proceedings of Ruakura Farmers' Conference Week". (New Zealand Department of Agriculture: Wellington.)
- SMITH, V. R., and PETERSEN, W. E. (1946).—The effect of increasing the level of negative pressure and widening the vacuum-release ratio on the rate of removal of milk from the udder. *J. Dairy Sci.* 29: 45-53.
- STEWART, W. E., SCHULTZ, L. H., and COKER, S. P. (1957).—Studies on the rate of machine milking of dairy cows. I. Normal variations. *J. Dairy Sci.* 40: 258-63.
- STEWART, W. E., and SCHULTZ, L. H. (1958).—Rate of machine milking of dairy cows. II. Effect of vacuum and pulsation rate. *J. Dairy Sci.* 41: 849-56.
- WHITTLESTONE, W. G., and VERRALL, S. A. (1947).—The influence of certain milking-machine adjustments on the rate of machine-milking. *N.Z. J. Sci. Tech.* A28: 406-16.

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