

**FLOW DYNAMICS IN MILKING PARLOR CLEAN-IN-PLACE SYSTEMS**

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**Summary:**

The results of a laboratory study of the air and water flow in air injected milking parlor Clean-In-Place (CIP) systems are presented. The effects of hose length, lift and air admission were examined. The water flow rate through milking units in the US commonly exceeds that thought to obtain adequate cleaning in other parts of the world. CIP flow in milking parlors can be controlled with simple means using proper system design and setup.

**Keywords:**

Milking Machines, Milking Parlors, Cleaning and Sanitation, Energy



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# FLOW DYNAMICS IN MILKING PARLOR CLEAN-IN-PLACE SYSTEMS

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## INTRODUCTION AND LITERATURE REVIEW

Clean-In-Place (CIP) technology is used extensively in milking parlors. A survey of literature, standards and personal communication with authorities familiar with milking parlor CIP practice was conducted to determine current recommendations for successful cleaning of milking parlors. Of particular interest were recommendations for liquid and air injection flowrates, system configurations and the basis for these recommendations.

Although system designs vary considerably, typical features of milking parlor CIP systems are shown in Figure 1. Cycled air injection may enter through the wash water draw line (A1 in Figure 1), the milkline (A2 in Figure 1) or both. When air is injected through the wash line (A1) it is common to include a hose or pipe from the wash draw line directly to the milkline (the dashed line in Figure 1). The diameter of pipes, hoses and equipment components can range from 6 mm in short milk tubes to 98 mm in milklines. Flow velocity and two phase flow patterns are affected by the diameter of system components and method of air injection. Slug flow is normally used to clean milklines, although some system designs flood the milkline during cleaning. The milking units and ancillary equipment may be flooded during cleaning or alternately flooded and emptied using cycled air injection. The use of cycled air injection through milking units has been called controlled flushing pulsation by Lind (1990).

Australian standards (Australian Standards Organization, 1986) require that wash lines be sized to meet the manufacturer's specifications for minimum water flowrate per jetter (although manufacturers do not appear to specify this value). The standard further states that water flowrate should not be less than 3 l/min through any unit and the flowrate through the first unit should not exceed that through the last unit by more than 50 percent. This standard does not give guidelines for air injection methods or air flowrates. Milking parlor CIP systems in Australia and New Zealand are routinely set up according to these water flow recommendations. The common method of measuring flow through units is by catching water in a sealed bucket in line between the milking unit and milkline. Milking unit cleaning apparatus (jettors) are commonly supplied with variable flow adjustment to achieve the desired flowrate and balance between units. Systems installed according to these recommendations have been observed to achieve successful cleaning. It was noted, however, that little work had been done to determine the minimum liquid flowrates needed for cleaning (Hubble, 1994).

British Standards cite a minimum of 1.5 l/min per unit for cleaning milking parlor systems with recorder jars and specify a minimum vacuum pump capacity of 480 l/min for any clean-in-place facility. No guidelines were given in these standards for methods of air injection techniques or air admission rates (BSI, 1988; BSI, 1991). Observations in the field suggested that the minimum acceptable flowrate for cleaning milking units was 3 l/min. Systems with certain types of milk meters were thought to require 7 l/min to 8 l/min per unit. Additional steady air admission through jettors was not considered helpful as it was thought to reduce water flowrate through clusters and promote temperature loss (Baines, 1994).

A recent study by Wolters et al, (1994) showed that increased system vacuum improved the removal of residual milk from milking units and milk meters in flooded systems during the prerinse process. The use of cycled air admission and controlled flushing pulsation also improved prerinse performance without the use of higher vacuum level. No measurements of water or air flowrates were reported, however. Lind, (1990) noted that equal distribution of water to all units is a problem in large parlors and that the capacity of the milk pump is often the limiting factor in the flow through each unit. He also recommends using cycled air admission with air passing through both milking units and the milkline.

Canadian guidelines state that air admission is required but give no details as to the location or volume of air admission (Agriculture Canada, 1990). The 3A Accepted Practices, commonly used in the US as recommendations, do not specify vacuum pump requirements or system details for cleaning but do specify a minimum vacuum pump capacity of 990 l/min (35 cfm) for any system (IAMFES, 1990).

The most extensive published information on milking parlor CIP systems is contained in a 1978 California Extension publication (WREP, 1978). This document suggests that large milking parlor systems should be cleaned sequentially, first washing the milkline and then the milking units by controlling valves in the wash water draw lines. This type of system is commonly used on large parlors in the US with either manually or automatically control valves to divert wash water to various parts of the system. A recent publication describes a similar automatically controlled system as a parallel wash system (Guo et al, 1993). The Western Regional Extension publication states that there is no clear evidence that liners are cleaned more effectively by operating the pulsators during cleaning. It is recommended that air injection should be located so air passes through both the milkline and milking units. No indications are made, however, as to the air and water flowrates required for successful cleaning (WREP, 1978).

One observer of parlor CIP systems in the US suggested that a flow of 16 liters over a 10 minute wash cycle (1.6 l/min) was adequate to clean most milking units. Wide variations in the flow through units were noted as a common problem. Cycled air injection on unit wash lines was considered detrimental, especially concerning balancing flow between units. Steady air bleeds in the jettors were noted as improving cleaning performance (Spencer, 1994).

It is clear from this review that more information is needed for milking parlor CIP design. Current recommendations are not well defined or documented. Little information is available as to the desired flowrate through milking units to achieve adequate cleaning. The benefits of air admission and system design to control air and water flowrates are also not well understood.

## **Objectives**

The objectives of this study were to:

- 1) Determine the flow characteristics of typical milking units,
- 2) Measure the flowrate through individual units and the distribution between units for typical milking parlor CIP system designs and,
- 3) Determine the effect of air admission on unit flow distribution.

## MATERIALS AND METHODS

The apparatus used to measure the flow characteristics of an individual milking unit during cleaning is illustrated in Figure 2. Water was drawn from a wash sink through a 48 mm stainless steel pipe to a milking unit/jetter combination. Water and air then continued from the milking unit/jetter to a weigh jar. Water and air were separated in the weigh jar and air flow continued from the weigh jar to a 73 mm milking line. All hose was 16 mm internal diameter. The total hose length from the water draw line to the weigh jar was varied from 2.4 to 6 m. System vacuum was varied between 30 and 55 kPa. Vacuum was measured in the 48 mm supply line and in the weigh jar. The elevation difference between the water supply line and weigh jar (lift) was varied from 0.7 m (weigh jar above water supply line) to -2.2 m (weigh jar below the water supply line).

A second study was done with 12 artificial units attached to a loop of 73 mm milking line (Figure 3). The artificial units were made of PVC pipe and had an internal volume typical of a jetter/milking unit combination. Air bleed holes were drilled in each artificial unit to admit air flow typical of a milking unit (10 l/min). Restrictions were placed at the inlet of each artificial unit to produce water flow typical of a jetter/milking unit combination. The units were also fitted with air bleed holes that could be opened or closed with air admission rates typical of those found on commercial jetter units (40 l/min). Hose length from the water draw line to the milking line was 3.5 m for all units. The water draw line was located 2 m above the milking line. The elevation difference from the water level in the sink to the wash line was approximately 2 m. System vacuum was set at 45 kPa, typical of low line milking systems. Tests were run with:

- 1) **steady** air admission at each unit typical of claw air bleed with **cycled** air injection to the milking line
- 2) **steady** air admission at each unit typical of claw air bleed plus jetter air bleed with **cycled** air injection to the milking line, and
- 3) **steady** air admission at each unit typical of claw air bleed with **cycled** air injection to the wash water draw line.

The water flow through each unit was measured, one at a time, by catching the water in a weigh jar in line between the artificial unit and the milking line. All measurements were replicated. The pressure difference across each artificial unit and hose was measured in the hoses at the exit from the wash line and the entrance to the weigh jar.

When cycled air was admitted to the milking line the injector was open for 3 s and closed for 13 s with steady air admission through the claw and 17 s with steady air admission at the claw and jetter. The open time was set to allow the slug generated at the wash valve to travel to the receiver. The close time was set so that sufficient water would collect at the milk/wash valve to form a slug. When cycled air was admitted to the wash line an additional hose was connected between the wash draw line and milking line (see Figure 1), as is typical in practice. When cycled air was admitted to the wash line the injector was open for 10.5 s and closed for 15 s. The air injector was open long enough to remove most of the water out from the milking units and hoses. The injector was closed long enough to allow flooded flow to develop in the twelfth milking unit and hose.

## RESULTS AND DISCUSSION

**Unit Flow:** The relationship between water flowrate and vacuum difference across a commercial milking unit/jetter combination is shown in Figure 4 for two experimental conditions. Data with varying lift, hose length and air admission were fit to a model, derived from the Bernoulli equation, in the following form:

$$\Delta V = C_1 + C_2 L_h Q_w^2 + C_3 \Delta Z$$

where:  $V$  = Vacuum difference across jetter/unit/ hose combination (kPa)  
 $C_{1,2,3}$  = Regression coefficients  
 $L_h$  = Hose length (m)  
 $Q_w$  = Water flowrate through unit (l/min)  
 $Z$  = Lift, elevation difference between milkline and washline(m)

The results of the regression analysis are given in Table I. Regressions were also done with a term for the frictional loss through the milking unit/jetter combination. The coefficient on this term was small compared to the term for frictional loss through the hose and not significant. This shows that the milking unit/jetter is not a major restriction compared to the milk hose. Water flowrates through the unit/jetter/hose combination ranged from no flow to over 20 l/min. Increasing hose length, increasing the lift between the wash line and milkline and extra air admission all acted to reduce the water flowrate though the unit for a given vacuum difference. Extra air admission decreased the value of the lift coefficient ( $C_3$ ), as expected because of reduced density of the water column.

Table I. Equation (1) Regression Results.

Jetter Air Admission	$C_1$	$C_2$	$C_3$	$R^2$ , Correlation Coefficient
No	13	0.021	4.2	0.88
Yes	14	0.048	3.1	0.93

**Full System Flow:** Water flowrate through each unit for the full system test with steady air admission at the claw and cycled air admission to the milkline is shown in Figure 5. The highest water flowrate through a unit and the greatest variation between units occurred under these conditions. The water flowrate per unit was about 13 l/min and was relatively constant for units 1 through 9. Water flowrate then dropped sharply to nearly no flow at the twelfth unit. The flow through the first unit was 650% greater than thorough the last unit.

Water flowrate through each unit for the full system tests with steady air admission at the claw and jetter, and cycled air admission to the milkline is shown in Figure 6. Additional steady air admission through the jetter reduced the water flow through the early units and greatly improved uniformity between units. The water flowrate through the first several units was about 10 l/min or about 25 percent less than with only steady air admission at the unit. Flow through the first unit was about 65% greater than the twelfth unit. The sharp drop in flowrate was not observed although this effect may have been beginning at the twelfth unit. Reducing the flowrate through the first units allowed for additional units to be added to the line without starving the later units.

Water flowrate through each unit for the full system tests with steady air admission at the claw and cycled air admission to the wash line is shown in Figure 7. Cycled air admission to the wash

line further reduced water flow through the units. When cycled air admission was added to the wash line, the flowrate through the first several units was further reduced to about 8 l/min reduced through the first unit. The flow through the first unit was 55% greater than through the last unit. It should be noted however that the flow through units and the uniformity between units was greatly affected by the timing of the cycled air injection.

The sharp drop in unit flow observed in Figure 5 was due to the combined unit flow exceeding the capacity of the wash draw line. The flow capacity of the wash draw line is determined by system vacuum, wash draw line diameter and length, and the lift from the wash sink. The flow capacity of the wash draw line for the system configuration tested was about 115 l/min. The test conditions correspond to unrestricted flow through commercial milking units. Increased air admission reduced the flowrate through units. The capacity of the wash draw line was not exceeded and the drop in flow through the last units did not occur. Reduced water flow will reduce cleaning action. Additional air admission, however, also increases turbulence in the milking unit which may aid in cleaning. Another method of reducing water flowrate through units is to add a flow restriction in the hose from the wash line to the jetter. This method also restricts cycled air admission to the wash line. Steady air admission at the jetter allows for independent control of water and air flow. Further studies are needed to determine the optimal combination of water and air flow for various milking units and milk meters.

The vacuum difference across units was not a good indicator of water flowrate in the full system test. Units with low water flowrate had large air volume in the hoses. This significantly increased the vacuum difference across the cluster when compared to hoses flooded with water.

## **SUMMARY AND CONCLUSIONS**

The water flowrate through milking units in the US commonly exceeds that thought to obtain adequate cleaning in other parts of the world. Furthermore, because of the excessive flowrate through the first several units, wash lines may be drained of water. This results in little or no flow through units at the end of the line and a potential cleaning failure. The diameter of the wash water draw line is not a major limitation in most milking parlors. The diameter of the wash water draw lines should be kept as small as possible to reduce the amount of water needed to wash the system.

Adding restrictions at the junction of the milk hose and wash water draw line or at the jetter is an effective way of adjusting water flow to that required for cleaning and balancing the flow between units. The distribution of water flow between units should be as uniform as possible to make the most efficient use of water and air when cleaning milking parlor equipment. The total water draw rate should be no more than required to avoid exceeding the capacity of the milk pump. Milk pump capacity is often the limiting factor in milking parlor CIP systems. Increasing air admission rate decreases the water flow through units but increases turbulence. Further work is being conducted at the UW MRIL to determine optimal cleaning water and air flowrate through different milking units and milk meters. This study indicates that CIP flow in milking parlors can be controlled with simple means and proper system design and setup.

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## Figure Captions

Figure 1. Typical features of milking parlor CIP systems.

Figure 2. Test apparatus used to measure the flow characteristics of an individual milking unit/jetter combination during cleaning.

Figure 3. Test apparatus for full milking parlor CIP system flow study.

Figure 4. Water flowrate versus vacuum difference across a commercial milking unit/jetter combination in single unit study.

Figure 5. Water flowrate through each unit versus unit position for the full system test with steady air admission at the claw and cycled air admission to the milklime.

Figure 6. Water flowrate through each unit versus unit position for the full system tests with steady air admission at the claw and jetter and cycled air admission to the milklime.

Figure 7. Water flowrate through each unit versus unit position for the full system tests with steady air admission at the claw and cycled air admission to the wash line.

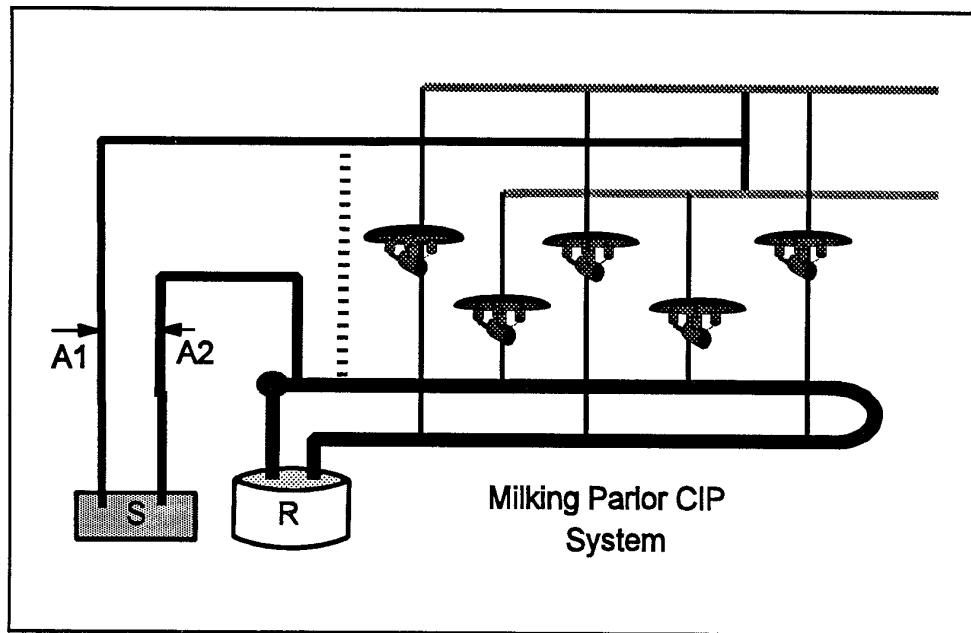


Figure 1. Typical features of milking parlor CIP systems

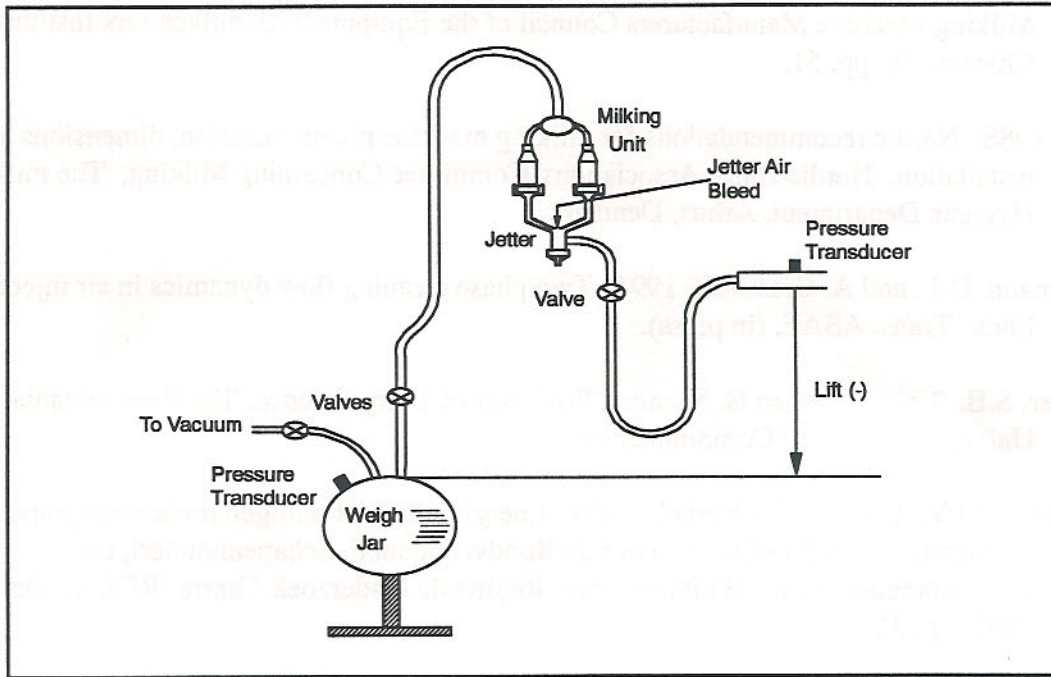


Figure 2. Test apparatus used to measure the flow characteristics of an individual milking unit/jetter combination during cleaning.

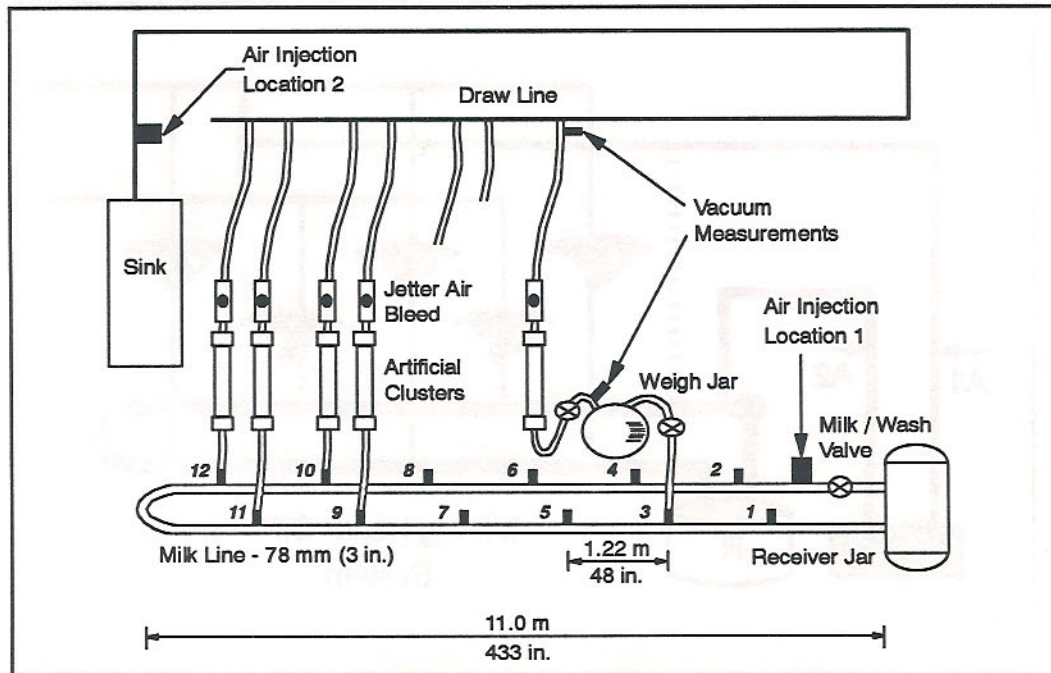


Figure 3. Test apparatus for full milking parlor CIP system flow study.

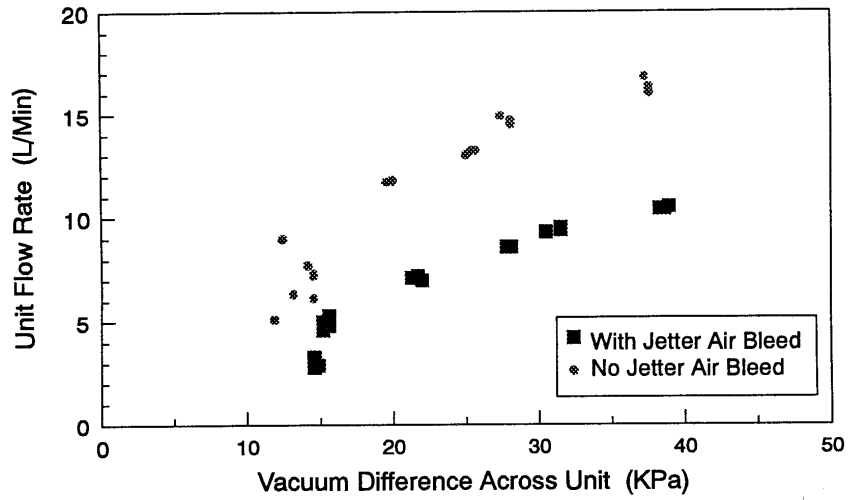


Figure 4. Water flow rate versus vacuum difference across a commercial milking unit/jetter combination in single unit study.

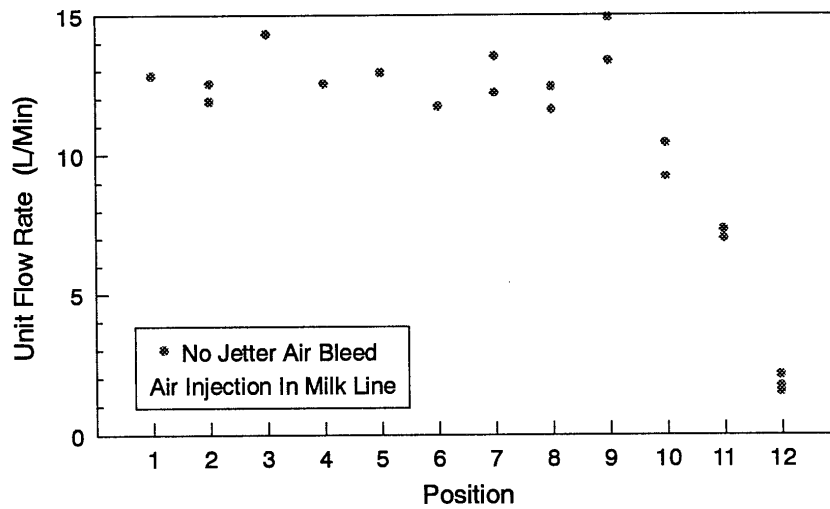


Figure 5. Water flow rate through each unit versus unit position for the full system test with steady air admission at the claw and cycled air admission to the milk line.

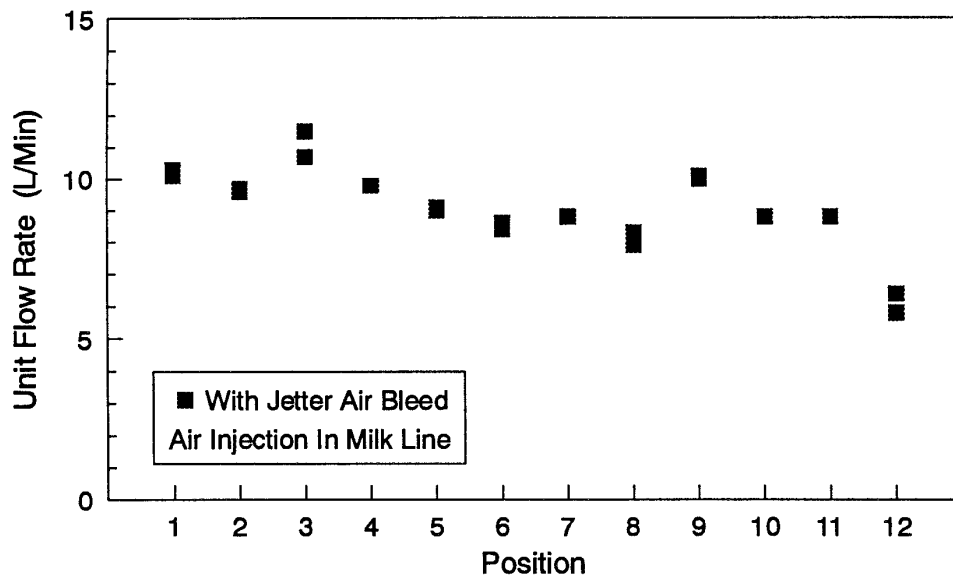


Figure 6. Water flow rate through each unit versus unit position for the full system

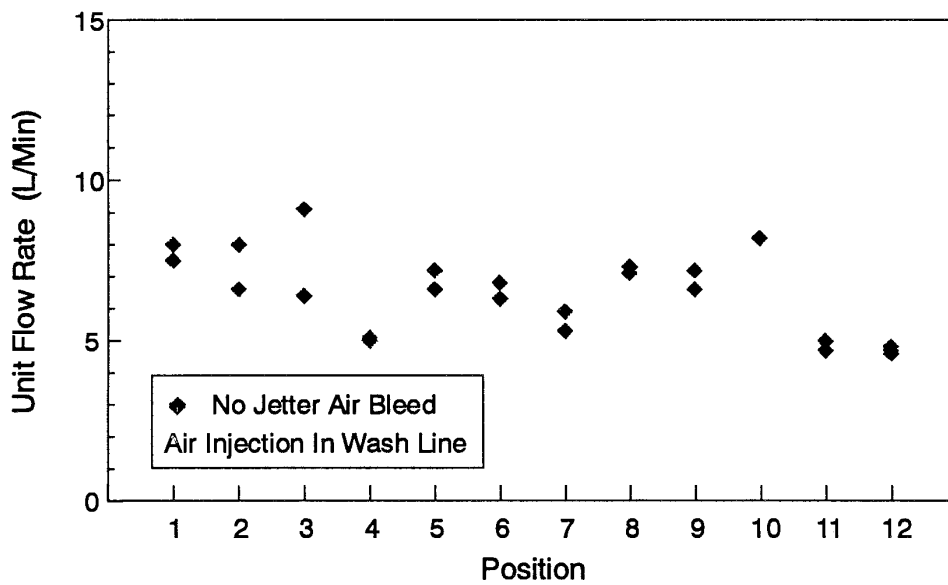


Figure 7. Water flow rate through each unit versus unit position for the full system tests with steady air admission at the claw and cycled air admission to the wash line.