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Design of Pulsator Airlines to Reduce Vacuum Fluctuations in Milking Systems

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Summary:

The intermittent admission of air by multiple pulsators produces vacuum fluctuations in milking systems. These fluctuations can affect milking performance in two ways 1) by altering the characteristics of the pulsation cycle, or, 2) by interfering with vacuum regulation and thereby magnifying the vacuum fluctuation throughout the system. Various designs have been employed to reduce these fluctuations to an acceptable level. These usually involve increasing the diameter of airlines, adding expansion tanks at locations thought to be critical, strategic placement of restrictions in airlines, and connection of the pulsation lines at various locations in the milking system. This paper presents the results of a study to investigate design guidelines for pulsator airline systems to avoid interference with vacuum regulation and to reduce the effects of vacuum fluctuations cause by pulsators to an acceptable level.

Keywords: Milking Machines, Design and Performance

Design of Pulsator Airlines to Reduce Vacuum Fluctuations in Milking Systems

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Introduction

The cyclic admission of air by multiple pulsators, especially when they are operated in synchronism, produces vacuum fluctuations in milking systems. These fluctuations can affect milking performance in two ways 1) by altering the characteristics of the pulsation cycle, or, 2) by interfering with vacuum regulation and further magnifying the vacuum fluctuation throughout the system. It is likely that vacuum fluctuations occurring at the regulator are of greater concern for meeting accepted performance standards. If the fluctuations at the regulator sensor are small (less than 2 kPa), then the risk of regulator ”hunting” is reduced. “Hunting” occurs when the regulator tries to respond to the cyclic fluctuations produced by pulsation system.

The ISO performance standards (ISO, 1996) for pulsator airlines are as follows.

1) *Minimizing vacuum fluctuations:* Vacuum drop during phase “b” shall not be more that 4 kPa below maximum pulsation chamber vacuum.

2) *Minimizing the vacuum drop*: The vacuum drop between the working vacuum in the receiver and any point in the pulsator airline shall not be more than 2 kPa.

ASAE S518 specifies that vacuum fluctuations in the receiver should be less than 2 kPa during normal milking. If the fluctuations produced at the receiver by the pulsation system are kept to a minimum value, the regulator can respond more easily to transient air admission during milking and therefore maintain the performance criteria specified.

Few references are available on the design and sizing of pulsator air line networks for milking systems. Traditional methods rely upon providing sufficient volume (pipe diameter) so that the vacuum fluctuations produced by pulsation are kept to an acceptable value. Field experience has indicated, however, that design of the piping system can have as large or larger effect on the vacuum fluctuations produced by pulsation as changes in piping volume. Various system designs have been employed to reduce these fluctuations to an acceptable level. These usually involve, adding expansion tanks at locations thought to be critical, strategic placement of restrictions in airlines, and connection of the pulsation lines at various locations in the milking system.

In a study on pulsator airline size O’Shea and O’Callaghan (1977) tested two systems, one with ‘ringed’ or looped pulsator airline and one with ‘straight’ or dead-ended lines. ISO criteria were used to assess a failure of the pulsation line. Three different pulsator airline diameters were tested; 25.4 mm, 31 mm, and 38 mm with up to 10, 15, and 20 pulsators on the lines respectively.
Guffey and Spencer (1984) expanded this work to include 31.8 mm, 50.8 mm, and 76.2 mm diameter pulsation airlines. Again, ISO criteria for “b” and “d” phases were used as the indicator of a problem. Three system configurations were used. Two of the configurations were

variations of a dead-ended system, the other being a looped system. Recommendations were made on the number of units that could be operating on a particular line size and configuration.

Tan et al (1990) presented a theoretical and experimental study of the frequency characteristics of vacuum fluctuations caused by air admission to a milking system for the purposes of improving regulator design. Increasing the internal volume of the system was shown to reduce the peak pressure variation but lengthen the recovery time. Increasing vacuum pump capacity was shown to reduce irregular variations but had little effect on periodic vacuum variations. The addition of a strategically-placed reserve tank could attenuate periodic variations but had no effect on irregular variations.

Objectives

The objective of this study was to investigate the effects of various airline system designs on vacuum fluctuations produced by pulsation both in the pulsator airline and at the regulator sensor, and to compare the results with the relevant ISO and ASAE performance specifications. In addition, the results were compared with our proposed performance guideline that the contribution of the pulsators to vacuum fluctuations at the regulator sensor should limited to some acceptable value.

Materials and Methods

A schematic of the test apparatus is illustrated in figure 1. All of the airlines in the experimental system were 76 mm ID, schedule 80 PVC pipe. Up to 32 pulsators were operated with alternating pulsation. A 60:40 pulsator ratio at 60 pulsations per minute was used for the tests presented here. An artificial pulsation chamber with an internal volume of 371 mm^3 was used to simulate the volume contained in the pulsation chambers of two teat cups, two short pulse tubes and 180 cm of long pulse tube. A restriction was added to the tube connecting the artificial pulsation chamber to the pulsator airline so that the “b” and “d” phases measured in the chambers matched those of typical commercial milking units.

Two piping configurations were studied. One configuration was a long looped line, which had 42 m of 76 mm schedule 80 PVC. Thirty two pulsators at a spacing of 1.2 m could be installed or thirty two pulsators at 0.6 m leaving about 21.5 m free on the looped end. The short pulsation line had 21.8 m of 76 mm schedule 80 PVC. This allowed thirty two pulsators at a 0.6 m spacing with 1.3 m free at the looped end. Both the long looped and short looped either terminated in a 166 liter distribution tank (figure 1) or were plumbed directly back to the vacuum pump (figure 2).

Three vacuum transducers were installed on the pulsator airlines (V1, V2, V5 in figures 1 and 2). Transducers were also located in the distribution tank (V3), on the line from the vacuum pump to the distribution tank (V4), and near the regulator sensor (V6 a,b or c). Gate valves were located at the beginning of each pulsator airline, and near the vacuum pump. The vacuum transducers were connected to our data acquisition system and operated at one thousand samples per second. Readings were taken for a three-second period. The system vacuum was set at 49 kPa..

The regulator was placed in two locations (figure 1 and 2): near the distribution tank (R1, Figure 1) and near the sanitary trap (R2, Figure 2). Air was admitted to the branched line (figure 1) and to the milkline (figure 2) to simulate milking clusters. Three vacuum pump capacities were used during the tests: 2300 L/min, 3400 L/min, and 5600 L/min

Results and Discussion

Vacuum recordings for 32 alternating pulsators and system configurations with the regulator mounted at the distribution tank and sanitary trap both with and without restriction in the pulsator airlines are shown in Figures 3, 4, 5 and 6. Note:

1) the vacuum recordings shown in these figures have been offset by about 1-2 kPa to show the fluctuations at individual recording points more clearly.

2) when the regulator was mounted at the distribution tank, the system configuration is as illustrated in Figure 1. When the regulator was mounted near the sanitary trap the system, the configuration is as illustrated in Figure 2.

It is evident that the vacuum fluctuations produced by pulsation appeared in all parts of the milking system. The peak fluctuation at the various measurement locations was affected by the system configuration.

The maximum vacuum fluctuation at the regulator sensor and far end of the pulsator airline for the various system configurations and for increasing number of pulsators is shown in Figures 7 and 8. As the number of pulsators increased, the maximum fluctuation at all measurement points increased for all system configurations. Fluctuations at the regulator sensor and far end of the pulsator airline were reduced when a restriction was placed in the pulsator airline (at the gate valves) for both system configurations. The restriction was chosen to achieve a predefined average vacuum difference across the restrictor with the pulsators operating.

The effect of varying vacuum drop across the restriction on the vacuum fluctuation at the regulator sensor and far end pulsator airline with 32 pulsators operational is shown in Figure 9. Most of the reduction was achieved with a vacuum drop of 0.7 kPa. This value was used for all subsequent tests.

The system configuration and location of the regulator also had a large effect on the vacuum fluctuation at the regulator sensor and far end of the pulsator airline. A greater reduction in vacuum fluctuation at the regulator sensor was achieved by changing system design than by restriction of the pulsator airline.

Several experiments were performed to examine the effects of increasing the system volume on peak vacuum fluctuations. The results of these studies were inconclusive because the effect of increased system volume was dependent upon where in the system the extra volume was added. In some cases the vacuum fluctuations were increased and in others the vacuum fluctuations were decreased in response to additional system volume.

Summary and Conclusions

Vacuum fluctuations caused by the pulsation system can be detected throughout the vacuum system. The largest vacuum fluctuations in these tests occurred at the end of the pulsator airline. The waveform at the end of the pulsator airline was also more erratic than in other parts of the system. Vacuum fluctuations in all parts of the system increased with increasing number of pulsators, for all system configurations. Vacuum fluctuations were not attenuated when passed through a distribution tank. Varying the air-moving capacity of the vacuum pump had little effect on the level of vacuum fluctuation caused by pulsation.

Vacuum fluctuations at the far end of the pulsator airline and at the regulator can be reduced by adding a restriction to the pulsator airline(s). The reduced vacuum fluctuation at the end of pulsator airline resulted from a smoothing of the waveform at that location.

Another method to reduce vacuum fluctuations produced by pulsation occurring at the regulator and receiver is to run separate airlines from the vacuum pump to the pulsator air handling system and the sanitary trap (Figure 2) (as opposed to the pulsator and sanitary trap sharing a common main airline). This configuration places the regulator farther from the source of vacuum fluctuations.

Other successful solutions used commercially include:

1) the independent operation of individual pulsators (that is, not synchronized by a central pulsator controller);

2) sequential operation of small groups of pulsators by a central controller.

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Figure 1. Schematic of test configuration I.

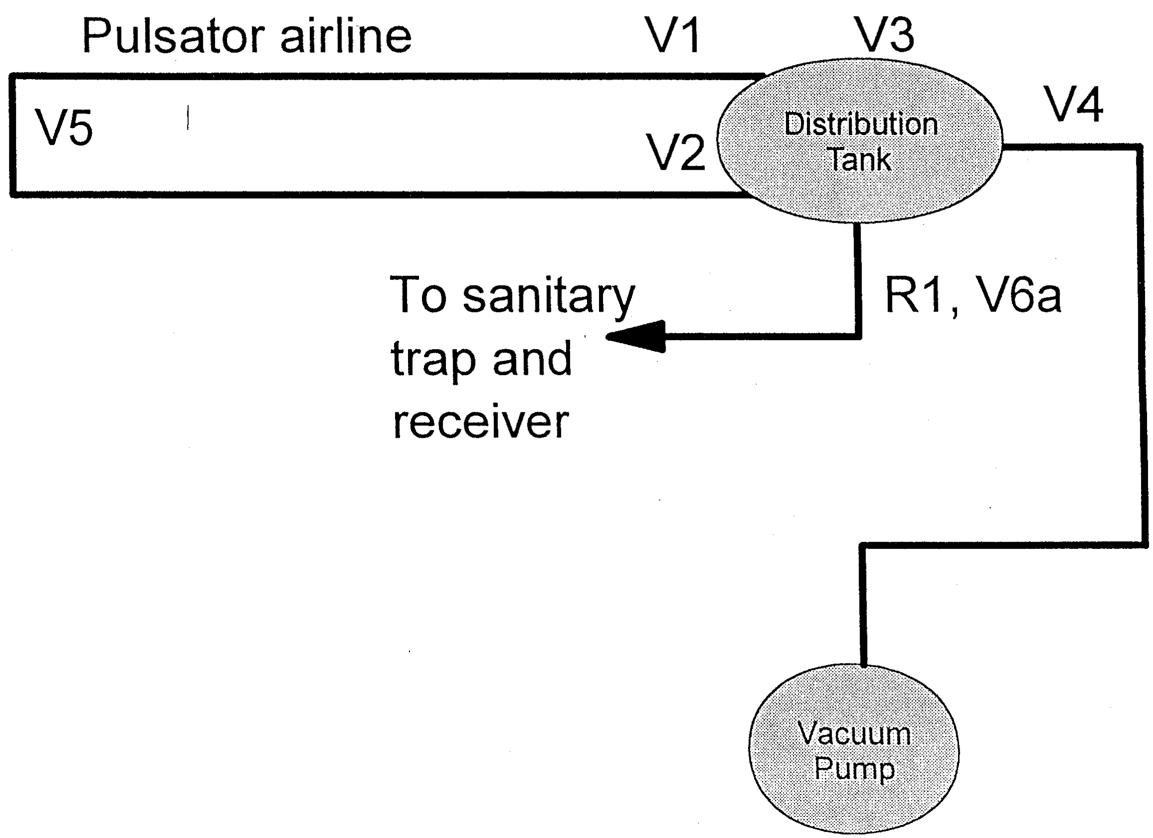

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Figure 2. Schematic of test configuration II.

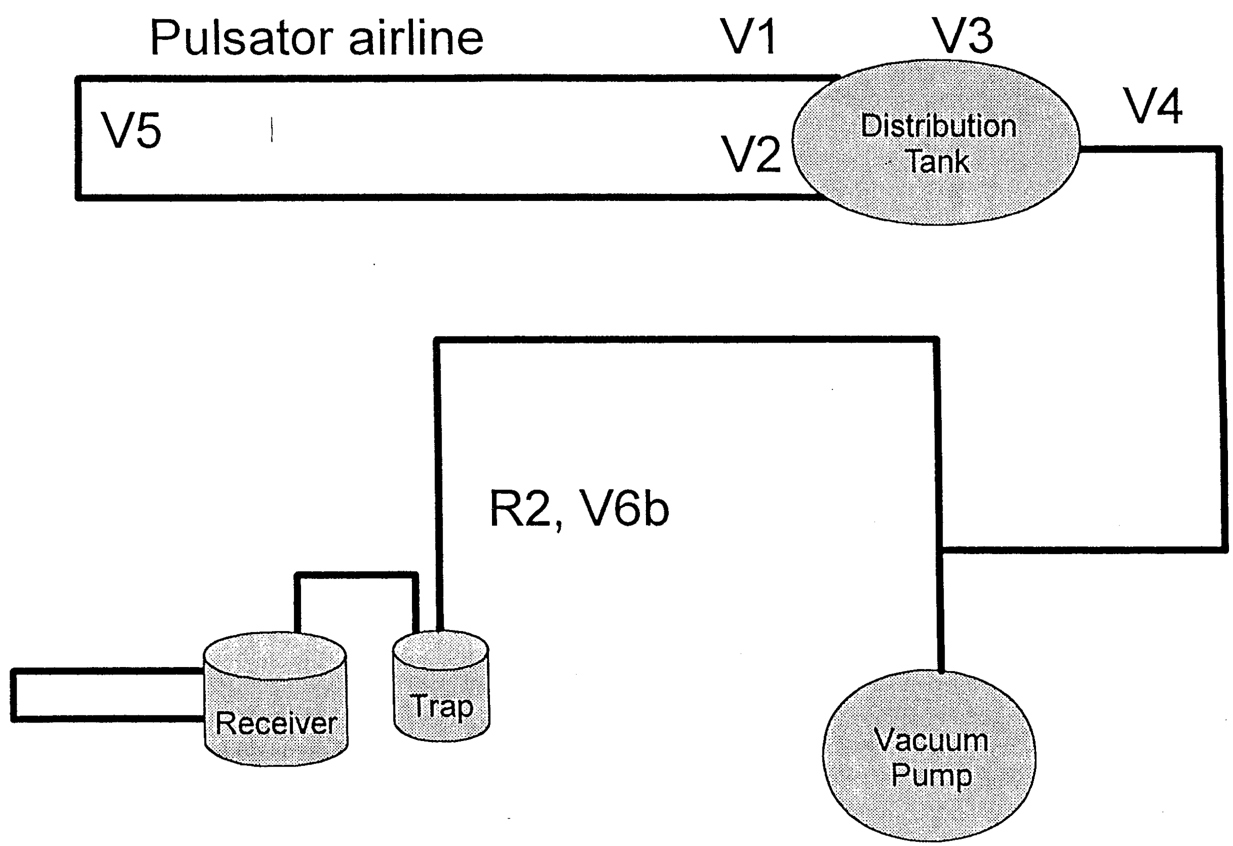

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Figure 3. Vacuum recording with regulator near distribution tank and 32 pulsators. Note: vacuum recordings are offset to facilitate comparison.

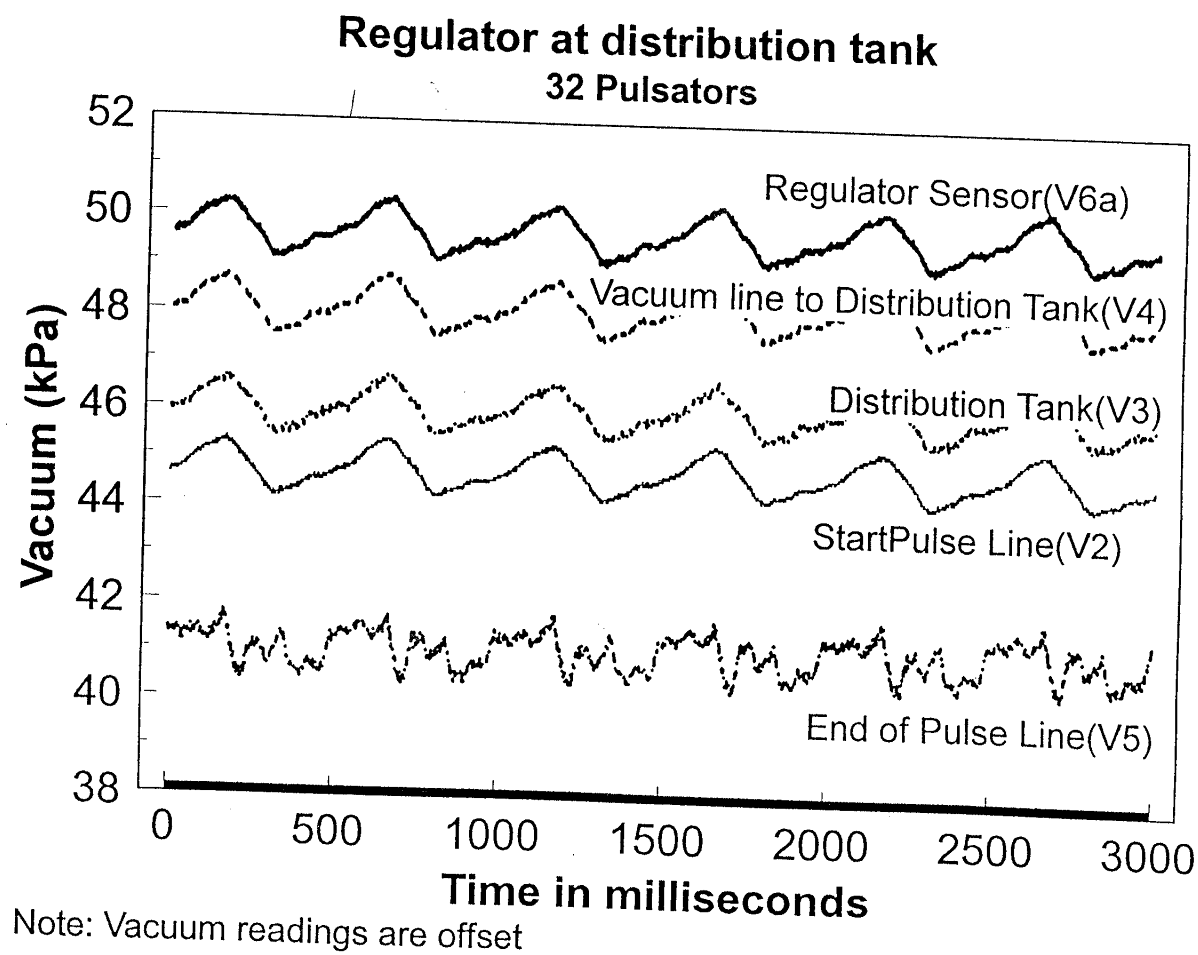

Figure 4. Vacuum recording with regulator near distribution tank, pulsator airlines restricted and 32 pulsators. Note: vacuum recordings are offset to facilitate comparison.

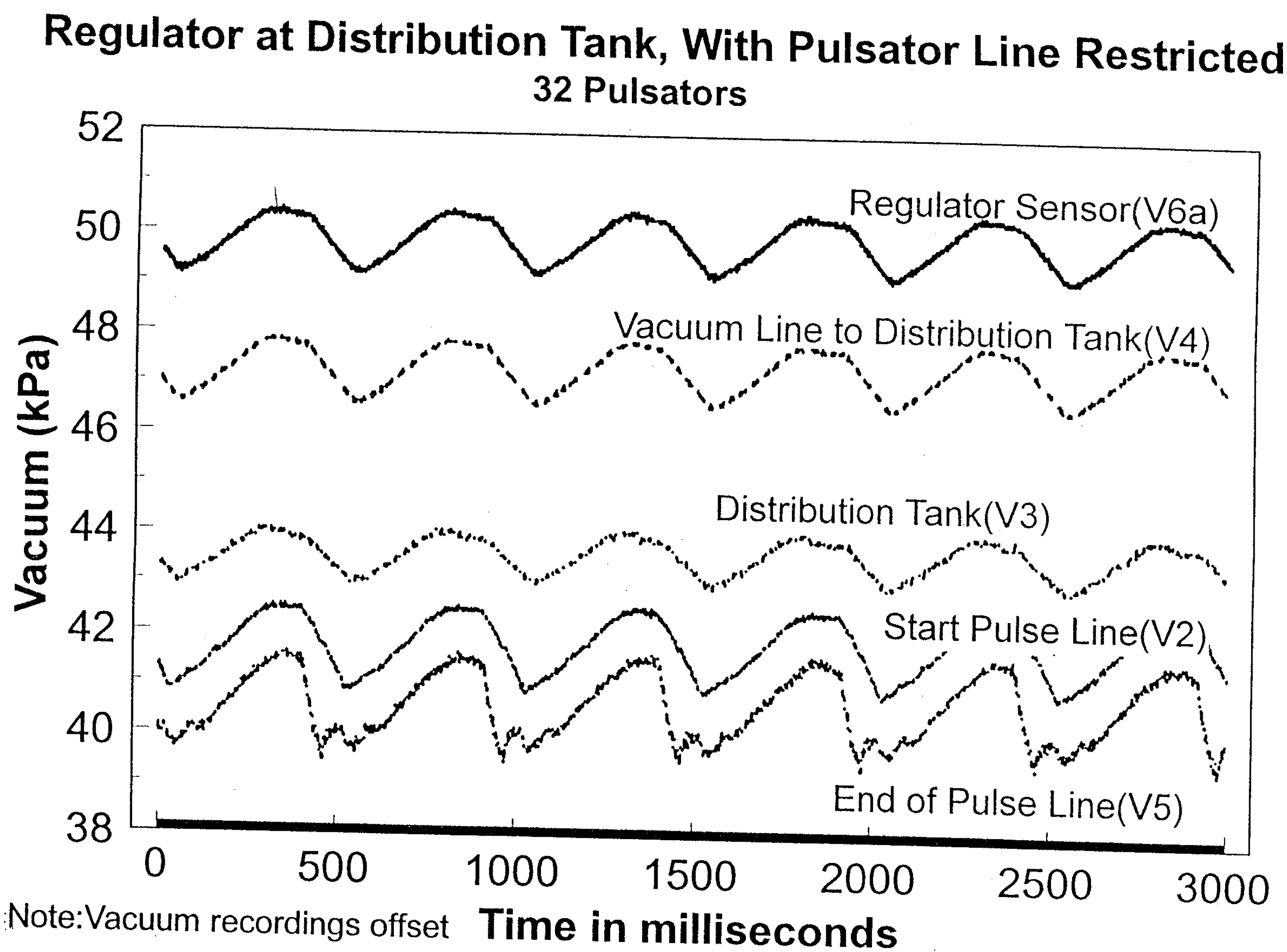

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Figure 5. Vacuum recording with regulator near sanitary trap and 32 pulsators. Note: vacuum recordings are offset to facilitate comparison.

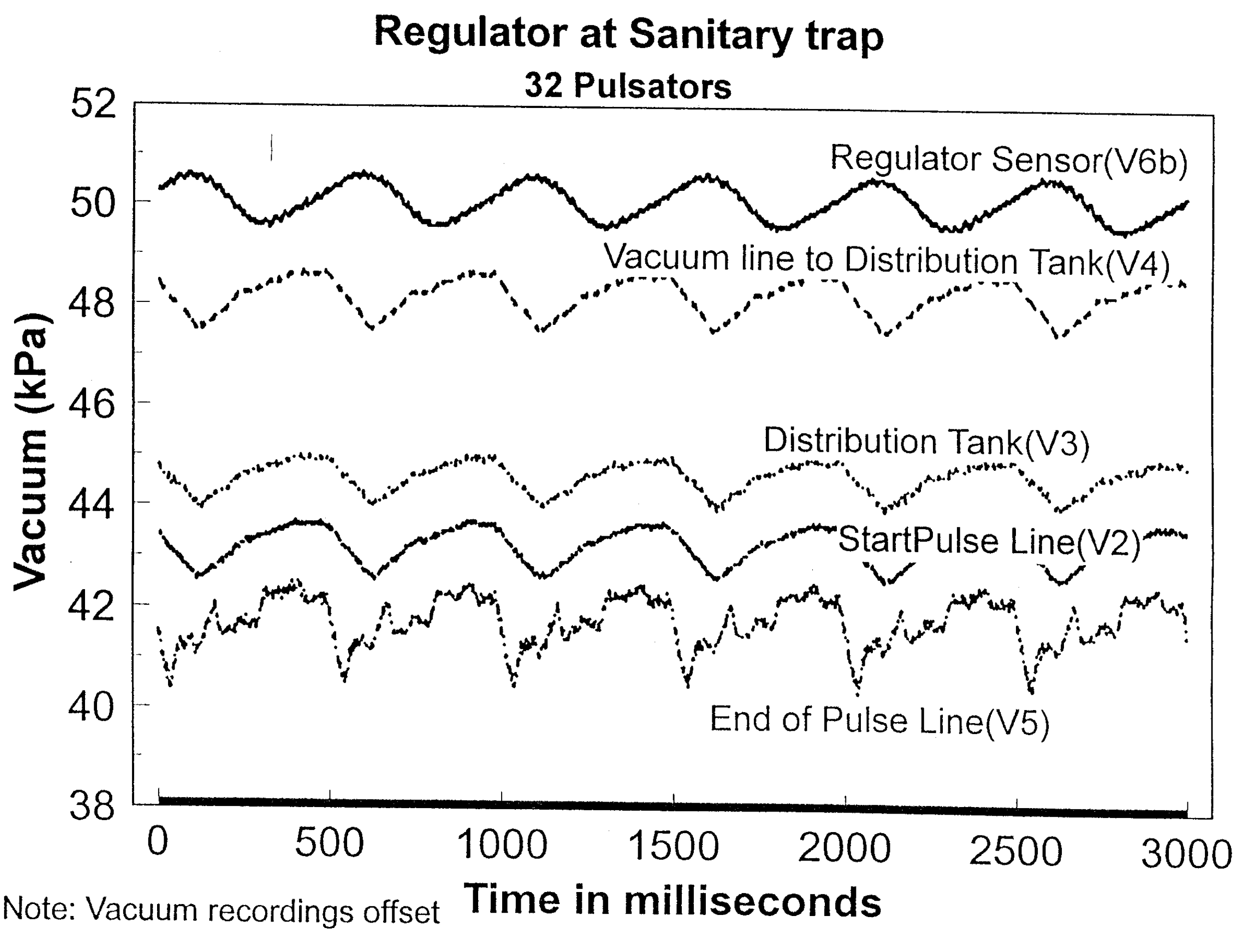

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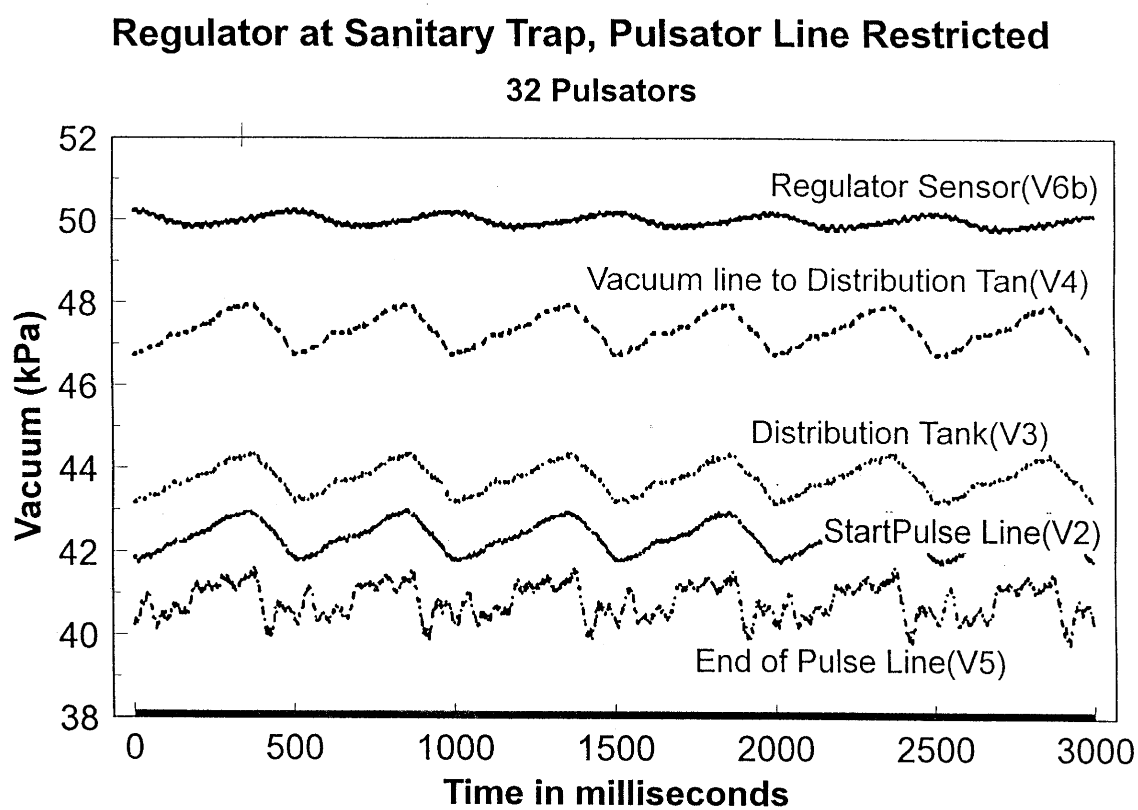
Figure 6. Vacuum recording with regulator near sanitary trap, pulsator airlines restricted and 32 pulsators. Note: vacuum recordings are offset to facilitate comparison.



Note: Vacuum recordings offset

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Figure 7. Vacuum fluctuations at regulator sensor for different system configurations and number of pulsators.

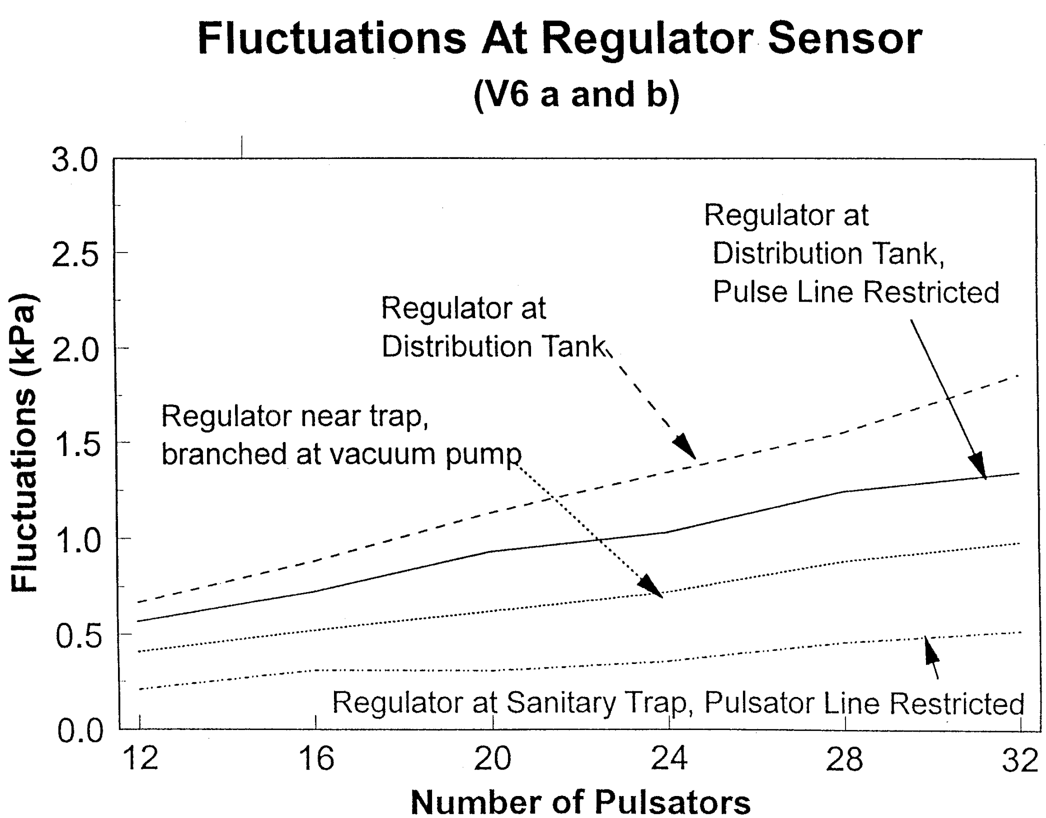

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Figure 8. Vacuum fluctuations at end of pulsator airline for different system configurations and number of pulsators.

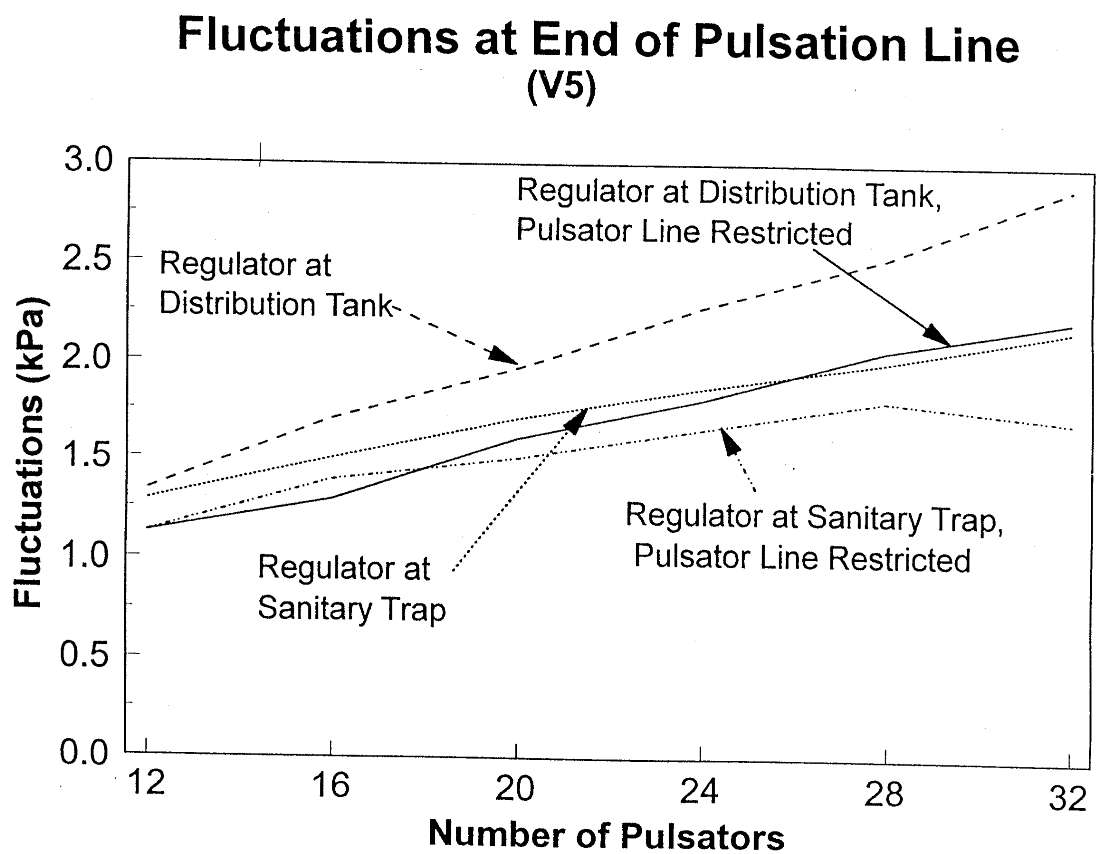

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Figure 9. Effect of pulsator airline restriction on vacuum fluctuations at pulsator airline and regulator sensor with 32 pulsators.