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# Milking performance evaluation and factors affecting milking claw vacuum levels with flow simulator

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## ABSTRACT

Milking performance of milking machines that matches the production capability of dairy cows is important in reducing the risk of mastitis, particularly in high-producing cows. This study used a simulated milking device to examine the milking performance of the milking system of 73 dairy farms and to analyze the factors affecting claw vacuum. Mean claw vacuum and range of fluctuation of claw vacuum (claw vacuum range) were measured at three different flow rates: 5.7, 7.6 and 8.7 kg/min. At the highest flow rate, only 16 farms (21.9%) met both standards of mean claw vacuum ≥35 kPa and claw vacuum range ≤ 7 kPa, showing that milking systems currently have poor milking performance. The factors affecting mean claw vacuum were claw type, milk-meter and vacuum shut-off device; the factor affecting claw vacuum range was claw type. Examination of the milking performance of the milking system using a simulated milking device allows an examination of the performance that can cope with high producing cows, indicating the possibility of reducing the risk of mastitis caused by inappropriate claw vacuum.

**Key words:** *claw vacuum, claw vacuum range, flow simulator test, mastitis, milking performance.*

## INTRODUCTION

Bovine mastitis causes the greatest economic loss to dairy farmers among all of the diseases affecting dairy cows. There is a range of factors for the occurrence of mastitis, including the dairy farm's cattle shed facilities, cow management practices, milking procedures and milking machines, cattle wellbeing, feeding management methods, quality control of feed and management of heifer cows. It is therefore necessary to examine the risk for occurrence of mastitis in all areas of dairy farming, and to develop measures to reduce each individual risk and prevent mastitis. Among the studies of factors for occurrence of mastitis, there are many reports concerning milking procedures (Natzke *et al.* 1978; Galton *et al.* 1982, 1986, 1988; Rasmussen *et al.* 1991; Magnusson *et al.* 2006) and milking machines (Natzke *et al.* 1978; Mahle *et al.* 1982; Baxter *et al.* 1992; Rasmussen & Madsen 2000; Ambord & Bruckmaier 2010; Enokidani *et al.* 2015; Mein & Reinemann 2015; Besier & Bruckmaier 2016; Besier *et al.* 2016). Baxter *et al.* (1992) report that the occurrence of mastitis is associated with liner slip, Mahle *et al.* (1982) reported an association with set operating vacuum and pulsation function, and Natzke *et al.* (1978) report an association with the milking times. In each of these cases, occurrence of mastitis was shown to increase due to inadequacies in milking machines.

Inspections of milking machines (Reinemann *et al.* 2005; Mein & Reinemann 2015; Besier & Bruckmaier 2016; Besier *et al.* 2016) may be carried out through observations; through dry testing, in which the milking machine is activated and the machine is checked without actually performing milking; and through dynamic testing carried out during milking. Observations means that the machine is examined by eye to look for any abnormalities, so the results depend upon the skill of the person carrying out the examination. While experience is probably not needed to identify deteriorated tubes or to discover air leaks, it would be very hard for someone with no experience of dry testing to diagnose deficiencies in the tubing configuration. Moreover, while crushed tubes become apparent through differences during dynamic testing, these could well be overlooked during observations unless the observer has experience of dynamic testing and is

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familiar with its associated problems. Conversely, it is necessary during testing to detect the problems of observations during dynamic testing. Dry testing can diagnose problems with vacuum in the pipes line (flow of air), but this method cannot be used to evaluate the milking unit from the milk line to the milking claw because the test does not include the flow of milk during milking. Dynamic testing allows evaluation of the effects of the milk flow on the milking system, but great care is needed in the interpretation of the results because the load on the milking machine is not constant, as milk yields vary each time milking is carried out. Thus, while the machine may pass the dynamic testing at low load (low milk yield), this does not guarantee that it will pass at high load (high milk yield). The test methods for milking machines that have conventionally been used are thus able to test for pass/fail at existing milk yield levels, but are unable to assess the status of milking machines at times of high load (high milk yield). During milking time test, it is important to diagnose whether high-producing cows, which have the greatest economic benefits, can be milked without the risk of mastitis. Therefore, rather than testing with the mean load from the mean milk yield, there is a need for diagnosis under a high load from the highest milk yield.

The health of the teat end is essential for mastitis prevention, and Mein and Reinemann (2015) and Reinemann *et al.* (2005) have put forward the claw vacuum and the claw vacuum range (the difference between maximum vacuum pressure and minimum vacuum pressure) during milking that are needed to maintain teat health. High claw vacuum during milking time directly damages the teat end. On the other hand, low claw vacuum reduces the milk flow rate, thereby extending the milking time, again damaging the teat end (Besier & Bruckmaier 2016). Inappropriate claw vacuum and claw vacuum range can therefore damage the teat end, and facilitate the occurrence of mastitis (Baxter *et al.* 1992). Consequently, the claw vacuum and the claw vacuum range must be kept within fixed limits during milking regardless of milk yield. The items of the unit parts that have been reported to affect claw vacuum are the milk tube length, aperture diameter, constricted aperture diameter, tubing configuration, lift formation, claw type, and use of a milk sampler (Enokidani *et al.* 2015). Furthermore, the performance of a milking machine (maintenance of claw vacuum and claw vacuum range on milking time when milk production is high) during milking may possibly limit the milk yield of machine-milked cows. In other words, if the performance of the milking machine is less than the cow's actual production capability, the milk yield may be limited by the performance of the milking machine, making milking performance a factor that inhibits milking appropriate to lactation physiology. This is a particular problem with high-producing cows, and as it prolongs milking time and affects the health of the teat end (Besier & Bruckmaier 2016), it is a possible risk factor for mastitis. From the foregoing, maintaining the appropriate claw vacuum and claw vacuum range from low load to high load is important for ensuring milking that corresponds to the lactation physiology of the cow and for ensuring the health of the teat, and is essential for mastitis prevention, particularly in high-producing cows.

Simulated milking devices (Reid 2002; Reinemann *et al.* 2005; Enokidani *et al.* 2015) are capable of simulating milking at a fixed load (flow rate), and can recreate conditions closely resembling actual milking. Such devices can be used to inspect claw vacuum and claw vacuum range during simulated milking from low load to high load by setting the desired values of milk yield (load).

In the present study, a model recreating milking from low load (low milk yield) to high load (high milk yield) by means of a simulated milking device was used to evaluate the performance of milking machines by measuring claw vacuum and claw vacuum range and to clarify the risk factors affecting claw vacuum and claw vacuum range.

## MATERIALS AND METHODS

### Dairy farms

Flow experiments (Wet test) using a simulated milking device were carried out at the milking parlors of 73 dairy farms during the period from November 2000 to March 2015. The milking machines used in the dairy farms ranged in size from a four-cow double to a 60-point rotary parlor, with 39 farms using the herringbone system, 24 farms using the parallel system, eight farms using the rotary system and two farms using the tandem system. The study was done in accordance with the Declaration of Helsinki (1975, as revised in 2008) and based on the ethics code for animal welfare of Azabu University.

### Flow experiment device

The simulated milking device used in the flow experiments was a Jenny Lynn Flow Simulator (Rocky Ridge Dairy Consulting, Hazel Green, WI, USA), comprising a bucket with a flow meter, and attached to the end of this a flow diverter with four simulated teats. This device allows the simulated milk yield to be changed as desired by adjustment of the flow rate. The simulated teats were located in the four liners in the same way as during actual milking, and held in location with tape to prevent liner slip. Three different flow rates, 5.7 kg/min, 7.6 kg/min and 8.7 kg/min, were set (Reid 2002; Reinemann *et al.* 2005), with an interval of 30 sec from the start of simulated milking for flow rate adjustment. After the 30 sec adjustment interval, the mean vacuum inside the claw (mean claw vacuum), maximum vacuum and minimum vacuum were measured for 2 min using a vacuum measurement device (Triscan, Surge: Babson Bros. Co., Naperville, IL, USA). Claw vacuum was measured by piercing the short milk tube with a 14G needle that was fitted to the measurement device, using a trap to prevent backflow. The fluid used was tepid water, with tepid saline solution used where a milk-meter was fitted in order to make the milk-meter function.

### Milking unit items for analysis

The following eight items, which include those identified by Enokidani *et al*. (2015) as factors affecting milking claw vacuum levels, were analyzed: milk tube length, milk tube diameter, lift formation, vacuum shut-off device, claw type (bottom and top flow), use or non-use of a milk-meter, pressure loss from the milk-meter body, and tubing configurations.

### Method to evaluate vacuum loss from each device in the milking unit

Vacuum loss from each device such as the milk-meter and vacuum shut-off device fitted to the milking unit and the various components was determined by comparing measurement results from flow experiments under normal milking conditions to measurement results taken with each device removed in turn. The effects of milk tube length, milk tube diameter, and claw type were measured using experimental tubes and claws. Milk tube lift formation was investigated by raising the simulated milking device to a high position to cancel lift, so that the formation or otherwise of lift could be determined. In the above conditions, the results for claw vacuum from experiments with and without each device were plotted graphically for comparison, and vacuum loss was considered to have occurred where a difference ≥ 2 kPa was found at the maximum flow rate of 8.7 kg/min. The claw vacuum range was considered to be large if it exceeded 7 kPa (Reinemann *et al*. 2005; Mein & Reinemann 2015; Besier & Bruckmaier 2016; Besier *et al*. 2016).

### Criteria for acceptable milking performance

At each of the three flow rates of 5.7 kg/min, 7.6 kg/min and 8.7 kg/min, which correspond to the high flow range of high-producing cows, a mean claw vacuum ≥35.0 kPa and a claw vacuum range ≤ 7.0 kPa were set as the cutoff values for acceptable milking performance (Mahle *et al*. 1982; Reid 2002). For each flow rate, devices were divided into pass and fail groups based on their milking performance and the eight items were compared between these groups.

### Statistical analyses

Devices were divided into the milking performance pass and fail groups for the measurements of mean claw vacuum and claw vacuum range, respectively, and statistical analysis was performed using Fisher's exact test for the presence of vacuum loss from each of the eight items of milking unit parts at each flow rate. Logistic regression analysis was performed on items with $P < 0.3$ from Fisher's exact test. All statistical analyses were performed with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (the R Foundation for Statistical Computing, Vienna, Austria). This is a modified version of R commander that enables the application of statistical functions frequently used in biostatistics (Kanda 2013).

## RESULTS

### Milking performance of milking parlors

With ≥35.0 kPa as the cutoff for mean claw vacuum, the number of farms that passed was 55 (75.3%) at a flow rate of 5.7 kg/min, 36 (49.3%) at a flow rate of 7.6 kg/min, and 29 (39.7%) at a flow rate of 8.7 kg/min. The number of milking machines that passed thus decreased with increasing flow rate.

With ≤7.0 kPa as the cutoff for claw vacuum range, the number of farms that passed was 31 (42.5%) at a flow rate of 5.7 kg/min, 28 (38.4%) at a flow rate of 7.6 kg/min, and 30 (41.1%) at a flow rate of 8.7 kg/min. Thus, the proportion that passed the standard was similar in all conditions, irrespective of the flow rate (Table 1). The number that passed both mean claw vacuum and claw vacuum range was 26 (35.6%) at 5.7 kg/min, 19 (26.0%) at 7.6 kg/min and 16 (21.9%) at 8.7 kg/min (Table 1).

### Analysis items

The number of farms in which there was judged to be vacuum loss from each analysis item on the basis of the result of flow experiments was: milk tube length, 16 (21.9%); milk tube diameter, 5 (6.9%); lift formation, 26 (35.6%); vacuum shut-off device, 33 (45.2%) and top-flow claw, 26 (35.6%). In addition, milk-meters were installed in 52 farms, of which there was vacuum loss from the milk-meter body in 18 (34.6%) and from the tubing configuration in 36 (69.2%) (Table 2).

**Table 1** Results of claw vacuum level examination with flow simulator

| Flow rate | No. (%) of claw vacuum levels | | No. (%) passed both conditions |
|---|---|---|---|
| (kg/min) | Mean ≧ 35.0 kPa | Range ≦ 7.0 kPa | |
| 5.7 | 55 (75.3) | 31 (42.5) | 26 (35.6) |
| 7.6 | 36 (49.3) | 28 (38.4) | 19 (26.0) |
| 8.7 | 26 (39.7) | 30 (41.1) | 16 (21.9) |

**Table 2** Results of risk factors and vacuum loss examination with flow simulator

| Variables | | No. (%) of over 2 kPa vacuum loss at 8.7 kg/min flow rate |
|---|---|---|
| Milk tube length | | 16 (21.9) |
| Milk tube diameter | | 5 (6.9) |
| Lift formation | | 26 (35.6) |
| Vacuum cut device | | 33 (45.2) |
| Top-flow claw | | 26 (35.6) |
| Milk-meter† | | |
| | Body | 18 (34.6) |
| | Tubing configurations | 36 (69.2) |

†Installed in 52 cases.

## Fisher's exact test

Analysis items showing a significant difference between both groups (passed/failed) for mean claw vacuum at a flow rate of 5.7 kg/min were vacuum loss from the milk-meter body ($P < 0.01$) and tubing configurations ($P < 0.05$); at a flow rate of 7.6 kg/min, items showing a significant difference were vacuum shut-off device ($P < 0.05$) and top-flow claw ($P < 0.01$); at a flow rate of 8.7 kg/min, items showing a significant difference were vacuum loss from the milk-meter body ($P < 0.01$), vacuum shut-off device ($P < 0.01$) and top-flow claw ($P < 0.01$). The only item with a significant difference in value between both groups for claw vacuum range was top-flow claw ($P < 0.05$) at a flow rate of 7.6 kg/min (Table 3).

## Logistic regression analysis

Logistic regression analysis was performed on items with $P < 0.3$ from Fisher's exact test. With mean claw vacuum, milk tube length at a flow rate of 5.7 kg/min ($P < 0.05$), vacuum shut-off device at a flow rate of 8.7 kg/min ($P < 0.01$), and top-flow claw at flow rates of 7.6 kg/min ($P < 0.05$) and 8.7 kg/min ($P < 0.05$) were significantly different from the other items. The remaining items—milk tube diameter, vacuum loss from the milk-meter body and tubing configurations—did not show any significant differences (Table 4). With claw vacuum range, only top-flow claw at a flow rate of 7.6 kg/min ($P < 0.05$) showed a significant difference from the other items (Table 5).

## DISCUSSION

Milk yield changes each time as a result of decrease in claw vacuum. Claw vacuum during milking varies depending on such factors as milk yield at the time of measurement, number of births, number of days in milk, disease and milking skills of the dairy farmer. Claw vacuum does not provide an accurate evaluation of the performance of a milking machine due to these variances.

**Table 3** *P*-values on univariate analysis of risk factors for claw vacuum levels

| | Flow rate | Variables | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (kg/min) | Milk tube length | Milk tube diameter | Lift formation | Vacuum cut device | Top-flow claw | No milk-meter | Milk-meter body | Tubing configurations |
| Mean claw vacuum | 5.7 | 0.06 | 0.09 | 0.41 | 0.17 | 0.17 | 1.00 | <0.01 | 0.03 |
| (≧ 35.0 kPa) | 7.6 | 0.16 | 0.36 | 0.47 | 0.02 | <0.01 | 1.00 | 0.06 | 0.25 |
| | 8.7 | 0.08 | 0.15 | 0.62 | <0.01 | <0.01 | 0.60 | <0.01 | 0.15 |
| Claw vacuum range | 5.7 | 0.40 | 0.07 | 0.46 | 0.35 | 0.34 | 0.61 | 0.18 | 0.16 |
| (≦ 7.0 kPa) | 7.6 | 0.57 | 0.64 | 0.14 | 0.81 | 0.02 | 0.79 | 0.16 | 0.23 |
| | 8.7 | 0.78 | 0.64 | 0.62 | 1.00 | 0.08 | 0.29 | 0.27 | 0.48 |

†Fisher's exact test.

**Table 4** Multivariate analysis of risk factors for mean claw vacuum (≧ 35.0 kpa) on each flow rate

| Variables | Flow rate (kg/min) | Adjusted odds ratio | 95% confidence interval | | *P*-value |
|---|---|---|---|---|---|
| | | | Lower | Upper | |
| Milk tube length | | | | | |
| | 5.7 | 4.67 | 1.140 | 19.100 | 0.03* |
| | 7.6 | 2.76 | 0.775 | 9.830 | 0.12 |
| | 8.7 | 4.42 | 0.907 | 21.600 | 0.07 |
| Milk tube diameter | | | | | |
| | 5.7 | 4.45 | 0.477 | 41.400 | 0.19 |
| | 7.6 | NT | NT | NT | NT |
| | 8.7 | <0.01 | 0.000 | Infinity | 0.99 |
| Vacuum cut device | | | | | |
| | 5.7 | 1.83 | 0.469 | 7.110 | 0.39 |
| | 7.6 | 2.36 | 0.775 | 7.170 | 0.13 |
| | 8.7 | 6.46 | 1.660 | 25.200 | 0.01* |
| Top-flow claw | | | | | |
| | 5.7 | 1.37 | 0.364 | 5.180 | 0.64 |
| | 7.6 | 3.41 | 1.120 | 10.400 | 0.03* |
| | 8.7 | 5.28 | 1.130 | 24.700 | 0.03* |
| Milk-meter body | | | | | |
| | 5.7 | 2.54 | 0.581 | 11.100 | 0.22 |
| | 7.6 | 1.70 | 0.409 | 7.110 | 0.46 |
| | 8.7 | 2.74 | 0.390 | 19.200 | 0.31 |
| Tubing configurations | | | | | |
| | 5.7 | 2.57 | 0.606 | 10.900 | 0.20 |
| | 7.6 | 1.21 | 0.385 | 3.810 | 0.74 |
| | 8.7 | 0.98 | 0.263 | 3.670 | 0.98 |

*$P < 0.05$ was considered statistically significant. NT, not tested.

**Table 5** Multivariate analysis of risk factors for claw vacuum range (≦ 7.0 kpa) on each flow rate

| Variables | Flow rate (kg/min) | Adjusted odds ratio | 95% confidence interval | | *P*-value |
|---|---|---|---|---|---|
| | | | Lower | Upper | |
| Milk tube diameter | | | | | |
| | 5.7 | <0.01 | 0.000 | Infinity | 0.99 |
| | 7.6 | NT | NT | NT | NT |
| | 8.7 | NT | NT | NT | NT |
| Top-flow claw | | | | | |
| | 5.7 | NT | NT | NT | NT |
| | 7.6 | 0.24 | 0.072 | 0.787 | 0.02* |
| | 8.7 | 0.39 | 0.134 | 1.140 | 0.09 |
| No milk-meter | | | | | |
| | 5.7 | NT | NT | NT | NT |
| | 7.6 | NT | NT | NT | NT |
| | 8.7 | 0.55 | 1.181 | 1.670 | 0.29 |
| Milk-meter body | | | | | |
| | 5.7 | 0.56 | 0.151 | 2.100 | 0.39 |
| | 7.6 | 0.42 | 0.094 | 1.850 | 0.25 |
| | 8.7 | 0.64 | 0.185 | 2.240 | 0.49 |
| Tubing configurations | | | | | |
| | 5.7 | 0.66 | 0.225 | 1.940 | 0.45 |
| | 7.6 | 0.99 | 0.306 | 3.230 | 0.99 |
| | 8.7 | NT | NT | NT | NT |

*$P < 0.05$ was considered statistically significant. NT, not tested.

Instead, flow experiments evaluate the milking performance of a milking machine by measuring to what extent claw vacuum decreases through artificially generating a consistently high flow rate. This method is therefore much more reliable since the influence of the above factors seen during actual milking can be excluded. This study adopted the low-line values recommended by Mein and Reinemann (2015) and Reinemann (2005) (35–42 kPa at peak milk yield, claw vacuum range ≤ 7 kPa) as standard values of Mean Claw

 

Vacuum and Claw Vacuum Range. In addition, a variety of three flow rates were used for flow experiments: 5.7 kg/min, which is the rate used by Reid (2002) and Reinemann *et al.* (2005) for adjusting the setting of operating vacuum of milking machines, and 7.6 kg/min and 8.7 kg/min, which mimic milking during high production.

Of the 73 farms where experiments were carried out, the milking performance of milking machines during the highest flow rate met the above standard of mean claw vacuum at 29 farms (39.7%) and claw vacuum range at 30 farms (41.1%). Both standards were met at only 16 farms (21.9%). Since maintenance of mean claw vacuum becomes increasingly difficult as flow rate is raised, the number of farms meeting the standard of mean claw vacuum dropped as flow rate rose. However, no clear correlation was found between claw vacuum range and flow rate. This is probably because when claw vacuum decreases, upper limit and lower limit both decline by the same margin, thereby minimizing any fluctuation in claw vacuum range. In this study of milking performance by flow experiments, the performance of 78.1% of the farms were considered as being inadequate, so it has become apparent that the milking performance of the milking machines that were investigated is insufficient to cope with year-to-year growth in production capability brought about by genetic improvements and better feeding management.

Statistical analysis of the items affecting mean claw vacuum at varying flow rates shows significant differences between the farms that were above or below the standard in vacuum loss from milk-meter body, vacuum shut-off device and claw type. Each of these items affects vacuum supply into the claw. It is likely that milk flow inside milk tubes becomes congested at narrow parts of each device in the system, so that vacuum supply to the claw weakens, leading to a reduction in claw vacuum. Furthermore, it may be conjectured that when flow rate is increased, milk flow becomes congested more frequently, and this would aggravate the effects of narrow sections. Leaving claw type aside, milk-meter and vacuum shut-off device are essential pieces of equipment for milking parlors, so problems with existing milking machines are thought to include faults with methods of installation relating to milk-meter and the performance of accompanying components (problems associated with year of manufacture, etc.). Milk-meters may be fitted with a vacuum shut-off device, or vacuum shut-off device may be separate. Where a vacuum shut-off device is fitted, vacuum is often used to make the device work. In this construction, the use of vacuum restricts the range of motion of a diaphragm, allowing milk to flow through the narrow part of the shut-off device. This mechanism is likely responsible for loss of vacuum from the milk-meter body. With regard to claw type, claws may be top-flow or bottom-flow, and with the top-flow type the vacuum is lost due to the presence of parts within the claw that, although small, form lift in the flow of milk (structures that suck up milk).

Claw vacuum range is caused by changes in vacuum supplied to the claw as a result of the pipe through which milk flows undergoing repeated cycles of being alternately blocked and unblocked by milk. If a milk tube is constantly full of milk, claw vacuum itself will decrease and fluctuation between upper and lower values will diminish. This means that claw vacuum range does not necessarily reach the maximum at the highest flow rate, and it also means that a small range alone cannot be interpreted as good performance—mean claw vacuum and claw vacuum range need to both meet the required standards. In this study, claw type is the only factor contributing to a significant difference in claw vacuum range. This is probably because as with milk tubes, problems occur with drawing milk and supplying vacuum. With the top-flow claw, milk is drawn upwards, so that the lift part of the inside of the claw is always blocked by milk; whereas the bottom-flow type uses flow of air from a bleed hole, so that milk can flow even if it does not completely block the pipe. This structural factor is likely to be the reason why claw type affects claw vacuum range.

The extent to which each factor affects claw vacuum was investigated by logistic regression analysis for each flow rate, and it was found that the particular item that had a significantly greater impact was milk tube length at a flow rate of 5.7 kg/min, claw type at an increased flow rate of 7.6 kg/min and vacuum shut-off device at a further increased flow rate of 8.7 kg/min. This indicates that with flow restriction of narrow sections, flow restriction of the vacuum shut-off device outruns that of milk tube length as flow rises. Moreover, with the top-flow claw type, mean claw vacuum differed significantly at 7.6 kg/min and 8.7 kg/min because the tubing that creates a small amount of lift inside the claw clearly plays a role in restricting the flow of milk as flow rate increases. With claw vacuum range, only claw type was found to have a significantly increased effect. As noted above, with mean claw vacuum, different constructions of vacuum supply in the top-flow claw heightened fluctuations in vacuum, which were reflected in the measurements. As claw vacuum decreases, claw vacuum range also declines; thus the impact also corresponds with flow rate.

This study was able to pinpoint one particular factor affecting claw vacuum change the most for each of the three flow rates, which demonstrates the strong correlation between flow rate and parts that limit flow. This means that when inspecting milking systems where different flow rates occur due to individual differences between cows, it is necessary to carry out flow experiments under specific conditions for each item of the system until it meets both standards at the maximum flow rate. Vacuum loss due to predetermined conditions for each device will become evident at each flow rate, thus suggesting which part of the milking unit needs rectifying. Upon evaluating the performance of milking machines by using a simulated milking device in this study, approximately 80% of the milking machines were deemed problematic. The problem areas were milk-meter installation, configuration of components attached to milk-meter and claw type. All of these are factors from the time of installation of milking parlors, therefore caution is needed at the installing or constructing stage. In addition, genetic improvement and advancement in feeding management have led to enlarged production capability, with the problem of mastitis becoming increasingly apparent. To reduce the risk of mastitis during high producing periods, examination of the performance of milking machines is crucial not only at the time of installation, but also necessary at regular intervals thereafter. In this regard, the method of flow experiments using a simulated milking device serves as a useful diagnostic tool.

This study reports the first-ever evaluation of milking machine performance and related risk factors using a simulated milking device mimicking milk loads ranging from low to high. The flow experiments performed here and management of the risk factors that were identified will help improve the performance of milking machines for high-producing cows, and contribute to a reduction in mastitis caused by inappropriate claw vacuum.

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