Paper No. 953273
An ASAE Meeting Presentation

EVALUATION OF VACUUM RECORDERS FOR MILKING MACHINE PERFORMANCE TESTING

by

K. Muthukumarappan and D.J. Reinemann
Research Associate Associate Professor
Department of Agricultural Engineering
and
G.A. Mein, Visiting Professor
Depts. of Dairy Science and Medical Sciences
School of Veterinary Medicine
UW-Madison, Madison, WI 53706

Written for presentation at the
1995 ASAE Annual International Meeting
sponsored by
THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
The Society for engineering in agicultural, food, and biological systems
June 18-23, 1995
Chicago, Illinois

Summary:

Keywords:

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PERFORMANCE TESTING[1]

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K. Muthukumarappan, D.J. Reinemann and G.A. Mein[2]

ABSTRACT

Both the new ASAE S-518 standard and the revised draft international standard DIS/ISO 5707 incorporate performance standards for vacuum stability in milking systems. New NMC procedures for system evaluation include dynamic tests for vacuum stability to demonstrate the adequacy of existing or new milking systems. Such dynamic (i.e. milking time) tests require the use of test instruments with response characteristics which are appropriate for the measurement of expected rates of vacuum change in a milking system.

The response characteristics of six different commercial vacuum recorders were measured in a laboratory study. The response of these recorders to vacuum fluctuations with frequency range typical of those occurring in milking systems were tested. Suggestions have been made that vacuum recorders used for dynamic testing should be capable of measuring vacuum fluctuations with frequencies of up to 60 Hz. However, in a study by Tan and Reinemann (1994) vacuum fluctuations in the claw and milkline were typically below 10 Hz with a rate of vacuum change seldom in excess of 50 kPa/s. Most of the recorders currently used are suitable for dynamic testing in the receiver, milkline or the milking claw. However, the fittings used to make connections to these sites were found to suppress the reading of the peak amplitude of high frequency vacuum changes. None of the instruments currently used was found to be suitable for measurement of "teat-end" vacuum rate of change using the recommended measurement connections.

INTRODUCTION

Vacuum recording devices are commonly used to evaluate performance during machine milking and also can be used to assess air-injected slug flow in milklines. Accurate recordings of vacuum levels and vacuum fluctuations during milking provide the best means of demonstrating the adequacy of any milking system. Most modern electronic vacuum recorders may have sufficiently rapid response time for this task. Both the new ASAE S-518 standard and the revised draft international standard DIS/ISO 5707 incorporate performance standards for vacuum stability in milking systems. The new standards now specify a performance guideline rather than a specified number of units on the milkline. The key performance guideline for acceptable vacuum stability in the milkline is not more

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This research is supported by the Hatch Project, College of Agricultural and Life Sciences, University of Wisconsin-Madison.

The authors are K. Muthukumarappan, Research Associate and D.J. Reinemann, Assistant Professor, Department of Agricultural Engineering and G.A. Mein, Visiting Professor, Depts. of Dairy Science and Medical Sciences, School of Veterinary Medicine, UW-Madison, Madison, WI-53706

than 0.6" Hg (2 kPa) transient drop in milkline vacuum below the receiver vacuum during normal milking conditions, including unit attachment and detachment and liner slips but not unit fall-offs. ASAE EP445 (1993) standard specifies that any vacuum recorder which will be used to evaluate the milking machine performance should indicate 90% of total change within 0.2 s. (i.e) the sampling rate should be at least 5 Hz. However ISO/DIS 6690 (1983) standard propose that the vacuum recorder should have a frequency response of at least 500 Hz and that the vacuum differences shall be measured with a maximum error of 10% of the actual difference. Recently, in a study by Tan and Reinemann (1994) vacuum fluctuations in the claw and milkline were typically below 10 Hz with a rate of vacuum change seldom in excess of 50 kPa/s. Johnson et al (1994) studied the effects of using hypodermic needles with different gauges to measure the vacuum fluctuations in a short milk tube. They concluded that the claw vacuum fluctuations can be measured with a 12g needle in the short milk tube.

A Task team of the National Mastitis Council (NMC) Machine Milking Committee proposed new procedures for milking machine system evaluation. This new NMC procedures for system evaluation include dynamic tests for vacuum stability to demonstrate the adequacy of existing or new milking systems. Such dynamic (i.e. milking time) tests require the use of test instruments with response characteristics which are appropriate for the measurement of expected rates of vacuum change in a milking system.

The aim of this study was to determine which commercial recorders, and which recording systems, are suitable for dynamic testing in the receiver, milkline, claw and liner.

OBJECTIVES:

The specific objectives of this study were to:

(1) evaluate different vacuum recorders for milking machine performance testing,
(2) study the effect of different connection fittings on the response of the recording system,
(3) determine which recording systems are suitable for dynamic testing in receiver, milkline, claw and liner, and
(4) propose guidelines for vacuum recording systems used for dynamic testing of milking machine performance.

MATERIALS AND METHODS

The response characteristics of six different commercial vacuum recorders were measured in the Milking Research and Instruction Laboratory at UW-Madison. They are:

(1) Pulsotest III: In this recorder, the pressure sensor converts the pneumatic signals into electrical signals which are then stored in the memory when a measurement is being taken. When the measurement is completed, the microcomputer retrieves the values from the memory, process them and outputs them to the display or printer. This recorder is factory set to measure the pulsation at the pulsator in accordance with ISO/DIN specifications. The sampling rate of this recorder is 100 Hz.

(2) SAII (Bou-Matic System Analyzer): The sampling rate of this recorder is 200 Hz with pulsation calculations were based on average of 5 complete pulsation cycles.

(3) Triscan (Surge Milking System Performance Tester): This recorder evaluates milking machine performance based on Babson recommendations and industry standards. The sampling rate of the recorder is 16 Hz in the vacuum mode and 64 Hz in the pulsation mode.

(4) Digimet 2000 (Western Dairy Research, Inc.): The Digimet 2000 is a microprocessor-based vacuum and pulsation multi-function meter for measuring vacuum level characteristics and pulsation attributes in a milking system. The sampling rate of this recorder is 1000 Hz.

(5) Detco (Dairy Test Equipment Co.): The Detco is an analog data recorder. The fastest chart speed is 0.1 s/div.

(6) Dectrace (Bou-Matic Milking System Test Instrument): The Dectrace is also an analog data recorder. The fastest chart speed is 0.25 s/div.

Simultaneous measurements were made with a data acquisition system (Kiethly DAS20 A/D board and Viewdac software) sampling at 1000Hz (unless otherwise specified) interfaced with a pressure transducer (1 millisecond response time) as the referenence standard for all measurements.

Determination of maximum response rate

The phase of pulsation in which the liner is opened is defined as the a-phase. According to international convention (ISO 3918, 1977) the a-phase is determined by the intersection of the curve with vacuum levels 4 kPa above atmospheric pressure and 4 kPa (1.2 inHg) below working vacuum (Figure 1). Most of the vacuum recorders have automatic procedures to determine the duration of the pulsation a-phase. The a-phase measruement was made near the pulsator as shown in Figure 1. One pulsator outlet was connected to the milking unit and an appropriate tee was connected to the other pulsator outlet. The end of the tee was closed such that the total length was within 2" of the end of the pulsator outlet nipple.The pulsator was operated at the rate of 0.83 Hz.

Three recorders namely SAII, Triscan and Detco were used to measure “a” phase near the pulsator at system vacuum 40, 45 & 50 kPa, respectively to examine the effect of vacuum level on the a-pjhase measurement. In this test the recorders were connected to the pulsator with a long tube (100" long and 5/32" ID).

All the recorders were tested using a short tube (10" long and 5/32" ID) and a long tube (100" long and 5/32" ID) with system vacuum at 45 kPa. The SAII and Digimet recorders were tested with and without filters. The Triscan recorder was tested with a tee, a moisture trap, three hypodermic needles (12, 14, or 16 guage of different lengths), respectively. Above all, the Detco recorder was tested with a tee, a moisture trap and two needles (12 or 16 guage of different lengths), respectively. All the “a” phase data were converted to vacuum fluctuation as kPa/s (response rate).

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Measurement of claw and liner vacuum fluctuations:

An artificial udder was used for this measurement. Water flowrate through the artificial udder was controlled by a pressure regulating valve and variable restrictor, and monitored by a Dwyer variable-orifice flowmeter in the water supply line to the four artificial teats. The artificial teats were designed so that the liquid flowrate through each teat was similar, and flow was stopped by the closing liner as it bevt around the end of the “teat”. Thus, liquid flowed only when the liner was more than about half open, as is the case when living teats are machine-milked. A schematic of the experimental set-up is shown in Figure 2.

A standard commercial milking cluster (Bou-Matic Flo-Star claw with R2CV liners and air vents in each Visi-shell, total air admission 10 l/min, 0.3 cfm) was connected to a milkline mounted 0.3 m (1 ft) below the claw using 16 mm (5/8") internal diameter milk hose. Water flowrate of 4.5 l/min (1.2 gal/min) per udder was used. Vacuum was recorded with Omega Pressure Transducers connected to Viewdac via DAS at the claw bowl and short milk tube. Vacuum was also recorded with other recorders at the claw outlet using a tee and at within the liner using a 12g 3" long hypodermic needle.

Effect of liner slip on claw vacuum fluctuations:

The same experimental set-up described above was used to compare measurements of vacuum fluctuations recorded with Triscan which was connected with different gadgets and Viewdac. The different gadgets used were short tube, long tube, moisture trap, 12g and 16g hypodermic needles. The Triscan was operated on pulsation (64 Hz) and vacuum (16 Hz) modes, respectively. The effect of liner slip was simulated using a computer controlled solenoid valve attached in the short milk tube.

Measurement of vacuum fluctuations in a milkline slug test:

Figure 4 is a schematic of the experimental system used. It was a low-line milking system with 73 mm (3" nominal) milkline. The vacuum pump capacity was 109 L/s (about 115 cfm-ASME Standard). The balance tank volume was 174 L and the total system internal volume was 620 L. Other important dimensions are shown in Figure 4. Water was fed into the milkline through standard 16 mm (5/8") milk hose at various locations (Figure 4) to account for the effects of multiple milking units. A clear section of milkline near the receiver jar allowed for observation of slug formation .

A computer controlled solenoid valve (Figure 4) admitted airflow disturbances into the milkline. Vacuum fluctuation at the milkline-down (downstream of disturbance) was measured using different recorders and a Omega transducer (@ 1000 Hz). The effect different recorder connection gadgets was also studied using long tube, moisture trap and 12g hypodermic needle. For each test, the vacuum fluctuation was measured for at least five slugs.

RESULTS AND DISCUSSION

Maximum a-phase Response Rate

Measured a-phase values at different milking vacuum levels for three recorders are presented in Table 1. The corresponding vacuum fluctuations (response rate) are also presented in the Table 1. In general the a-phase increased with increasing milking vacuum for all three recorders tested. At higher vacuum levels the response rate of the detco recorder was low compared to other two recorders.

Measured a-phase values for different vacuum recorders with different connection gadgets are presented in Table 2. The corresponding vacuum fluctuations (response rate) are also presented in the Table 2. From the data in Table 2 it is clear that the response rate of the recorders decreased with increased length of the connecting tube. The response rate of the SAII recorder with filter was significantly lower than without filter connected to the long tube. However for the Digimet recorder the response rates with and without filter were not significantly different. Addition of moisture trap and different hypodermic needles to the Triscan recorder also reduced the response rates significantly. Similar trend was obtained for the Detco recorder as well (Figure 3).

Measurement of claw and liner vacuum fluctuations:

Vacuum fluctuations measured in the claw and liner using different recorders and connection gadgets are presented in Table 3. Both the vacuum fluctuation and mean vacuum in the claw were higher than in the liner. The Viewdac measured highest vacuum fluctuation both in the claw and in the liner compared to other commercial recorders. Among different commercial recorders the Digimet measured highest vacuum fluctuation in the claw followed by Pulsotest, Triscan, SAII, Dectrace and Detco. However in the liner it was the Pulsotest which measured highest vacuum fluctuation followed by Digimet, SAII, Dectrace, Triscan and Detco.

Effect of liner slip on claw vacuum fluctuations:

Variation of claw vacuum measured by the Triscan (@16 Hz) connected with a 3" long 12g hypodermic needle and Viewdac (@ 1000 Hz) with time for a simulated liner slip is presented in Figure 5. The results of claw vacuum fluctuation measured by the Triscan (operated at 64 Hz) are presented in Figure 6. When the Triscan was operated at 16 Hz the vacuum fluctuations were damped compared to measurements taken using the Triscan operated at 64 Hz. Similar observations were made when the Triscan was operated using different connection gadgets namely short tube (ST), long tube (ST), moisture trap (Trap) and trap & 16g needle (Trap16g). From the vacuum data the vacuum fluctuations were determined for both the Triscan and the Viewdac. The vacuum fluctuation (range) measured using the Viewdac were higher than the Triscan for all the cases. Using the Viewdac results as a reference, the percentage of vacuum fluctuation (range) was determined and presented in Figure 7. From this figure it is clear that the dynamic tests in the claw or liner during milking should be done with a vacuum recording system capable of measuring vacuum rate of change up to 800 kPa/s and, if a digital recording system, with a sampling rate of atleast 16 samples per second.

Effect of slugs on the vacuum fluctuation in a milkline:

All the recorders tested in the milkline study performed very well except the Detco. Average vacuum fluctuations recorded with all the recorders were lower than the Viewdac, in general. The vacuum fluctuation measurements in a milkline slug test using different recorder connection gadgets were not significantly different. This is primarily because of the low vacuum fluctuations in the milkline.

SUMMARY AND CONCLUSIONS

Measured a-phase values at different milking vacuum levels for three recorders showed that the a-phase increased with increasing milking vacuum. At higher vacuum levels the response rate of the detco recorder was low compared to other two recorders. The response rate of the recorders decreased with increased length of the connecting tube. Addition of moisture trap and different hypodermic needles to both the recorders (Triscan and Detco) also reduced the response rates significantly.

From the vacuum fluctuations measured in the claw and liner using different recorders and connection gadgets it was found that the vacuum fluctuation and mean vacuum in the claw were higher than in the liner. The Viewdac measured highest vacuum fluctuation both in the claw and in the liner compared to other commercial recorders. Among different commercial recorders the Digimet measured highest vacuum fluctuation in the claw followed by Pulsotest, Triscan, SAII, Dectrace and Detco. However in the liner it was the Pulsotest which measured highest vacuum fluctuation followed by Digimet, SAII, Dectrace, Triscan and Detco.

When the Triscan was operated at lower sampling rate (16 Hz) the vacuum fluctuations were damped compared to measurements taken using the Triscan operated at higher sampling rate (64 Hz). From the measurements it is clear that the dynamic tests in the claw or liner during milking should be done with a vacuum recording system capable of measuring vacuum rate of change up to 800 kPa/s and, if a digital recording system, with a sampling rate of atleast 16 samples per second.

All the recorders tested in the milkline slug study performed very well except the Detco. The vacuum fluctuation measurements in a milkline slug test using different recorder connection gadgets were not significantly different primarily due to low vacuum fluctuation in the milkline.

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Table 1. Measured a-phase and vacuum fluctuation (VF) values at different milking vacuum levels

Vacuum, kPa	a-phase, msec			VF, kPa/s		
	SA II	Triscan	Detco	SA II	Triscan	Detco
40	20	21.5	16.3	1600	1488	1963
45	25	25.5	33.0	1480	1451	1121
50	30	38.0	59.4	1400	1105	707

Table 2.Measured a-phase and vacuum fluctuation (VF) values for different recorders and connection gadgets

Recorder	Connection gadgets	a-phase, msec	VF, kPa/s
Pulsotest III	short tube	8	4797
	long tube	26	1475
SAII	short tube	12	3249
	long tube w/o filter	15	2599
	long tube with filter	37	1054
Digimet	short tube	4	9669
	long tube w/o filter	13	3001
	long tube with filter	13	2970
Detco	short tube	64	700
	long tube	90	433
Dectrace	short tube	35	1114
	long tube	37	1054
Viewdac	Omega transducer	6	6497
Triscan	short tube	6	6497
	long tube (LT)	32	1208
	LT+12g 3" needle	49	796
	LT+14g 3" needle	116	330
	LT+16g 1.5" needle	156	248
	LT+Trap	64	604
	LT+Trap+12g 3"	83	462
	LT+Trap+14g 3"	195	196

	LT+Trap+16g 1.5"	272	140

Table 3. Measured vacuum fluctuations at the claw and liner using different recorders and connection gadgets

Recorder	Connection gadgets	Liner Vacuum, kPa Mean	Fluctn.	Claw Vacuum, kPa Mean	Fluctn
SAII	with filter	46.2	5.1	48.3	5.6
	w/o filter	46.2	4.6	48.3	4.9
Triscan	with trap	46.3	2.7	47.6	6.1
	w/o trap	---	---	47.6	6.8
Dectrace	with filter	46.1	3.0	46.7	5.0
Detco	with filter	44.7	2.6	44.7	2.2
Digimet	with filter	47.1	6.4	47.8	10.9
	with f&t	46.8	2.8	---	---
Pulsotest	w/o f or t	45.5	7.6	46.3	7.7
Viewdac	N/A	41.2	11.9	43.5	12.1

Table 4. Average vacuum fluctuations (VF, kPa) in a milkline slug test

Gadgets	SAII	Vd*	R*	Detco	Vd	R	Digimet	Vd	R	Triscan	Vd	R
LT	4.70	4.96	94.9	2.93	3.63	80.7	4.19	4.52	92.6	4.58	4.82	95.0
LTTrap	3.46	3.59	96.4	3.66	5.49	66.7	4.49	4.64	96.7	4.63	4.79	96.6
LT12g	4.78	5.39	88.7	4.13	4.70	87.8	4.90	5.08	96.5	5.29	5.40	98.2
LTTr12g	4.36	4.86	89.6	2.44	3.76	64.9	5.13	6.15	83.4	5.15	5.29	97.4

*Vd = Viewdac VFs
R = Range (% of the viewdac reference)