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"chapter 3" In: **A.J. BRAMLEY et al.: "Machine milking and lactation", 1992, Insight Books vol. 69, page iii-viii, 69,185-186,323-324, 361,**



# DESCRIPTION

## TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates generally to computerized systems for use in the dairy industry, and more particularly to a system for implementing an adaptive milking process.

## BACKGROUND OF THE INVENTION

[0002] EP 1 279 326 A1 discloses a method of automatically milking a dairy animal, in particular a cow. The method comprises: a) the step of activating the teat cup for milking the teat; b) the step of measuring a milking parameter during milking the teat during step a) for obtaining a value of the milking parameter, and c) the step of deactivating the teat cup when a deactivation threshold has been reached. The deactivation threshold is determined at least partially with the aid of the value of the milking parameter. A device for automatically milking a dairy animal, in particular a cow. Said device is provided with means for activating the teat cup for milking a teat of the dairy animal, means comprising a milking parameter for measuring a milking parameter during milking the teat for obtaining a value of the milking parameter, means for deactivating the teat cup, and means for generating a threshold signal indicating that a deactivation threshold has been reached. The deactivation means are put into operation with the aid of the threshold signal, the means for generating the signal indicating a deactivation threshold generating the signal at least partially with the aid of the value of the milking parameter.

[0003] Automatic milking machines have traditionally relied on the fact that at the end of the milking process, the milk flow from a dairy animal (e.g., a cow, a goat, or any other milk-producing mammal) would slowly decrease from full flow to a low level that was designated as the detach flow rate. Normally, this decay time would take tens of seconds or even minutes to occur. This gave the detacher controls enough time to make a decision about when to remove the milking unit, and the user could make simple adjustments to have the cows milked out more completely (drier) or to leave more milk in the udder (wetter).

[0004] Recently, advances in milking equipment and procedures have changed this behavior. With proper equipment and cow preparation, cows can now be milked out in a much shorter time, and the milk flow may go from full flow to no flow in just a few seconds. If all of the milk is removed from the cow's udder and the unit remains on the teat for any length of time with no milk flow, the teat can be damaged. To prevent overmilking, users normally try to leave a small amount of milk in the udder. When the drop in milk flow was gradual, it was possible to use one standard detach threshold flow rate for most of the cows in the herd without over milking or under milking any of the cows significantly. With the new milking procedures, it is not possible to use a single threshold for all cows without over milking the high producing cows (who tend to

drop off in flow rate faster at the end of the milking) or under milking the lower producers.

**[0005]** Pre-assigning individual thresholds to individual cows based on prior milking habits of each cow is not a practical solution because it requires a lot of manual effort to determine the correct thresholds and then enter and maintain the settings for all of the cows. It also requires that every cow be correctly identified during the milking process using electronic identification systems, and that each cow exhibits the same or similar milking characteristics each time the cow is milked.

### **SUMMARY OF THE INVENTION**

**[0006]** According to the presently claimed invention, an adaptive milking system is provided that comprises a milk meter operable to: measure a first flow rate of milking an animal during a first period of time, monitor the flow rate of milking the animal and measure a second flow rate of milking the animal during a second period of time; a controller communicatively coupled to the milk meter and operable to calculate a percentage of the first measured flow rate; calculate a percentage of the second measured flow rate; trigger a delay timer when the monitored flow rate of milking the animal becomes lower than the larger of (a) a default threshold flow rate and (b) the calculated percentage of the first measured flow rate and (c) the calculated percentage of the second measured flow rate; and a detacher communicatively coupled to the controller and operable to remove a milking unit from the animal when the delay timer reaches a threshold time.

**[0007]** Various embodiments of the invention may have none, some, or all of the following advantages. Technical advantages of this adaptive milking system is that the determination of when to stop the milking process for a given cow depends on the performance of that cow as it is being milked. It reduces or eliminates the need for user intervention or guesswork. It also does not require correct identification of a given cow and reliance on the prior milking characteristics of the cow. Instead, it determines an appropriate time to stop milking the cow based on the particular performance of the cow, including the peak flow rate of milk from the cow. This allows the adaptive milking system to customize the milking process for each cow. This results in a higher yield of milk production from both high producing cows and low producing cows. It also results in healthier cows due to the reduction of over milking cows, which can damage the teats of a cow, and the reduction of under milking the cows, which can cause the cows to reduce their production of milk over time. Other advantages will be readily apparent to one skilled in the art from the description and the appended claims.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0008]** For a more complete understanding of the present invention and its advantages, reference is now made to the following description taken in conjunction with the accompanying

drawings, in which:

FIGURE 1 illustrates a block diagram of an adaptive milking system according to one embodiment;

FIGURE 2 illustrates one embodiment of a chart measuring the milk flow rate of two cows over time, using the adaptive milking system of FIGURE 1;

FIGURE 3 illustrates one embodiment of a data table used by the adaptive milking system of FIGURE 1; and

FIGURE 4 illustrates one embodiment of a flow chart of an adaptive milking process.

### DETAILED DESCRIPTION

**[0009]** FIGURE 1 illustrates an adaptive milking system 10 that includes milking units 12, milk meters 14, detacher units 16, and a controller 18. In general, milking system 10 is used to milk a cow, a goat, a sheep, or any other livestock suitable for milking. The remainder of this description will be detailed with respect to the milking of a cow. As milk is drawn from the cow using milking units 12, milk meters 14 measure certain information about the milking process, such as the flow rate of milk being produced, and communicates this information to controller 18. As will be described in greater detail below, controller 18 determines an appropriate time to terminate the milking process for a given cow based on the milking performance of that cow in any particular instance. Controller 18 communicates a control signal 26 to a detacher unit 16, as appropriate, and detacher unit 16 removes the milking unit 12 from the teats of the cow in response to this control signal 26. In this way, controller 18 is able to customize the milking experience for a given cow based on the performance of that cow during a particular milking cycle.

**[0010]** Milking unit 12 comprises an assembly attached to the cow's udder during milking. The milking unit 12 generally includes a claw, four shell assemblies, four milk tubes, four air tubes, and an air fork used to maintain an appropriate spacing between the other components of the milking unit 12. Milking unit 12 may also include a pulsator device used to alternately apply atmospheric air pressure or vacuum pressure to the teat cup liners which are attached to the teats of a cow in order to draw milk out of the cow. Although FIGURE 1 illustrates two milking units 12, system 10 may include any number of milking units 12 to accommodate any particular size of milking parlor.

**[0011]** A milk meter 14 is associated with each corresponding milking unit 12, and comprises a measurement device that can weigh the milk as it passes through a milk line 30 to a milk tank 32. In general, milk meter 14 can measure and record a variety of information, referred to as measurement data 44, including, for example, an average flow rate (lbs/min), a current flow

rate (lbs/min), teat flow rates (lbs/min), milking duration (sec), milk yield (lbs), milking unit attachment time (h:m:s), milk flow rate at stop (lbs/min), and any other suitable information used to manage an adaptive milking process according to system 10. Milk meter 14 may include any suitable combination of sensors and electromechanical components to perform the measurements described above.

**[0012]** Detacher unit 16 comprises an electromechanical device used to retract milking unit 12 from the teats of a cow. Detacher unit 16 may include a valve to turn off the milking vacuum to the milking unit 12 to facilitate the retraction of milking unit 12 from the teats of a cow. Detacher unit 16 may include a flexible retract member fastened at one end to the milking unit 12 and at the other end to a retract device for exerting a pulling force on the retract member to cause the milking unit 12 to be retracted from the teats of a cow. Detacher 16 may perform the retraction of an associated milking unit 12 in response to control signal 26 generated by controller 18, as described in greater detail below. Each detacher 16 operates independently of each other detacher 16, and controls the retraction of an associated milking unit 12 in response to a corresponding control signal 26.

**[0013]** Controller 18 comprises a processor 20 and a memory 22 used to control the adaptive milking process of system 10. Processor 20 may execute adaptive milking logic program 40 to perform the functions described herein. Memory 22 may store a default threshold flow rate 42 that may be used in one embodiment in the adaptive milking process described herein. Memory 22 further stores measurement data 44 associated with different cows and collected by milk meters 14 and communicated to controller 18. Memory 22 may further store a data table 46 used by processor 20 to perform the adaptive milking process described herein.

**[0014]** The adaptive milking process of system 10 is described in greater detail with reference to FIGURE 2. FIGURE 2 illustrates one embodiment of a chart 100 measuring the milk flow rate of two cows over time. The vertical axis of chart 100 is the flow rate of milk production. Although chart 100 is detailed with reference to a measurement of pounds per minutes, any suitable measure of milk could be used, such as pounds, kilograms, ounces, liters, etc, over any suitable period of time, such as minutes, seconds, etc. The horizontal axis of chart 100 illustrates the time that a milking unit 12 is attached to a cow. Although chart 100 is detailed with reference to a measurement of seconds, any suitable measurement of time could be used, such as seconds, minutes, hours, etc. Chart 100 includes a graph 102 for a cow "A", and a graph 104 for a cow "B". Graph 102 for cow A shows a higher peak flow rate while graph 104 for cow B shows a lower flow rate and a slower drop in rate at the end of milking. In general, cow A is a fast-producing cow and cow B is a slow-producing cow.

**[0015]** One way of detaching a milking unit 12 from a cow is to measure the flow rate after a time delay, and when the flow rate falls below a default threshold flow rate 42 as shown at point 106 for cow A, a detach delay timer is started. If the measured flow rate for cow A stays below the default detach threshold 42 for the detach delay time 108, the milking unit 12 is removed from cow A at time 110. As shown, removal of the milking unit 12 at time 110 is well after the flow of milk has stopped for cow A. This causes an overmilking of cow A and can be

detrimental to the health of cow A. Changing the default detach threshold 42 and the detach delay time 108 for cow A may not allow for the proper milking of cow B. The measured flow rate for cow B falls to the default detach threshold 42 at point 112, starting the detach delay 114, resulting in a detachment of milking unit 12 from cow B at point 116, which may already be sooner than desired even before changing the parameters of default detach threshold 42 to accommodate cow A.

**[0016]** One embodiment of the adaptive milking process of system 10 is to keep a minimum default detach threshold 42 to provide a setting suitable for a slow-milking cow, but to monitor the milk flow rate of a particular cow during different periods of time and adapting the detach threshold based on the milking performance of the particular cow. For example, the flow rate of milking for cow A may be monitored between thirty and sixty seconds after the milking process begins, resulting in a flow rate 120. A percentage of flow rate 120 is calculated, as described in greater detail below, and if it is larger than the default detach threshold 42, it becomes the new detach threshold 122 for cow A. Furthermore, the flow rate of milking for cow A is measured between sixty and one hundred-twenty seconds resulting in a flow rate 124 for cow A. A percentage of flow rate 124 is calculated, and if it is larger than the default detach threshold 42 and the new detach threshold 122, then it becomes the new detach threshold 122 for cow A.

**[0017]** As graph 102 illustrates, the milk flow rate of a cow peaks somewhere between a first period of time between thirty and sixty seconds after milking begins, or a second period of time between sixty and one hundred-twenty seconds after milking begins, and then drops off either gradually at first or steeply later in the milking cycle. As the flow rate for cow A drops below the new threshold 122 at point 123, a detach delay timer 126 is triggered, resulting in the milking unit 12 being removed from cow A at time 128. The advantage of the adaptive milking process of system 10 is that the milking unit 12 is detached from cow A at time 128 as opposed to time 110. The earlier detach time is preferred to avoid overmilking cow A.

**[0018]** Cow B may also be monitored for flow rate between thirty and sixty seconds resulting in flow rate 150. A percentage of flow rate 150 is calculated, and if it is larger than the default detach threshold 42, then it is used as the new detach threshold, which is not the case in the example illustrated in chart 100 for cow B. Furthermore, the flow rate of milking for cow B is measured between sixty and one hundred-twenty seconds after milking begins, resulting in a flow rate 152 for cow B. A percentage of flow rate 152 is calculated, and if it is larger than the default detach threshold 42 and the new threshold measured between thirty to sixty seconds after milking begins, it becomes the new detach threshold, which in this example is approximately the same as the default detach threshold 42. Therefore, in this example, cow B is detached at the same time 116 as described above using default detach threshold 42. The ability of system 10 to adapt the detach threshold for faster milking cows automatically allows the detach threshold and/or the detach delay to be lowered for a slower milking cow, possibly resulting in a later, more appropriate detach for such a cow.

**[0019]** In another embodiment of the adaptive milking process implemented by system 10, the default detach threshold 42 is set to zero. The flow rate of milking for cow B is measured

between thirty and sixty seconds after milking begins resulting in flow rate 150. A percentage of flow rate 150 is calculated and is used as the detach threshold. Furthermore, the flow rate of milking for cow B is measured between sixty and one hundred-twenty seconds resulting in a flow rate 152 for cow B. The percentage of flow rate 152 is calculated and if it is larger than the thirty to sixty second threshold, it becomes the new detach threshold. Thus, all cows use a detach threshold based on their peak flow rate measured between thirty and one hundred-twenty seconds.

**[0020]** The discussion above assumes a user settable detach threshold percentage and a user settable detach delay that are shared by all cows. However, the adaptive milking process system 10 may further be implemented to utilize detach threshold percentage and detach delay times based on the peak flow rate of a particular cow. These percentages and delay times could have user settable coefficients, allowing increasing or decreasing proportionality, as described below with respect to FIGURE 3.

**[0021]** FIGURE 3 illustrates one embodiment of a data table 46 used by the adaptive milking system 10. Data table 46 includes columns 202a-g and rows 204a-h. Column 202a includes data related to the peak flow rate of milking for a cow (e.g., measured in pounds per minute). Column 202b provides a base detach threshold percentage, which is provided as 60% in data table 46. Column 202c provides a calculated detach threshold percentage coefficient ranging from 0.6 to 1.3 in rows 204a-h of data table 46. Column 202d provides a detach threshold percentage result ranging from 36% to 78% in rows 204a to 204h of data table 46. Column 202e provides a base detach delay measured in seconds, which is listed as 5 seconds for each of rows 204a through 204h of data table 46. Column 202f provides a calculated detach delay coefficient ranging from 1.8 to 0.4 in rows 204a through 204h of data table 46. Finally, column 202g provides a detach delay result measured in seconds ranging from 9.0 seconds to 2.0 seconds from row 204a through row 204h of data table 46. As can be seen from the example data provided in data table 46, the calculated detach threshold percentage provided in column 202d is proportional to the peak flow rate of milking a cow as provided in column 202a. Moreover, the detach delay measured in seconds provided in column 202g is inversely proportional to the peak flow rate provided in column 202a.

**[0022]** In this example data table 46, a cow with a peak flow rate of 5 pounds per minute would automatically be assigned a detach threshold percentage of 48% and a detach delay of 7 seconds, while a cow with a peak flow rate of 12 pounds per minute would automatically be assigned a detach threshold percentage of 66% and a detach delay of 4 seconds. For a given cow, controller 18 looks up the measured peak flow rate in data table 46 and uses the corresponding threshold percentage and/or detach delay time for the detach process. Both coefficients in columns 202c and 202f could have a sensitivity parameter and a positive or negative correlation entered by the user into formulas to create the values in the data table 46. The data in data table 46 is merely an example and could be modified according to additional constraints and parameters.

**[0023]** FIGURE 4 illustrates one embodiment of a flowchart 300 of an adaptive milking process

implemented by system 10. Memory 22 of controller 18 stores a default detach threshold flow rate 42 for a particular cow at step 302. Milk meter 14 measures a first milk flow rate for the cow for a first period of time, such as from thirty to sixty seconds after the milking process begins, at step 304. This information may be communicated as measurement data 44 to controller 18. At step 306, processor 20 of controller 18 calculates a percentage of the first flow rate measured at step 304. Processor 20 may use data from data table 46 to determine the appropriate percentage, as described above with reference to FIGURE 3.

**[0024]** Execution proceeds to step 308 where processor 20 determines whether the percentage of the first measured flow rate calculated at step 306 is larger than the default detach threshold flow rate 42. If so, memory 22 stores the percentage of the first measured flow rate calculated at step 306 as a new detach threshold for the cow, at step 310. If not, or after execution of step 310, execution proceeds to step 312, where milk meter 14 measures a second flow rate of the cow for a second period of time such as between sixty and one hundred-twenty seconds after the milking process begins. Again, this information may be communicated from milk meter 14 to controller 18 as measurement data 44. At step 314, processor 20 calculates a percentage of the second flow rate measured at step 312.

**[0025]** Execution proceeds to step 316 where processor 20 determines whether the percentage of second measured flow rate calculated at step 314 is larger than the percentage of measured flow rate calculated at step 306 and the default detach threshold 42. If so, execution proceeds to step 318 where memory 22 stores the percentage of second measured flow rate calculated at step 314 as the new detach threshold for the cow. If not, or after the execution of step 318, execution proceeds to step 320 where milk meter 14 continues to monitor the flow rate of milking for the cow. This measured flow rate is communicated to controller 18 as measurement data 44 on a periodic or continuous basis.

**[0026]** Execution proceeds to step 322 where processor 20 determines if the flow rate of milking for the cow as monitored at step 320 becomes less than the default threshold 42 and/or the new detach threshold for the cow as determined at steps 310 and/or 318. If not, execution returns to step 320, where milk meter 14 continues to monitor the flow rate of the milking for the cow. If so, execution proceeds to step 324 where processor 20 of controller 18 generates a control signal 26 used to stop the milking process for the cow. At step 326, processor 20 of controller 18 communicates the control signal 26 to detacher unit 16. Execution proceeds to step 328, where detacher unit 16 detaches the milking unit 12 from the cow. Execution terminates at step 330.

## REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

**Patent documents cited in the description**

- EP1279326A1 [0002]

**PATENTKRAV****1. Et adaptivt malkningssystem, omfattende:**

5 en mælkemængdemåler (14), som operativt kan:

måle en første strømningshastighed ved malkning af et dyr i et første tidsrum;

overvåge strømningshastigheden ved malkning af dyret;

10 måle en anden strømningshastighed ved malkning af et dyr i et andet tidsrum;

et styringsapparat (18), der er i kommunikationsforbindelse med mælkemængdemåleren (14) og operativt kan:

15 beregne en procentdel af den første målte strømningshastighed;  
beregne en procentdel af den anden målte strømningshastighed;  
og

20 trigge en delay-timer (126), når den overvågede strømningshastighed ved malkningen af dyret bliver lavere end den højeste af  
(a), en default-tærskelværdi for strømningshastigheden (42) og  
(b), den beregnede procentdel af den første målte strømningshastighed og (c) den beregnede procentdel af den anden målte strømningshastighed; og

25 en frigører (16), som operativt er i kommunikationsforbindelse med styringsapparatet (18) og operativt kan fjerne en malkningsenhed (12) fra dyret, når delay-timeren (126) når en tærskelværditid.

30 **2. System ifølge krav 1, hvorved default-tærskelværdien for strømningshastigheden (42) omfatter måling af mælk, der er malket fra dyret i et tidsrum.**

3. System ifølge krav 1, hvorved det første tidsrum er fra cirka tres sekunder til cirka et hundrede og tyve sekunder efter, at malkningen af dyret påbegyndes.
4. System ifølge krav 1, hvorved procentdelen i det mindste delvist bestemmes  
5 på basis af en spidsværdi af strømningshastigheden ved malkning af dyret.
5. System ifølge krav 4, hvorved spidsværdien af strømningshastigheden ved malkningen af dyret bestemmes ved middelværdidannelse af den målte strømningshastighed ved malkningen af dyret fra cirka tres sekunder til cirka et hund-  
10 rede og tyve sekunder efter, at malkning af dyret påbegyndes.
6. System ifølge krav 4, hvorved procentdelen er proportional med spidsværdien af strømningshastigheden ved malkning af dyret.
7. System ifølge krav 1, hvorved tærskelværdi-tiden bestemmes, i det mindste delvist, på basis af en spidsværdi af strømningshastigheden ved malkning af dyret.  
15 ret.
8. System ifølge krav 7, hvorved spidsværdien af strømningshastigheden ved malkning af dyret bestemmes ved middelværdidannelse af den målte strømningshastighed ved malkning af dyret fra cirka tres sekunder til cirka et hundrede og tyve sekunder efter, at malkningen af dyret påbegyndes.  
20
9. System ifølge krav 7, hvorved tærskelværdi-tiden er omvendt proportional med spidsværdien af strømningshastigheden ved malkning af dyret.  
25
10. System ifølge krav 1, hvorved  
30 det første tidsrum er fra cirka tredive sekunder til cirka tres sekunder efter påbegyndelse af malkning af dyret; og  
det andet tidsrum er fra cirka tres sekunder til cirka et hundrede og tyve sekunder efter påbegyndelse af malkning af dyret.

**11. System ifølge krav 1, hvorved:**

dyret er et første dyr;

en anden mælkemængdemåler (14) operativt kan:

- 5 måle en strømningshastighed ved malkning af et andet dyr i et tredje tidsrum; og  
overvåge strømningshastigheden ved malkning af det andet dyr;

styreapparatet (18) ydermere operativt kan:

- 10 beregne en procentdel af den målte strømningshastighed for det andet dyr; og  
trigge en anden delay-timer (126), når den overvågede strømningshastighed ved malkning af det andet dyr bliver lavere end den største af (a) default-tærskelværdien for strømningshastigheden (42) og (b) den beregnede procentdel af den målte  
15 strømningshastighed for det andet dyr; og

en anden frigører (16) operativt kan fjerne en anden malkningsenhed fra det andet dyr, når den anden delay-timer når en forudbestemt tid.

20

**12. System ifølge krav 11, hvorved**

den målte strømningshastighed omfatter en første målt strømningshastighed for det andet dyr;

- 25 den anden mælkemængdemåler (14) ydermere operativt kan måle en anden strømningshastighed ved malkning af det andet dyr i et fjerde tidsrum;

styreapparatet (18) ydermere operativt kan beregne en procentdel af den anden målte strømningsværdi for det andet dyr; og

- 30 den anden delay-timer (126) trigges, når den overvågede strømningshastighed ved malkning af det andet dyr bliver lavere end den største af (a) default-tærskelværdien for strømningshastigheden (42), (b) den beregnede procentdel af den første målte strømningshastighed for det andet

dyr, og (c) den beregnede procentdel af den anden målte strømningshastighed for det andet dyr.

13. Systemet ifølge krav 12, hvorved:

5

det tredje tidsrum er fra cirka tredive sekunder til cirka tres sekunder efter, at malkningen af det andet dyr påbegyndes; og det fjerde tidsrum er fra cirka tres sekunder til cirka et hundrede og tyve sekunder efter, at malkningen af det andet dyr påbegyndes.

10

14. Systemet ifølge krav 1, hvorved default-tærskelværdien for strømningshastigheden (42) er nul.

15

20

DRAWINGS

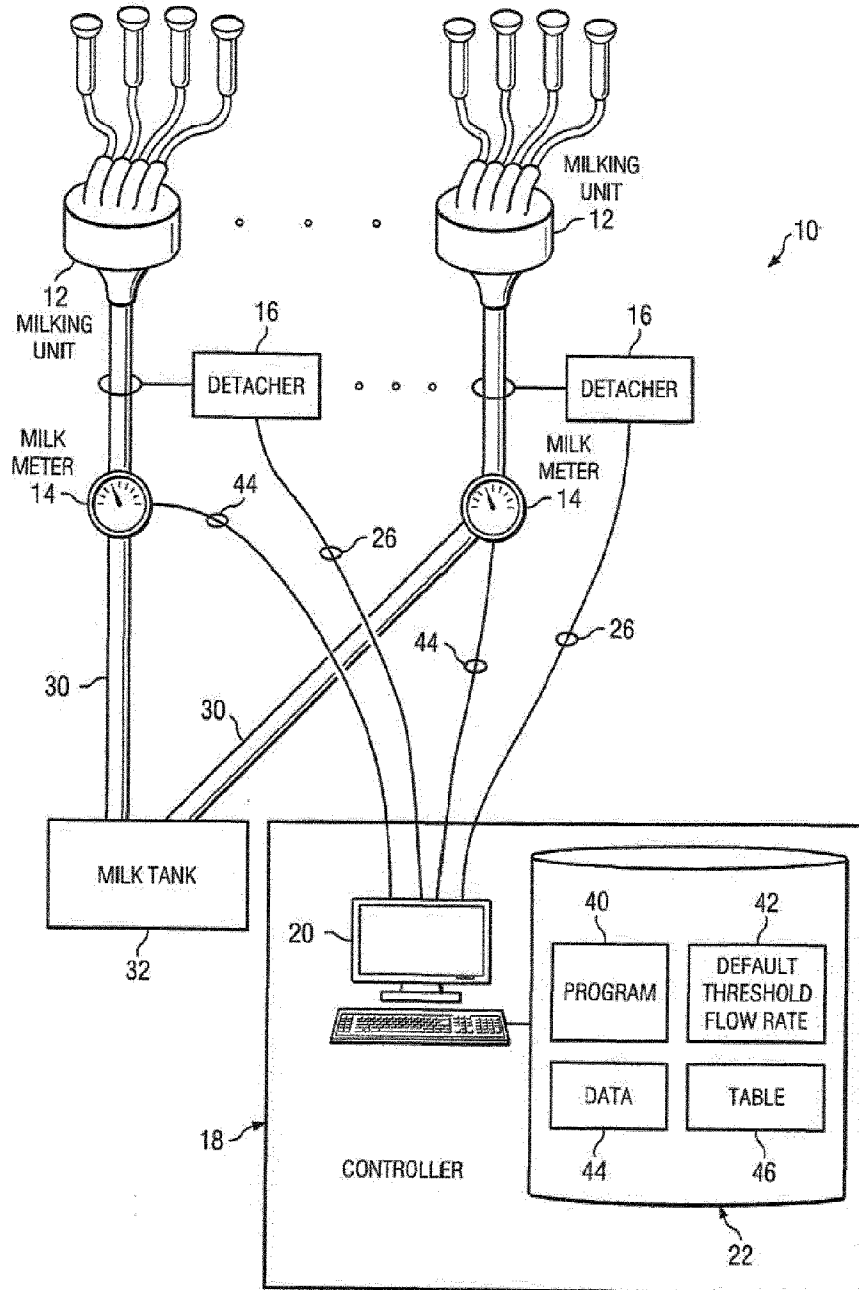


FIG. 1

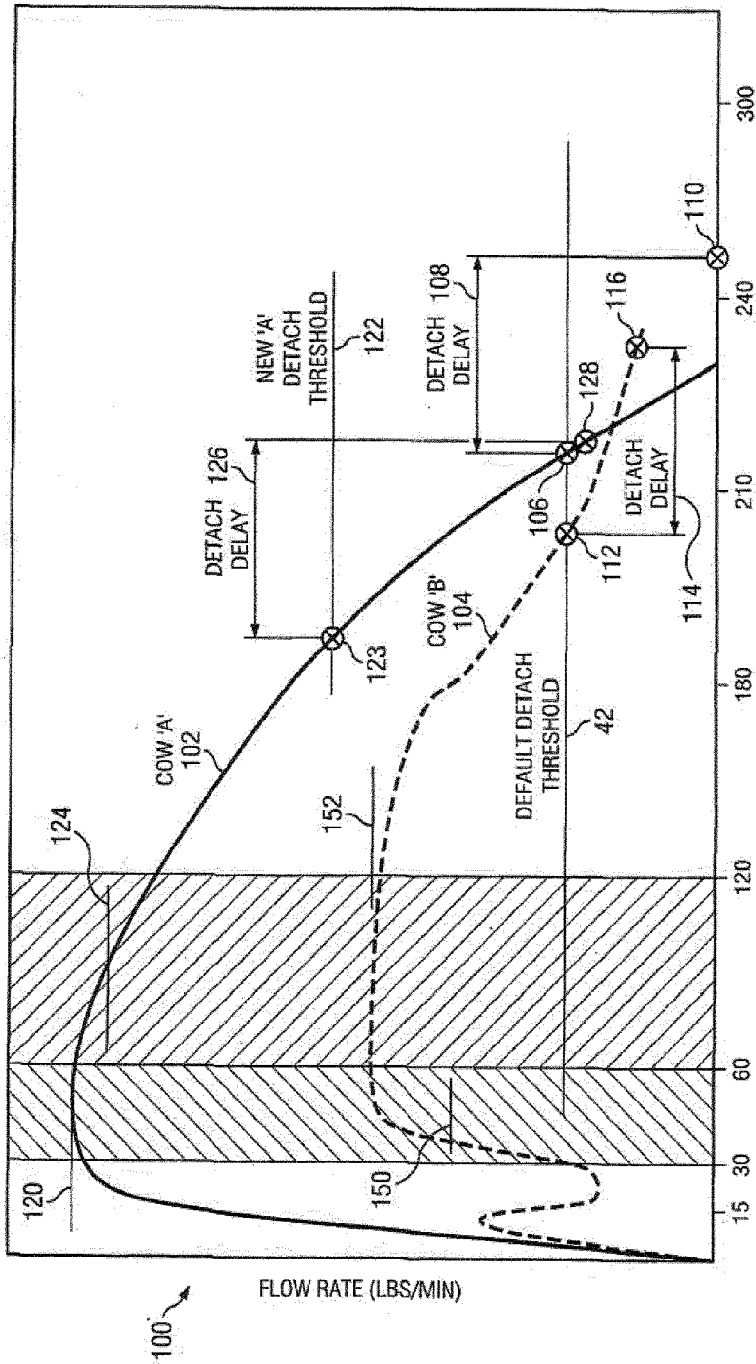


FIG. 2

46 ↗

	202a	202b	202c	202d	202e	202f	202g
	PEAK FLOW RATE (LB./MIN)	BASE DETACH THRESHOLD PERCENTAGE	CALCULATED DETACH THRESHOLD PERCENTAGE COEFFICIENT	DETACH THRESHOLD PERCENTAGE RESULT	BASE DETACH DELAY (SEC.)	CALCULATED DETACH DELAY COEFFICIENT	DETACH DELAY RESULT (SEC.)
204a	0 - 2	60%	0.6	36%	5	1.8	9.0
204b	2.01 - 4	60%	0.7	42%	5	1.6	8.0
204c	4.01 - 6	60%	0.8	48%	5	1.4	7.0
204d	6.01 - 8	60%	0.9	54%	5	1.2	6.0
204e	8.01 - 11	60%	1.0	60%	5	1.0	5.0
204f	11.01 - 14	60%	1.1	66%	5	0.8	4.0
204g	14.01 - 18	60%	1.2	72%	5	0.6	3.0
204h	OVER 18	60%	1.3	78%	5	0.4	2.0

FIG. 3

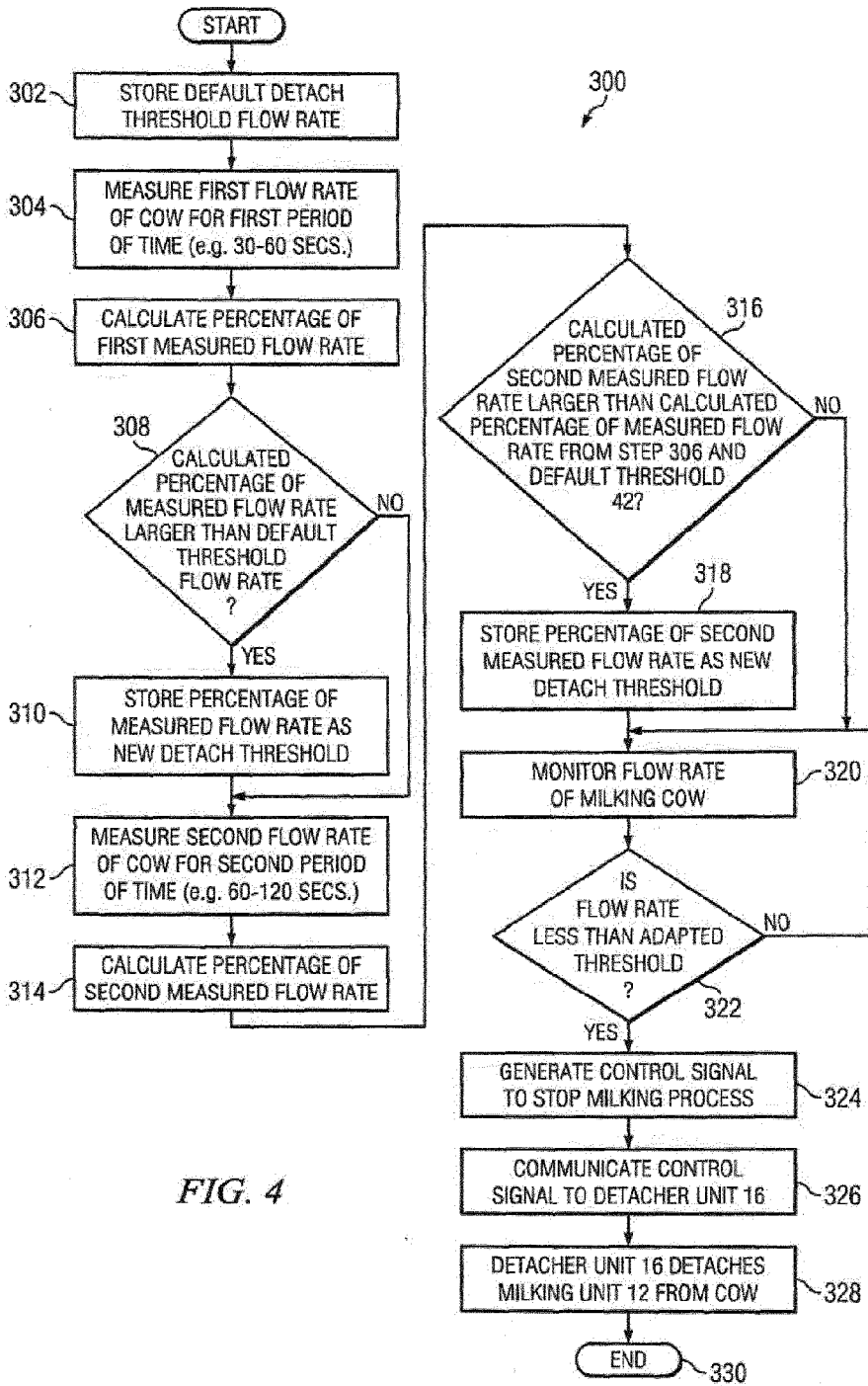


FIG. 4