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initiation of the adequately conducted large scale field trial of the vaccine. Only keenest co-operation of the field officers engaged in the vaccinating work rendered the successful initiation of the scheme possible.

Dr Filmer: complimented Mr Buddle on his paper and on the work which had been carried out in the production of vaccine for heifer vaccination. He suggested that the campaign for control of contagious abortion through vaccination was a good example of what could be accomplished in the control of animal diseases by proper use of existing organisations. Research workers had carefully followed the American work, then imported the bacterial strain being used in America for vaccine production, had studied it in the laboratory and then on a small scale in the field, and had thus obtained the knowledge required for a large scale trial. Veterinarians and Stock Inspectors of the Livestock Division and veterinarians in some of the veterinary clubs had undertaken the vaccination, while the Herd Recording organisation had assisted considerably in the collection of data.

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THE THEORY AND PRACTICE OF MECHANICAL MILKING

by

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The milking machine is unusual in being one of very few mechanical devices which come in direct contact with and act upon a living animal. For this reason to understand completely the action of a milking machine it is necessary to examine the basic mechanical principles of the machine in relation to the physiological factors involved when the machine acts on a cow. It is possible to give a fairly exact description of the mechanics of the machine milking process; the physiological aspects are not quite so well defined. In the following outline it is proposed to discuss briefly the physiology of the milk ejection process. This will be followed by a short historical introduction to the mechanics of the modern mechanical milker. The basic principles of typical modern machines will then be outlined and the requirements for efficient milking discussed.

MILK EJECTION:

It is necessary right at the commencement of this topic clearly to define the difference between milk ejection and milk secretion. The latter process is, within limits, a continuous activity of the mammary gland. It is the specific activity of the milk secreting cells which convert the glucose, proteins, etc. of the blood into lactose, casein, etc. of the milk. Given normal conditions this process will continue steadily until slowed up by increasing intra-mammary pressure.

The nature of the milk ejection process is quite different. In the light of recent experimental work (1) the "letting down" of the milk would appear to be the result of a contraction of smooth muscle tissue surrounding the alveoli and finer ductules in the udder, the contraction being caused by stimulation of the udder and/or the sights and sounds of the cow-shed. Broadly, the sequence of events is as follows: The stimuli, handling of the udder, pulsation of the milking machine and associated sounds reflexly cause the secretion of an oxytocic factor from the posterior pituitary lobe. This causes contraction of the alveoli and small ductule musculature. The facts upon which such a theory is based are the following:-

1. Intra-mammary pressure, if recorded throughout the period between two milkings shows a slow rise until with the beginning of the milking process there is a very sharp increase (2).
2. There is histological evidence for the existence of smooth muscle tissue surrounding the alveoli and ductules (3).

3. Denervating the mammary gland during the dry period does not affect milk ejection during a subsequent lactation (1).
4. Injection of the oxytocic principle from the posterior pituitary lobe causes the milk to be "let down" in an exaggerated manner. For instance, a higher yield than average is obtained and the fat percentage is above normal (1).
5. Fright or the injection of adrenalin will completely inhibit the letting down process.

Babcock (4) noted that there is a decrease in yield of milk as four quarters are milked singly in different order. Beach (5) confirmed Babcock's results showing that while the second quarter milked gives just a little more than the first, the third and fourth show yields decreasing in that order.

These results have been further confirmed by Miller and Petersen (6) who also show that manipulation of the udder twenty minutes before milking causes a decrease in total yield and in fat percentage. The same workers find that rapid milking is conducive to a large milk flow.

The explanation for this effect is not entirely clear. Muscular fatigue alone may be a factor, but because the hormone is readily dissipated from the blood an equally satisfactory hypothesis is that the posterior pituitary lobe is limited in the amount of the hormone which can be produced at any one period of stimulation and so the muscles involved in the "letting down" process relax due to a fall in concentration of the hormone causing their contraction. Both factors may be involved.

THE ORIGIN OF THE MILKING MACHINE:

Although hand milking has been practised since the beginning of organised human life there is no evidence until 1719 of any attempt to milk cows mechanically. According to Erf (7) there is evidence from early editions of the "New England Farmer" that the insertion of straws into the teats was tried during the early years of the 18th century in America. In 1878 a milk tube arrangement was put on the market by a Mr George of New York. Such methods were, of course, unfortunate in their effects and were soon abandoned. However, in Scotland prior to this experiments were made with the use of a steady vacuum to draw out the milk from the udder. In 1860 a machine was produced which employed this principle. By 1890 Mr W. Murchland of Kilmarnoch had produced a fairly satisfactory machine of this type. Parallel with these developments in Scotland the Americans were experimenting with elaborate mechanical contrivances intended to imitate hand milking. In 1886 a very complex device was patented using rollers running in a pair of milking cylinders so that the rollers squeezed the teats from top to bottom. A hand operated mechanical squeezing machine was patented in Denmark in 1885. It is clear that due to a general shortage of farm labour about this time conditions were ripe for the development of the milking machine. In 1895 Dr Sheils of Glasgow produced his "Thistle" milker; a machine which employed an intermittent vacuum swinging between $4\frac{1}{2}$ and 15 inches of mercury (the first "vacuum break" machine). The teat cups of this machine were constructed of stout rubber. With this machine the basic principles of the modern milker were established.

The Murchland machine had not been very successful because it did not apply an adequate stimulus to the teat. As a result the cows were not completely milked out. The "Thistle" machine was an improvement and the method, namely, the use of a single chambered cup with a pulsating vacuum applied to it, is still used on a small percentage of machines in other countries.

The last fundamental invention was that of the double chambered teat cup with a rubber liner or "inflation". Patents for this principle were taken out in 1902 by Hulbert and Park, New York; and in 1903 by Alex. Gillies in Australia. This type of cup consists of a metal casing connected to a valve supplying a vacuum which swings from some predetermined value to atmospheric pressure and back again regularly. Inside this casing a rubber sleeve or inflation is fitted in such a manner that there is no connection between the inside of the sleeve and the outer casing. The inside of the sleeve is connected to either a bucket or the milk pipe of the machine and is held at a steady vacuum. There are modifications of these principles to be found amongst the many types of modern machines but these will not be discussed as, firstly, most machines employ the principles outlined, secondly, there would appear to be no advantage in complicating a machine with a view to getting different types of effect. It should be noted that nearly all modern machines have a small air admission hole drilled either in the claw which connects the teat cup to the milk and pulsator lines or in the tops of the cups when these are made of metal.

The action of the dual chambered cup on the cow is briefly as follows:- When the pulsator tube is evacuated the "inflation" is in the relaxed or "release" position, the pressure being the same on both sides. As soon as the pulsator valve opens to the air the vacuum in the inside of the inflation causes it to collapse, so squeezing the teat.

Generally, it is possible to classify inflations into two groups - soft and moulded. The former consist of light extruded tubing which may or may not be shaped; the latter are quite massive and moulded into elaborate shapes in many cases. There are, however, intermediate forms, some moulded types being of the same weight as soft inflations. It is claimed for some types of heavy moulded inflations that they exert a mechanical action similar to hand milking, thus squeezing the milk from the teat. Observations made with specially made cups with glass walled cases and transparent windows in the inflations indicate that all types of cups milk the cow purely by suction, the squeezing action applying a stimulus to the teat but not assisting by mechanical action in removing the milk. Of course, badly stretched soft inflations can hinder efficient milking, as can poorly designed moulded inflations, by obstructing the milk flow. There would not, however, appear to be any fundamental difference in the action of the two types.

THE BASIC PRINCIPLES OF THE MODERN MILKING MACHINE:

From what has been said it will be seen that the mechanical milker must fill two requirements; Firstly, it must stimulate the cow; secondly, it must be capable of drawing the milk from the udder efficiently. The following is an outline of the structure common to most modern machines:-

Vacuum Pump: In New Zealand most vacuum pumps are of what is known as the rotary type in which two vanes fitted into slots in an eccentrically placed rotor sweep the air from a cylindrical stator. The vanes function both as pistons and as valves. For evacuating a milking machine such pumps are very satisfactory as they can be constructed of few parts and require no valves when operated at a low vacuum. They have good air handling capacity and run quietly.

Piston pumps are still used. These have advantages over the rotary pump under certain operating conditions. They tend to be noisy but probably maintain their efficiency with little attention for longer periods than the rotary type.

The most popular source of motive power is the electric motor, though internal combustion engines of both diesel and

spark ignition types are used and in some areas where there are suitable streams water power is still used.

The Vacuum Tank: This is a receptacle placed between the pump and the rest of the machine. It serves three purposes:-

- (1) Having considerable volume it acts as a reserve in case of emergencies when air is accidentally admitted into the vacuum lines in excessive amounts.
- (2) When the machine is being cleaned out after milking the washing solution accumulates in the vacuum tank and so does not enter the pump where it could cause damage.
- (3) By means of a baffle arrangement milk froth and spray carried over from the releaser is trapped before reaching the pump so removing another source of undue wear and corrosion.

The Releaser: This device serves to deliver the milk from an evacuated system into an open vat. It consists essentially of two connected chambers one being large and connected to the milk pipe. This large chamber is fitted with a flap valve which opens into the smaller chamber, the latter being connected to a pulsator valve and opening to the air via a flap valve similar to that connecting it to the main chamber. The pulsator valve alternately opens the small or "spit" chamber to the air or connects it to the vacuum in the air line. When the "spit" chamber is evacuated its outer flap valve closes due to atmospheric pressure while the inner flap is opened by the hydrostatic pressure of the milk accumulated in the main chamber. Thus the "spit" chamber is partly filled with milk. On coming to atmospheric pressure this chamber empties because of the closing of the inner flap and the opening of the outer flap by the pressure of the accumulated milk. It is, of course, possible to construct a milking machine without the use of a releaser. For instance, a diaphragm pump has been employed which at once creates the vacuum in the machine and discharges the milk. From many points of view the releaser is to be preferred and is the most generally used method of discharging the milk from milking machines. Where the milk runs from the cups into evacuated buckets there is no need for a releaser. Such a method involves considerable labour in carrying the buckets and so is used only on small farms where its cheapness outweighs its inconvenience.

The Pulsator: Essentially this is a valve which alternately connects the outside chamber of the teat-cup to the vacuum and to the atmosphere. The commonest type of valve is a reciprocating slide and the modern tendency is to use one valve per set of cups. As has been indicated the pulsator supplies the swinging vacuum on the outside of the teat-cup liner. It is, therefore, the main mechanical factor involved in stimulating the teat. Experience indicates that pulsators which do not give a "snappy" swing in vacuum are unsatisfactory. So far there has been no carefully planned work done to determine the optimum conditions of operation for a pulsator. It is hoped that such work will be done at Wallaceville in the future. The fact that there are many different types of pulsator valve indicates that milking machine engineers are not in agreement as to the best methods. On general grounds it is to be expected that a "snappy" action would be more stimulating to the cow than a sluggish squeeze. However, if a machine causes a cow discomfort the otherwise stimulating effect would be lost. The cow is not only an elaborate chemical device for producing milk from grass, she is also a psychological organism. A dissatisfied cow causes as much trouble as an inefficient milking machine, and in designing the parts of the machine directly affecting the cow this has to be considered. Too snappy a pulsator may be uncomfortable just as a sluggish one may be unstimulating.

The Vacuum Gauge: This indicates the vacuum at which the machine is operating - or at least it does so on some milking machines. The Bourdon type of gauge almost universally used is very unsatisfactory. It is readily susceptible to corrosion and misuse and is so out of place in the cow-shed. A recent survey of some thirty plants showed that over 50 per cent. of gauges had errors exceeding one inch of mercury. The Bourdon gauge depends for its action on the tendency for a curved springy metal tube of oval cross-section to curl up when the external pressure on it exceeds that in its interior. The small movement so produced is amplified by rather delicate lever and gear mechanism.

The Relief Valve: This is the safety valve of the milking machine. Essentially it consists of a valve loaded by a spring or weight which is acted on by atmospheric pressure in such a manner that when the negative pressure on the side of the valve opposite to that open to the atmosphere exceeds a predetermined value the valve opens, so admitting air into the system. Three kinds of valve are in general use:

- (1) The ball type consisting of a small ball held against a circular seat by a spring.
- (2) The spring loaded poppet type consisting of a poppet or mushroom type valve head closed by a spiral spring.
- (3) Weighted valves in which a poppet or similar type valve is held closed by a weight.

Ball valves are unsatisfactory while the most sensitive and reliable type is the weighted valve. If the cows are to be protected against the vacuum rising unduly and so causing discomfort and possibly damage the relief valve must be sensitive to small increases in vacuum while much trouble can be avoided in the shed if the valve closes promptly when a set of cups falls off.

THE GENERAL CONSTRUCTION OF A TYPICAL MACHINE:

Probably the best way to examine the way in which a machine is set out is to follow the course of the milk and air through it.

On leaving the teat cups the milk flows via short rubber tubes to the claw whence it flows via a length of rubber tubing to the so-called "dropper" tube which elevates it to the milk pipe normally four to five feet from the floor. Milk flowing up the droppers is mixed with air which reduces the amount by which the vacuum falls at the cups when milk is flowing. At the top of the dropper the milk flows through a tap into the milk pipe which conveys it to the releaser. The action of the latter has been described. Returning to the cups: By a similar type of branched tube at the claw, the outside chambers of the cups are connected to a dropper which in the case of a machine with individual pulsators is connected to a pulsator valve mounted on a pipe running parallel to the milk line. In some machines one pipe serves both as air and milk line. The vacuum gauge and relief valve are usually mounted side by side on the end of the air line distal from the releaser and vacuum tank.

Where the milk pipe is mounted just above floor level there are, of course, no "droppers" and the milk flows downhill to the pipe. At the end of the shed an elevating mechanism supplements or replaces the usual releaser. A bucket plant has no milk pipe, the milk flowing into buckets evacuated by connection with the single air line.

FACTORS INVOLVED IN EFFICIENT MILKING:

In order to get the best from a mechanical milker the following points must be adhered to:-

- (1) The machine must be in good mechanical order. In particular, the vacuum must be stable, the pulsators operating efficiently and the inflations must be tight and elastic.
- (2) Shed routine should be strictly adhered to. This follows from the suggestion that the letting down process is a conditioned reflex. Stripping can probably be eliminated if the cows are conditioned to release all of their milk to the machine.
- (3) Every attempt should be made to speed up the milking process. There must be nothing in the construction of the machine to hinder the rapid escape of the milk into the milk pipe.

Further, the cups should be removed as soon as milk flow stops, so training the cows to expect a short milking period. Where the action of a machine is pleasing to a cow it is evident that habits associated with prolonged milking may well be developed. Stripping and double stripping, if pleasurable to the cow will be expected once started and so will become part of the conditions necessary for a complete "letting down" of the milk.

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- (5) Beach, Conn. (Storrs) Agr. Expt. Sta. Rept., 135, 1904.
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DISCUSSION

Mr. Waters: What effect does music have on the "letting down" of milk?

Reply: There is no record of experimental work on this subject. If the view which regards the "letting down" process as a conditioned reflex is correct there is no a priori reason for rejecting the idea that once cows have become used to a radio set in the shed its absence might disturb the cow's usual reactions. All of the various factors associated with milking would be part of the conditioning of the "letting down" reflex.

Mr. Hamilton: Has any further work been done on "non-stripping"?

Reply: Experiments are in progress at Ruakura and the performance of non-stripped herds is being followed.

Mr. James: Is there any experimental evidence in favour of the low-level milk pipe machine?

Reply: As yet we have no results indicating any significant difference between the "low-line" machine and the orthodox type.