finds that the ovaries of stilbestrol injected cows are atrophic. There was no sign of normal follicular development, let alone cystic follicles.

Reply: We have not had stilbestrol treated cows in continuous estrus, but where a number of responsive animals were being injected at the same time there rarely seemed to be a day on which no cow was in heat. In view of the varied experiences at the Dairy Research Institute and at Ruakura, it appears that animals may vary widely in their response. All injections at the Institute were given using stilbestrol dissolved in a very small quantity of peanut oil. We have examined only a few of the ovaries from animals that have been injected, and in no case have we found cystic follicles. Theoretically we might expect to find the condition found by Mrs. Bassett, as it has been shown in a large variety of animals that injection of estrogen suppresses the gonadotrophic F.S.H. hormone of the pituitary.

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A NEW TECHNIQUE FOR THE STUDY OF MILK EJECTION IN THE DAIRY COW.

by

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In the problem of studying the way in which dairy cows eject their milk under normal practical conditions we have an illustration of a difficulty in all scientific experiments, namely, the difficulty of making accurate observations without affecting the object observed. The dairy cow is something more than a group of biochemical reactions and anything which displeases or frightens her completely upsets the results of experiments on any aspect of her behaviour which involves nervous reflexes. When, therefore, we undertook to construct apparatus which would faithfully record the rate at which milk flowed from a cow under varying conditions, it was necessary that the apparatus should, firstly, have no immediate effect on the action of the milking machine, secondly, should not alter the shed routine, thirdly, should not require the presence of a stranger in the shed. These demands together with the type of physical conditions encountered in a cow shed, e.g. the presence of much water, meant that some kind of tele-recording apparatus was required. Such an apparatus has been constructed at Wallaceville and has given dependable service for some months. The basic principles of the apparatus are as follows:-

The Transmitter: This consists of a tinned copper cylinder to which is attached a bakelite measuring cylinder of small diameter (actually 2") the latter being fitted with a spiral of fifty metal contacts and a centre cylindrical electrode. By the use of a multi-port valve specially constructed for this work the main cylinder may be connected via a lead from the top to the milk pipe of the milking machine or via a lead from the bottom also to the milk pipe, the top lead being simultaneously opened to the air when this connection is made. A separate pipe with froth trap connects the cylinder to the teat cups via a dropper tube. The valve controlling the unit is fitted with electric contacts which operate indicator lamps on the recording unit. The bottom of the dropper tube is fitted with a small rubber diaphragm operating a switch which is closed when the vacuum is applied.

The Recorder: The basis of this instrument is a 25 outlet automatic telephone uni-selector switch altered to run as a 50-outlet switch. The 50 contacts on the measuring cylinder are connected by a 25 pair lead-covered telephone cable to the 50 contacts of the uni- selector. The latter is controlled by a gas tube relay system and a mechanical impulse making rotary switch so that depending on the position of a controlling switch it will search either for an open contact or for a closed one.

The uni-selector is connected to a cylinder to which paper is fitted. The cylinder rotates once as the selector covers 50 contacts. This gives the volume axis of the graph.

The time-base is a threaded rod driven by a small synchronous motor controlled through a relay by the vacuum switch on the dropper. This thread drives a pen across the paper, supplying the time base, and also accurately records the actual times the cups are on the cows.

Method of Operation: The following is the procedure when making milk flow graphs. A sheet of paper is fitted to the machine and the pen put in the writing position. By means of a small switch an indicator lamp in the shed is turned on letting the cow-man know that the apparatus is ready to run. As soon as the cups are applied the time-base starts. The uni-selector (set to search for open contacts) rotates the recording drum as the milk rises in the measuring cylinder due to the following action. The rising milk shortcircuits a stud in the cylinder to earth causing a gas tube relay to close a contact supplying the uni-selector energising coil. The selector promptly steps to the next contact which, being open, causes the current to the energising coil to be cut off. This process continues until the cow is milked out. The cow-man then removes the cups, so stopping the time-base and turns the control valve which causes the main cylinder to drain into the milk pipe. This operation is indicated at the recorder whose operator switches the uni-selector into the position in which it hunts for the first closed contact. This means that it runs right round coming to rest on the lowest stud which is always under milk, the draining tube being set at a level above the lowest contact. While another cow is being brought in and the cylinder drained the paper on the recorder is changed and the time base set to zero. When the control valve is turned to the "run" position the uni-selector is switched back to the "operate" position when it promptly seeks out the first open contact and stops. This ensures that the pen always starts at the real zero regardless of possible errors due to careless draining on the part of the cow-man. The application of the cups start the time-base and the cycle is repeated.

The present apparatus while satisfactory can be greatly improved and a new model using an improved measuring cylinder and a shield grid thyratron operated relay is under construction. It is hoped to develop the new method, which requires less apparatus, into a portable form. The new apparatus will be entirely automatic. That is, it will continuously feed out a strip of paper with the graphs drawn on it, the whole of the controlling gear being operated by a multiple relay controlled by the vacuum at the cups. Further, the new apparatus will eliminate the need for the clumsy 25 pair telephone cable.

One interesting by-product of this project has been the design of a device which can draw a graph of the first differential of the volume-time curve. Again the versatile uni-selector switch is used.

THE RESULTS OF SOME PRELIMINARY EXPERIMENTS

The following experiments had to be started after the dairy season was well advanced and therefore suffer from the fact that in most cases the results were obtained from cows in the latter half of their lactation periods. However, many interesting and practical results have been observed.

RATE OF MILK EJECTION UNDER NORMAL SHED CONDITIONS

The milk ejection curve.

Figure 1 illustrates four milk flow curves just as they come from the recording unit. Curve A. is an excellent sample, B is a case of a cow which is slow starting and "strippy". C. is a case of a poor milker and in this case the cups were left on too long. D. illustrates the effect of a fright on the milking rate of a nervous cow.

The milk flow curve may be divided into three portions: (a) The starting phase. (b) The main flow phase. (c) The stripping phase. Sections (a) and (c) should be at a minimum while the gradient of (b) should be as great as possible. The last horizontal line represents the time the cups have been left on the cow after the last unit of milk has been drawn.

Each unit represents .235 lbs. of milk.

A set of milk flow curves for cows milked under normal conditions has been analysed. The conditions of the test were as follows:-

Vacuum	15"	
Pulsator Rate	45.	
Pulsator Ratio	40:60	(Except in experiment started on 24.2.44. which will be described later.)

Soft 7/8 by 3/32 inflations slackened between milkings and tightened weekly.
No stripping.
No starting; teats washed and cups applied immediately.

The accompanying tables set out the results and the following notes explain the tables:-

W = The total weight of milk produced in pounds.

T = The time taken to yield the last unit of milk drawn. The actual time the cups are on the cow is longer than this in all cases. The figure given depends on the milking out of the cow and not the efficiency of the man in the shed.

$T_{.9W}$ = The time taken to yield 0.9 of the total milk drawn.

W/T = The average milking rate in lbs./min.

$T_{.9W}/T$ = A factor indicating the departure from linearity of the curves. A linear relationship between W and T will, of course, give a $T_{.9W}/T$ ratio of 0.9. Holding of the milk at the beginning and a decrease in gradient at the end of the curves causes this ratio to depart from 0.9.

One interesting feature of the results is the short time taken by the cows to give 90 per cent. of their milk. None exceeds 4.0 minutes. The form of the curve given indicates the difference between a good milker and a "strippy" cow. Where there is a "foot" due to slow starting and a region of low gradient at the end we have the chief bad features illustrated.

<u>The Efficiency of the Shed Workers</u>: In the Wallaceville shed it is customary, as it is on most farms, to judge the end of milking by the temperature of the milk droppers. The accompanying table sets out figures indicating the efficiency of the process.

T' - The actual time the cups are on the cows. This is recorded automatically by the machine. Obviously the nearer the ratio T/T' is to 1 the more efficient the milker. The average figure of 0.84 indicates that with some more effective way of determining the end of milking quite a fair percentage of time could be saved.

<u>General</u>: The average rate of milking (W/T) is very small. One of the fastest milking cows, "Faith" which was recorded during her flush produced a flow rate of 5.86 lbs. of milk/minute. This would indicate that the machine is capable of handling milk at a faster rate than the cows will deliver it. There is a marked tendency for several cows to approach a flow rate of 3.6 lbs./ minute. This is seen in the case of "Ada" and is found to hold for several others. It will be interesting to find how this flow rate varies with vacuum.

The tables give the average figures for seven tests spread over one month.

Cow	W.	T.	$T_{\cdot 9W}$	W/T
Cis.	5.7	3.9	2.7	1.5
Dina	4.6	5.5	3.9	0.8
9.	3.6	4.7	3.3	0.8
5.	4.1	5.0	3.4	0.8
Ada	9.8	5.5	3.1	1.8
Dawn	5.7	5.4	3.3	1.1
Chloe	7.1	5.8	3.9	1.2
11.	5.9	4.3	2.9	1.4
Means -	5.8	5.0	3.3	1.2

Cow.	$T_{\cdot 9W}/T$	T/T'
Cis	.69	.76
Dina	.71	.84
9.	.70	.82
5.	.68	.90
Ada	.56	.89
Dawn	.61	.85
Chloe	.67	.84
11.	.67	.80
Means =	.66	.84

<u>AN EXPERIMENT TO DETERMINE THE EFFECT OF THE STIMULUS APPLIED TO THE TEAT OF A COW BY THE MILKING MACHINE ON THE RATE OF MILKING:</u>

<u>Methods</u>: The rate of milking and other factors associated with the efficiency of milk ejection were determined by means of the milk flow measuring apparatus previously described. The total weight of milk obtained (W) and the time taken to deliver the last increment of milk as shown by the milk flow graph (T) were read off from the latter and the average flow rate (W/T) determined. This figure is a convenient figure of merit as it rises for cows showing short starting periods and short stripping time while it falls with cows which are slow starting and/or "stripping".

The stimulus was controlled by a special pulsator arrangement which could be caused to alter from a normal pulsation to a very short "squeeze" by simply moving a lever in the bail. The two stimuli used are shown in the accompanying graph showing pulsator vacuum plotted against time. The curve (N) is a normal one while (S) is exceptionally short, the pulsator valve not being open long enough to permit the pulsator chambers of the cups to come to atmospheric pressure. The effect on the cows' teats is, of course, in the case of the normal curve to give a strong definite "Squeeze" while in the case of the short squeeze curve we have the application of a squeeze of only one-half the normal force for about one-fifth of the normal time - a much smaller stimulus than any likely to be met in practice.

The teat cups used in the experiment were "Ideal" telescopic cups fitted with Reid standard grey inflations which were released between milkings and kept at uniform tension during use. The pulsator ran at a rate of 45 pulsations per minute and the vacuum in the machine was 15". The cows were milked in a definite order, there was no "starting" other than that associated with the washing of the teats immediately prior to the application of the cups and no weights were applied to the claws or the cups pulled in any way after milking was complete.

The experiment was run in three consecutive periods. The first period (28 days) consisted of a run with normal pulsation for all cows in the experiment under the conditions outlined. During period 2 (24 days) one-half of the cows were milked with a short squeeze, the remainder normally. During period 3 (28days) the position was reversed. The cows were paired for the second and third period according to their milk flow curves as obtained during the preliminary control period.

Results: The results of the experiment are set out in the accompanying table and set of milk flow curves. All are taken at afternoon milkings. The table gives W, T, W/T, and the difference between the values of W/T found for the pairs of cows. During the control period (1) the mean difference between the two groups was + 0.02 (for the mean value of N - S as divided for period 2). The mean differences for the two experimental periods were - 0.01 and + 0.096 (S - N as taken in period 2). These differences are not significant. The larger difference in period 3 is due to the mismatch of two pairs - Ada-Chloe and Dawn-5. These cows are not drying off at the same rate and therefore show increasingly wide differences which are unrelated to the experiment. Despite this fact there is no significant difference between the average milking rates for the two groups.

The graphs give much more information than the tables. The arrows mark the beginnings of the experimental periods and the sets of curves are given in the order in which the related data appear in the table.

1. Ada and Chloe. These two cows are the best milkers of the group. Chloe's reactions when compelled to alter her usual milking procedure and enter a new bail are interesting. Her first curve shows a very slow and unsatisfactory milking rate. In neither case is there any marked change when the pulsator is changed. The effect of the end of the lactation period is seen clearly in the case of Chloe. The milk flow rate falls as the total amount of milk falls. This means that the milking time does not get shorter as the yield falls off.

2. <u>9 and Dina</u>. There is a great variation in the flow graphs of these cows but again there is little difference between the normal and short squeeze groups. The change from normal to short squeeze with Dina shows an abnormal curve which quickly rights itself. The extraordinary variations within one group for one particular cow are undoubtedly contributed to by the fact that the animals are used for other experiments. For instance, it has been noted that on the day when the cows have been bled for another experiment the milk flow curves are far from typical. However, these effects apply to both groups and do not invalidate the general results of the experiment. The effect of advancing lactation is clearly seen in these curves.

3. <u>5 and Dawn</u>. With both of these cows the change from normal to short squeeze has the effect of delaying "letting down" and in the case of Dawn there is a poor milk yield on the day of the change. Apparently the effect does not last as the next test gives a normal curve in both cases. The psychological effect of the strange pulsation is probably the factor. As soon as the cow is used to the effect normal milking is resumed. In this case the cow adjusted itself in a few days. These cows are not matched with respect to stage of lactation. The effect is shown clearly by the curves.

4. <u>Cis and 11.</u> In the case of this pair the change from normal to short squeeze for Cis was accompanied by a record milking and the converse change, with an abnormally low yield. However, in neither case was the shape of the curve altered. Any differences between the periods in this group are certainly not significant.

Generally, it may be said that there is no difference between the milking rate of a group of cows milked with a normal pulsator and of a group milked with a pulsator giving a very short light "squeeze" phase.

This conclusion led us to examine the behaviour of a group of cows milked with the normal pulsation applied at different times throughout the milking period.

Graphs 5 and 6 show the effect of starting milking with the pulsator running then shutting it off after 1.6 minutes. The left hand curves are controls taken on the previous day. "P" indicates the pulsation period, "N.P." the period when the vacuum behind the inflations was steady. In neither case is there any effect shown in the graph. It should, however, be noted that most cows show some symptoms of discomfort when the pulsator has been stopped for some time.

<u>Graph 7</u>. In this case the pulsator was running for 0.7 minutes when it was shut off. The milk flow curve flattened to rise again when the pulsator was started again. This may be due to the cow not having let down her milk when the pulsator was turned off.

<u>Graph 8</u>. The pulsator ran for 1.3 minutes in this case before being stopped. It was started again when the curve started to flatten. As can be seen the curve is a normal one.

Graph 9. In this case the pulsator ran 1.2 minutes. When the milk flow had ceased the stimulus was again applied. The dotted portion of the curve represented the period during which there was no milk flow. Recommencement of pulsation had no effect.

<u>Graph 10</u>. This cow was treated as for graph 9 except that pulsation was applied when the curve started to flatten. Again there is no significant effect except that the cow's annoyance was expressed more actively than in previous cases.

Graph 11. The left hand graph is, as in previous cows, the control taken the previous day. The right hand curve is the result of attempting to milk the cow with no pulsation. The cups were kicked off several times and the cow showed the greatest annoyance. At the point marked by the arrow the pulsation was applied. Nothing happened as apperently the cow was completely upset. An attempt to carry out this experiment on another cow caused even more trouble so the experiment was discontinued.

It should be noted that graphs 5, 6 and 9 were taken on cows to which the short squeeze pulsation was applied during the main experiment; the remainder were in the normal group.

The experiment demonstrated, firstly that no pulsation applied to the teat cups caused such acute discomfort to the cow that the milk is not "let down"; secondly, that if the pulsator is operated long enough to cause the milk to be let down the flow curve remains normal when the pulsator is shut off after 1-2 minutes.

It would appear, in the light of the above experiments, that, provided there is enough mechanical action of the inflation to give a stimulus of some kind to the teat, cows will milk normally. Further, it appears that once the milk has been "let down" properly the cow milks normally. This point will be the subject of further experiments carried out with a view to determining whether the discomfort caused by no pulsation can under some circumstances cause a strong enough "fear reaction" to inhibit the "letting down" process in the middle of milking.

EXPERIMENTS ON THE HORMONAL CONTROL OF MILK EJECTION:

The object of the following experiment was to confirm the view of Petersen (J.D.S., XIV, 3, 211) that the factor controlling the rise in intramammary pressure associated with the "letting down" of the milk originates in the pituitary gland.

Method. Approximately 2 minutes before the application of the teat cups the animal was given intravenously 3 ml. of 1/1,000 adrenalin. The milking procedure was then carried on as usual with the flow recorder in operation. As soon as it was evident that the milk flow had stopped completely 4 ml. of "Infundin" posterior pituitary extract (10 units/ml.) were given intravenously.

Results. Graph 12 shows the milkflow curve for cow "Dawn" when treated as above. The curve on the left is the normal curve obtained the previous day. The arrow marks the point at which the pituitary extract was given.

Graph 13 shows the results of the same experiment on cow No. 11.

The following figures are of interest:-

Cow	Total Milk lbs.	Milk given before Pituitary Extract Injected	Percent given before "letting down"
Dawn	5.8	3.1	53
11.	4.7	1.4	30

There is no doubt from these results that the "letting down" process, artificially inhibited by adrenalin, is set in operation by posterior lobe pituitary extract. It may be considered that the volume of milk given after the action of adrenalin has taken place represents the volume of the milk cistern and larger ducts. This is the view of Hammond, Swett, Zumont and others working on this problem. This volume apparently varies greatly from cow to cow. Figures given by different workers range from 70 percent. (Swett, Miller and Graves (J. Agric. Res., 45, 385 and 401)) to 36 per cent. (Ragsdale, J.D.S., 7, 299). In the case of cow "Chloe" used for the "no pulsator" experiment (graph 11) we get a yield of 1.5 lbs. when milked without the "letting down" reflex being stimulated, while the yield on the previous day under normal conditions was 7.8 lbs. i.e. only about 19 per cent. of the milk was given without the normal stimulus.

THE INFLUENCE OF PULLING DOWN ON THE CUPS OF COWS AT THE END OF THE MACHINE MILKING PERIOD.

The following results were obtained on cows nearing the end of the lactation period. They are, therefore, not typical of normal milking but indicate the significance of the procedure of pulling down on the cups prior to letting the cow out of the bail when hand stripping is not practised.

The following table gives the total milk yielded and the amount given when the cups were pulled after normal milking had stopped, in actual weight and as a percentage.

Cow	Total Milk.	Milk Given on Pulling Down.	Per Cent.
Cis.	4.7	0	0
	5.0	0.5 (?)	10
Ada.	6.7	0.6	9
	7.0	0.9	13
Chloe	4.6	0.4	9
	3.4	0.7	21
Dawn	6.5	0.7	11
	-	-	
Dina	2.3	0.7	30
11.	2.9	1.7	59
	5.4	0.7	13
5.	3.2	0	0
	1.7	0.7	41
9.	2.2	0.7	32
		Average	19

As can be seen, the total yields are low and are typical only of end of the season conditions.

The milk flow graphs are reproduced on the accompanying sheet. The arrow indicates the point at which the cups were pulled. The point was judged by the cow-man by feeling the milk down dropper in the usual way. The response of the cows to this operation is variable and ranges from no effect to a very considerable effect. In the case of two cows on one day of the experiment it was necessary to pull down on the cups to start milking within a reasonable period. It appears that towards the end of the season the cows let their milk down more slowly than during the flush.

While the above experiments are not very satisfactory because of the variability of the cows at the end of the season they indicate the need for attention to the manipulation of the udder to ensure starting of the cows when the cups are put on and the pulling or otherwise handling the cups before their removal when hand stripping is not practised.

Date	Period	Group A. Cow	W.	T.	W/T	Group B Cow	W.	T.	W/T	W/T Differances. (N - S)
27.1.44)	1.	Ada.	8.5	6.1	1.4	Chloe	2.3	7.0	0.3	- 1.1
28.1.44)			9.4	6.3	1.5		6.0	5.8	1.0	- 0.5
1.2.44)			10.4	3.9	2.7					
8.2.44)			9.6	5.0	1.9		8.7	5.9	1.5	- 0.4
17.2.44)			9.4	5.4	1.7		9.3	5.8	1.6	- 0.1
21.2.44)			9.5	5.2	1.8		7.2	5.0	1.4	- 0.4
23.2.44)			11.0	5.9	1.9		7.9	6.0	1.3	- 0.6
				S.				N.		
24.2.44)	2.		9.9	6.2	1.6		8.5	5.4	1.6	0.0
28.2.44)			10.1	4.5	2.2		9.0	7.7	1.2	- 1.0
3.3.44)			7.9	4.6	1.7		6.5	5.4	1.2	- 0.5
9.3.44)			7.9	4.9	1.6		7.6	7.3	1.0	- 0.6
16.3.44)			6.4	4.4	1.5		7.8	5.3	1.5	0.0
				N.				S.		
17.3.44)	3.		8.7	5.8	1.5					
21.3.44)			5.1	5.1	1.0		7.3	5.4	1.4	- 0.4
23.3.44)			7.8	4.6	1.7		6.8	6.4	1.1	+ 0.6
30.3.44)			7.9	6.7	1.2		5.2	4.6	1.1	+ 0.1
6.4.44)			4.7	2.2	2.1					
13.4.44)			6.6	4.4	1.5		2.3	5.2	0.4	+ 1.1
14.4.44)			5.2	4.7	1.1		1.3	5.0	0.4	+ 0.7

Date	Period	Cow	W.	T.	W/T	Cow	W.	T.	W/T	W/T Differances. (N - S)
27.1.44)	1.	9.				Dina	4.2	6.4	0.7	
28.1.44)			4.9	5.1	1.0		4.9	4.7	1.0	0.0
1.2.44)			5.2	6.0	0.9		5.0	4.4	1.1	+ 0.2
8.2.44)			3.0	4.2	0.7		3.5	5.2	0.7	0.0
17.2.44)			4.2	5.6	0.7		6.5	5.5	1.2	+ 0.5
21.2.44)			3.0	3.1	1.0		4.4	2.8	1.6	+ 0.6
23.2.44)			0.9	3.4	0.3		3.7	7.3	0.5	+ 0.2
				S.				N.		
24.2.44)	2.		4.2	5.4	0.8		4.3	8.2	0.5	- 0.3
28.2.44)			3.7	4.7	0.8		4.0	2.2	1.8	+ 1.0
3.3.44)			1.2	3.5	0.3		3.3	4.0	0.8	+ 0.5
9.3.44)			1.9	3.7	0.5		4.7	4.1	1.1	+ 0.6
16.3.44)			2.4	4.3	0.6		3.0	4.6	0.7	+ 0.1
				N.				S.		
17.3.44)	3.									
21.3.44)			2.6	4.8	0.5		0.3	0.7	0.4	+ 0.1
23.3.44)			2.9	5.2	0.6		4.0	4.6	0.9	- 0.3
30.3.44)			2.1	4.6	0.5		1.6	5.5	0.3	+ 0.2
6.4.44)			1.4	0.9	(1.5)		1.8	3.5	0.5	(+ 1.0)
13.4.44)			0.9	3.7	0.2		1.4	4.1	0.3	- 0.1
14.4.44)			0.7	3.8	0.2		1.0	3.9	0.3	- 0.1

Date	Period	Group A. Cow	W.	T.	W/T	Group B. Cow	W.	T.	W/T	W/T Differences
27.1.44)	1.	5.	5.0	5.0	1.0	Dawn	5.1	6.5	0.8	- 0.2
28.1.44)			4.6	5.4	0.9		6.7	5.5	1.2	+ 0.3
1.2.44)			4.5	4.3	1.0		5.9	5.9	1.0	0.0
8.2.44)			4.0	4.0	1.0		4.7	4.7	1.0	0.0
17.2.44)			3.7	4.7	0.8		5.9	5.0	1.2	+ 0.4
21.2.44)			3.4	5.1	0.7		4.9	4.2	1.2	+ 0.5
23.2.44)			4.0	5.8	0.7		6.2	6.5	1.0	+ 0.3
				S.				N.		
24.2.44)	2.		3.7	5.4	0.7		6.0	4.7	1.3	+ 0.6
28.2.44)			4.0	3.9	1.0					
3.3.44)			3.7	3.0	1.2		5.1	4.7	1.1	- 0.1
9.3.44)			2.1	2.8	0.8		6.3	3.5	1.8	+ 1.0
16.3.44)			3.3	3.5	0.9		4.7	4.5	1.0	+ 0.1
				N.				S.		
17.3.44)	3.									
21.3.44)			2.8	2.6	1.1		1.1	1.5	0.7	+ 0.4
23.3.44)			1.9	3.3	0.6		5.2	3.8	1.4	- 0.8
30.3.44)			1.5	2.3	0.7		5.2	3.6	1.4	- 0.7
6.4.44)			2.7	3.5	0.8		4.7	2.3	2.0	- 1.2
13.4.44)			2.1	3.2	0.7		5.6	4.5	1.2	- 0.5
14.4.44)			1.5	2.0	0.8		5.7	4.2	1.4	- 0.6
27.1.44)	1.	Cis	3.5	2.6	1.3	11.	6.5	4.3	1.5	+ 0.2
28.1.44)			4.5	3.6	1.2		6.6	4.1	1.6	+ 0.4
1.2.44)			4.9	3.7	1.3		5.4	4.7	1.1	- 0.2
8.2.44)			5.1	4.4	1.2		5.7	4.6	1.2	0.0
17.2.44)			7.4	4.7	1.6		5.1	4.4	1.2	- 0.4
21.2.44)			6.6	3.9	1.7		6.8	4.0	1.7	0.0
23.2.44)			5.4	3.9	1.4		5.4	3.9	1.4	0.0
				S.				N.		
24.2.44)	2.		8.5	4.6	1.8		5.3	4.5	1.3	- 0.5
28.2.44)			5.4	5.9	0.9		5.2	5.4	1.0	+ 0.1
3.3.44)			4.9	3.1	1.6		6.5	3.7	1.8	+ 0.2
9.3.44)			4.4	3.9	1.1		5.9	4.2	1.4	+ 0.3
16.3.44)			5.4	3.2	1.7		4.9	4.7	1.0	- 0.7
				N.				S.		
17.3.44)										
21.3.44)	3.		3.6	1.9	1.9		4.0	4.2	1.0	+ 0.9
23.3.44)			5.4	2.7	2.0		5.1	5.7	0.9	+ 1.1
30.3.44)			4.8	3.9	1.2		4.2	4.5	0.9	+ 0.3
6.4.44)			3.2	2.4	1.3		4.7	3.8	1.2	+ 0.1
13.4.44)			3.8	3.3	1.2		4.9	4.8	1.0	+ 0.2
14.4.44)			3.2	2.1	1.5		5.6	4.1	1.4	+ 0.1

Mean difference for experimental group (1) = + 0.02
" " " control " = - 0.01
" " " experimental group (2) = + 0.096

SUMMARY

The results of the first experiment indicate several practical points. It is evident that a definite amount of time could be saved in the cow-shed if the cups were removed as soon as milk flow ceased. Another significant point is the fact that, provided the cows are adequately stimulated by washing or otherwise handling the teats, the milk flow starts immediately the cups are put on. This is at variance with Petersen's views. In a recent paper (Petersen: The Cow's Udder and its Activity. Int. Assoc. Milk Dealers Assoc. Bull. 35 (14) 191 (1943)), he suggests as a practical milking procedure that the cows should be started one minute before the cups are put on. Our experiments suggest that at least when the cows are used to it, the cups may be applied immediately after the teats have been stimulated.

The variation in milking characteristics between cows would suggest that where maximum efficiency was required in the shed the cows with poor milk flow curves should be culled. In this connection the fact that the milking rate generally tends to rise with the total amount of milk yielded means that poor producing cows take a longer time to deliver a given quantity of milk than good milkers.

In view of the importance usually placed on the pulsator by milking machine experts the results of the experiment on the relation between stimulus and milking efficiency are surprising. However, the views previously held on this subject had no sound basis and on theoretical grounds our results are not unexpected. The practical significance of the results lies in the fact that it is necessary to apply only a very short squeeze to the teat by means of the pulsator. The shorter the squeeze phase the less obstruction to milk flow and therefore the faster the machine can take the milk away. It is unlikely that the effect of very short squeeze on milking rate will be very marked as our results have shown that a good machine with no "gadgets" will handle the milk as fast as the cow can deliver it with a normal pulsation. Nevertheless, there is no point in having a longer squeeze phase than is mechanically convenient. A practical ratio of 25:75 is suggested. The experiment on the effect of the stimulus given demonstrates the fact that cows need not be started any significant time before the cups are put on.

There can be no doubt about the effect of pituitary extract on the milk ejection process. The results given show that it is highly likely that the reflex secretion of a hormone by the pituitary gland is the mechanism of the "letting down" reflex. The variation in amount of milk which can be drawn when the reflex is prevented by the injection of adrenalin is interesting and it is hoped can be related to the mechanical structure of the udder. When a cow can deliver a fair proportion of her milk before the rest is "let down" we have the optimum conditions for fast milking as the "letting down" reflex can come into full play before the milk cistern and larger ducts are drained. In the case of cows which let their milk down slowly and yield only a small amount of milk which can be drained before the reflex functions, Petersen's suggestion of stimulation one minute before milking would be helpful.

The effect of pulling down on the cups after milk flow has slowed up is very marked. This is in agreement with practical experience and is explained by Petersen (Abstract of paper given to American Dairy Science Assn., J.D.S., 26, 8, 752, 1943, and full paper to be published in this Journal) as due to the fact that as the udder empties the teat cups crawl up the teats, so closing the orifice between the teat and gland sinus. The pulling down of the cups causes the orifice to open and so permits of complete drainage of the udder. An examination of the behaviour of some machines would suggest that this is probably a correct explanation. There i little doubt that if hand stripping is done away with this pulling down on the cups or, as the Americans call it, machine stripping, should be practised.

Our results so far raise several theoretical questions of great interest. In particular the fundamental character of the "letting down" reflex and its relation to shed technique requires elucidation. Before discussing this point it would help to draw attention to certain aspects of the nature of the conditioned reflexes. A conditioned reflex arises when a stimulus (conditioned stimulus) not normally associated with a natural reflex arising from a normal stimulus (unconditioned stimulus) is linked up with that natural reflex in a number of ways. The classical natural reflex used by Pavlov is the secretion of saliva caused by the eating of food. The presence of the food in the mouth is the natural stimulus to the natural reflex, the secretion of saliva. Now, if a whistle is sounded for say 30 seconds and after a short interval the animal (in Pavlov's case, the dog) is fed, and this cycle is repeated several times, it is found that mere sounding of the whistle will cause secretion of saliva. If the sequence of events is reversed, however, no amount of repetition will establish a conditioned reflex.

A point arising from this fact is of considerable interest in relation to the milking problem. If a conditioned stimulus (or a sequence of stimuli) regularly precedes a natural stimulus evoking a particular response, that response will ultimately be evoked by the conditioned stimulus alone. In the case of the milk ejection reflex the natural stimulus is the tactile stimulation of the teats. However, modern mechanical milking requires a relatively orderly sequence of events prior to the actual application of the natural stimulus to the teats. Hence we would expect that the sequence of events would become the conditioned stimuli for the ejection reflex which thus becomes primarily a conditioned reflex. However, any events happening subsequent to the ejection of milk will not influence the reflex. This is important because it means that the hand stripping of a cow can play no part in the conditioning of the "letting down" process if Pavlov's theories are correct. In other words, hand stripping is necessary only to remove the milk from the cow which cannot be obtained by the machine for mechanical reasons. "Machine stripping" which enables all of the milk to be drawn is all that is necessary.

Two exceptions to this statement should be made. Firstly, in a shed where "rafferty rules" are the normal state it is conceivable that some cows will not let down their milk until they are hand stripped. In other words, the additional natural tactile stimulus is necessary and in such cases the milk drawn by the machine will be that contained in the milk cistern and larger ducts. The second exception would be the case of a cow which milked very slowly due to a tight sphincter at the base of the teat or an inefficient machine. In such a case the initial "letting down" reflex might become "tired" (due to tiring of the musculature or dissipation of the hormone controlling the process) and the application of a second stimulus due to hand stripping would renew the reflex if "tiring" were due to dissipation of the hormone.

Another feature of conditioned reflexes having a possible bearing on the problem of efficient milking is the fact that an animal can have a reflex conditioned so that while the sequence of events, a, b, c, may be positive in its action, any other sequence will be without effect or will have a diminished effect. If it can be shown (and future work is planned with this in mind) that a cow is as sensitive as a dog to conditioning it would appear of practical importance to ensure that the milking routine be strictly adhered to. Almost all of the environmental factors in the shed can become conditioned stimuli. Pavlov has shown that sound, visual phenomena, electric shock, temperature, smell - in fact anything capable of stimulating a receptor organ - may become a conditioned stimulus. Even regular intervals of time between events can become effective as conditioned stimuli.

It can be shown that a well established conditioned reflex will temporarily disappear if the animal concerned has been subjected to some marked external stimulus not related to the usual stimuli associated with the reflex. For instance, a flash of light or an unusual sound will upset a conditioned reflex, though the latter will re-establish itself if the inhibiting stimulus is removed. This phenomenon Pavlov called external inhibition. It is different from the type of phenomena arising if an animal is treated in such a way that an emotional response evoking hormonal changes is produced. Our experiments have demonstrated the effect of fright and the related factor adrenalin. These must not be confused with an inhibiting of a conditioned reflex due to a mild stimulus evoking a natural response other than that associated with the inhibited reflex, such a response not producing any endocrine change. This brings us to an explanation of the results of the experiment with two different levels of stimuli applied by the milking machine. There was no difference in response between the cows milked with a normal stimulus and those milked with an abnormally small stimulus. On the other hand when the machine was applied without any pulsation this normal reflex failed. The notable feature about the application of the machine without pulsation was the evident discomfort caused to some of the cows. It would appear that the failure of the reflex arose not from the absence of a stimulus to the teat as such but from the fact that the application of a teat cup under vacuum with no squeezing action causes considerable discomfort - there being no massaging of the teat end. This unusual and uncomfortable situation would cause an inhibition of the usual conditioned reflex. Once the reflex has been evoked, subsequent discomfort due to stopping pulsation did not cause the withdrawal of the milk to be hindered. The limit to this would presumably apply when the cow became actively annoyed by the discomfort and as a result the secretion of adrenalin would antagonise the action of the pituitary principle.

It might be suggested that the inhibition of the ejection reflex could be explained entirely by the action of adrenalin. However, this hormone is normally associated with fright and similar emotional conditions but the ejection reflex is apparently upset by factors which, while extraneous to the milking process, are not likely to cause fright. In one of our preliminary experiments a small dose of adrenalin was injected. This was adequate to cause such symptoms as slight frothing at the mouth, cessation of chewing the cud and bulging eyes, but had no significant effect on the milk ejection curve. Yet in the case of a cow whose ejection curve was upset by a heifer rushing into the shed there was no marked emotional response suggesting a rise in adrenalin secretion. Pavlov found with his dogs that the evoking of an inquisitive response - described aptly as a "what is it?" reflex - would inhibit a conditioned reflex. This could well apply in the case of the cow as well. We are led to the conclusion that two factors may upset the milking process: inhibition of the letting-down reflex as such the inhibition occurring between the reception of the stimuli and the secretion of the hormone, and inhibition of the action of the pituitary hormone on the mammary musculature due to the antagonistic action of adrenalin which is in turn dependent on a natural reflex evoked by fear. In future experiments it is hoped that these two factors can be disentangled and their relative importance assessed.

The practical conclusions which can be drawn tentatively are:-

1. Most efficient milking will be achieved if a thoroughly regular procedure is adopted. The cows should become

conditioned to letting down their milk during the process of washing the teats after which the cups are applied immediately.

2. No extraneous stimuli such as loud noises or unusual actions should be permitted and nothing likely to evoke curiosity or fear in the animals should occur.

3. "Machine stripping" should be practised as soon as it is evident by the sight glass that milking has ceased. Sight glasses should, therefore, be part of the normal equipment.

The work is at present only of a preliminary nature and it is felt that we are merely at the beginning of what promises to be an extremely interesting series of investigations. The development of a portable apparatus will enable us to extend the work into the field so that along with laboratory experiments we can carry out work on milking efficiency under typical field conditions. Incidentally, the extension of the principle of our apparatus to the study of milk ejection in other animals is quite practical and our future plans include a study of the development of the ejection reflex in cows which have never been milked by methods other than natural suckling of the calf.

DISCUSSION

Mr C.E. Ballinger:

(1) Has Mr Whittleston any graphs taken when milking two quarters first followed by the other two later on?

(2) Is there any tendency on the part of the cow towards the end of her lactation to need stripping more than in the beginning?

Reply:

(1) The milk is let down simultaneously in the four quarters. manipulation of two teats would affect the other two quarters. So far no experiments recording milk ejection from other than the complete udder have been done.

(2) Yes; the tendency towards "strippiness" increases towards the end of lactation.

Mr A.H. Ward: I think no tribute can be too high to Mr Whittleston's inventive genius in this respect because the apparatus he has designed in the study of milk ejection in the cow opens up tremendous possibilities for further study of this problem. The question I want to ask at this stage is: Has Mr Whittleston any data on the effect of washing the udder and putting the cups on immediately as compared with the effect of washing the udder and putting the cups on some minutes afterwards?

Reply: Petersen recommends the starting of the cow a minute before the cups are put on. In all of our experiments we have made a practice of starting the cow by washing the teats and applying the cups immediately. As you can see milking started almost immediately. There appears to be very little point in leaving a minute between stimulation and the application of the cups. I think, from a practical point of view, it is quite satisfactory to apply the cups immediately the teats have been washed.

Mr J.B. Swan: Has Mr Whittleston any explanation to offer for the delay in the effect of adrenalin in slowing down or suppressing milk ejection? We are all familiar with the rapidity with which adrenalin acts. Is there any information on the long latent period before it acts on the milk flow?

Reply: The adrenalin acts almost instantaneously; the fact that one obtains some milk after the action of adrenalin has taken place is due to the fact that the milk held in the larger ducts is withdrawn and that milk will be withdrawn even under conditions in which the animals have been severely frightened. It appears that the cow can have no control over the milk which can be drawn without the need for the letting down process coming into effect.

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