# A STUDY OF THE CLEANING AND SANITIZING OF MILK PIPE LINES

by

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# I

## INTRODUCTION

During recent years many progressive dairy plant operators have become intensely interested in developing new systems or methods for cleaning and sanitizing their milk pipe lines. This interest has been prompted to some extent by the desire to attain stricter bacteriological quality control in dairy products. However, the greatest incentive, for the development of new cleaning and sanitizing procedures, is the desire to find a way to reduce the tremendous labor cost which accompanies the cleaning and sanitizing methods utilized with the conventional pipe line systems in popular usage in most dairy plants. Dairy plant operators have long recognized the fact that the cost of the labor required for the disassembly, cleaning, reassembly, and sanitizing of milk pipe lines, is one of the biggest items in their plant operation expense.

Although everyone concerned is acutely aware of the existing problem, many plant operators have been hesitant toward making changes and thereby utilizing new cleaning procedures. The chief reason for such hesitation seems to be the cost involved in equipment change-over. Likewise, it is a recognized fact that existing health standards must not be sacrificed for the sake of economy. A feasible solution to the existing problem, would seem to be the development of a cleaning procedure which would be satisfactory both from the standpoint of bacterial quality and operational expenditure.

Several studies have been made with the above conception in mind. They were conducted utilizing the principle of non-disassembly or in-place cleaning of the line by means of forced circulation or flush cleaning. Practically all of the above studies were made utilizing pyrex glass and permanent stainless steel as the component materials of the pipe lines. In general, satisfactory results were obtained in these studies. Nevertheless, because the use of the above mentioned materials would involve a considerable cost in equipment change-over, many plant men do not feel that the benefits would exceed the costs for changing to an in-place installation under such conditions.

Therefore, the primary purpose of this investigation was to determine whether or not the conventional or ordinary stainless steel pipe line installations, now in popular use in most milk plants, can be converted to in-place installations, utilizing exactly the same line, to give a satisfactory reduction in cleaning and sanitizing costs and yet allow the plant to maintain efficient bacteriological quality control.

For additional information, a supplementary study was begun using pyrex glass tubing as a substitute for stainless steel in the experimental pipe line.

## II

## REVIEW OF LITERATURE

The use of sanitary pipe in dairy plants dates back to the beginning of the twentieth century according to Buck [3] who states that the part played by a sanitary piping system in a dairy plant is a continuous daily cycle of putting pipe together, using, taking apart, washing, sterilizing and putting up to dry. It is the most used and most handled piece of equipment in the plant. Its construction and shape make it somewhat difficult to wash and detrimental cleaning methods are often used. This continual wear and tear must be remembered at all times in its design and construction.

In referring to the disadvantages of conventional pipe line installations and cleaning methods, Holman [10] states that the demountable piping systems, in common use for noncontinuous operation in smaller milk plants, require a well designed plant and able operators for efficient operation. He further states that the line may not always be either clean or leakproof and likewise that careless handling of pipe sections may often leave dents or scratches on male or female seats of union joints or in seal rings. Likewise, improper sterilization may leave an odor in the pipes which may pass on to the milk.

Haskell [9] states that one of the most expensive and time consuming tasks in the operation of a dairy plant is the complete disassembling, washing, reassembling, and sanitizing of sanitary pipe lines. An evaluation of hand cleaning results over the past years unquestionably reveals a great number of failures to produce clean equipment. The preceding statements tend to bear out the generally accepted idea that demountable piping systems are often unsatisfactory.

Haskell [9] claims that in-place sanitizing of pipe lines has been officially recognized in this country for several years. This claim is based upon Public Health Bulletin 220, Milk Ordinance and Code 1939, which permits the use of various sanitizing methods on assembled equipment. Little [15] and Jacobsen [12] write that circulating cleaning solutions are recommended and used extensively where enclosed systems such as plate heat exchange systems, internal tubular systems, vacuum pasteurizers, and pipe lines are found in large processing plants.

Haskell [9] further states that time studies conducted by disinterested parties show a significant saving in labor in favor of in-place pipe line systems. All segments of properly constructed pipe lines receive equal applications of the cleaning treatment. When cleaning of individual pipe lengths and fitting is performed on dismantled lines, all segments of the line are not always treated equally. He further states that the factors of prime importance in the flush washing of pipe lines are: (1) the construction of the line, (2) concentrations of chemical cleaning compounds, (3) temperatures of cleaning and sanitizing solutions, and (4) the time involved in circulation for cleaning.

In a study made at the University of Illinois in 1950, Moore, Tracy, and Ordal (18) state that they found no measurable pickup of organisms resulting from the use of their experimental permanent pipe line. In this same study they held samples of milk, that has passed through the experimental line, for as long as seven days at 40 °F. These samples showed no marked growth of mesophils and only slight increases in psychrophils. Swab counts on the pipe line were low. They report that while sterility was not attained, the results would be judged excellent by the standards recommended for restaurant utensils. In the Illinois study both glass and ordinary stainless steel were used as the component materials of the pipe line. They state that, bacteriologically speaking, there was no choice between the two.

In any discussion of cleaning systems, it is natural that the cleaning and sanitizing agents used should be discussed. Malmann (16) states that the cleaning of dairy equipment and the type of cleaner used are the most important factors in the production of quality milk with the possible exception of personnel. Kolar (13) claims that the choice of the proper cleaner will greatly reduce the amount of labor involved in cleaning milk equipment.

Jacobsen (12) states that the circulation method of cleaning takes advantage of the fact that the newer types of cleaners on the market have quicker penetrating action on milkstone, improved soil carrying power, and better rinsibility.

Jacobsen (12) further states that usually both acid and alkaline type cleaners are employed where hot milk systems are involved. The acid type cleaner with wetting agent is used to dissolve the milk salts and to cause the milk deposits to become more susceptible to the action of alkaline cleaners. The alkaline cleaner with wetting agent is employed to act upon the remaining protein and fat. Little (15), in speaking of the type of cleaner to utilize, states that one of the fundamentals of any well organized cleaning program is the selection of materials that will give the maximum soil dissolving properties with a minimum of hard labor for each cleaning process.

Another important factor which should be given adequate consideration in any discussion of cleaning systems would be the component materials of the pipe line. There are three possibilities: (1) stainless steel, (2) pyrex glass, and (3) plastic tubing. Canterbury [4] says that plastics are destined to play an important role in the food and dairy industries, and will receive the ever increasing attention of the producer, processor, and allied fields. Possessing the properties of transparency, strength, chemical inertness to most acids, alkalies and salts, particularly those in common use among dairymen, odorlessness, and hardness; Lucite, the boilable type, will withstand a temperature of 235 °F for 15 minutes. It has an unusually high shock resistance for thermoplastics and will probably attain a permanent place in the post-war fabrication of many pieces of dairy machinery, equipment, and supplies.

According to Hucker and Thomas [11], the special qualities of glass-thermol resistance, corrosion resistance, smoothness and hardness, transparency and mechanical strength - seem to be particularly adaptable to dairy pipe line requirements. They further state that glass shows a remarkable reluctance to accumulate films and scale and milkstone deposits, and that glass piping withstands sudden changes from cold to hot or hot to cold temperatures. This makes possible sterilization with hot water or live steam.

Myrick [19] states that possibly one of the most amazing characteristics of stainless steel is its ability to resist corrosion. Subjected as it is in the dairy plant to lactic acid that will destroy concrete, to strong cleaning compounds that quickly corrode lesser metals, and to the daily knocking about that cleaning operations involve, the metal still retains its fine mirror-like luster.

# III

## THE INVESTIGATION

This study was made to secure data concerning bacterial quality and cost analysis of different types of pipe line installations and cleaning procedures.

### A. Objectives of Investigation

The general objective of this study was to determine whether or not a conventional stainless steel pipe line installation as utilized by most dairy plants, can be converted into an in-place cleaning installation which may be cleaned and sanitized effectively and at the same time offer a significant reduction in cleaning and sanitizing costs. The specific objectives are:

(1) To compare a daily disassembly system with an in-place installation, from the standpoint of effectiveness of cleaning, by means of an estimation of the bacterial quality of the milk processed through the lines.

(2) To compare a daily disassembly system with an in-place installation from the standpoint of the labor and material costs involved in the cleaning and sanitizing of the two types of installations.

(3) To determine the advisability of utilizing in-place cleaning methods for both raw and pasteurized milk lines.

B. Outline of Investigation

1. Series I: Cleaning efficiency and cost analysis of a conventional stainless steel pipe line installation under complete daily disassembly conditions.

    a. Description of line

    b. Cleaning procedure

    c. Bacterial quality of processed milk

    d. Sanitizing efficiency

    e. Labor costs

    f. Costs and amounts of cleaning materials

    g. Durability and condition of pipe

2. Series II: Cleaning efficiency and cost analysis of the same conventional stainless steel pipe line under in-place cleaning conditions.

    a. Description of line

    b. Cleaning procedure

    c. Bacterial quality of processed milk

    d. Sanitizing efficiency

    e. Labor costs

    f. Costs and amounts of cleaning materials

    g. Durability and condition of pipe

The remaining sections of this thesis dealing with methods and procedures, results, and discussion of results, are arranged exactly in the same order as the above outline.

C. Description of Facilities

The experimental portion of this study was performed through the utilization of the facilities available in the Virginia Polytechnic Institute Creamery, Blacksburg, Virginia. This modern three story creamery houses the equipment and materials used for the classroom and laboratory instruction of courses taught in the dairy manufacturing curriculum and also provides facilities for processing Grade - A pasteurized milk and ice cream for use in the college dining hall. Facilities are also available for the processing of cheese, butter, condensed milk, and chocolate milk. Laboratories for dairy research, dairy chemistry, and Babcock testing are located in this building.

The milk processing section of the creamery is set up in the following manner: the weigh vat or receiving tank is located on the first floor in the rear of the creamery. The sanitary pipe line begins at the weigh vat and connects on to a Waukesha positive sanitary pump which forces the milk through the line up to the holding vat located on the second floor. The piping system leading from the holding vat is so arranged that the milk can be either pumped to a forewarmer to be prepared for condensing or can be pumped, by means of a centrifugal pump, through a filter and thence to either one or both of two pasteurizers. The piping system leading from the pasteurizers is arranged in such a manner that the milk flows by gravity through the line to a surface cooler and thence to the bottling machine. The creamery processes an average of 4,500 pounds of milk per day, or a total of 1,642,500 pounds of milk per year. The total length of sanitary pipe line is approximately seventy-eight feet. The experimental phase of this investigation was set up to utilize approximately sixty-eight and one-half feet of this line.

The bacteriological phase of this experimentation was performed through the utilization of materials and apparatus available in the dairy research laboratory located in the creamery building. This includes all materials and apparatus necessary for making standard plate counts, coliform counts, and chlorine strength determinations.

Cleaning and sanitizing materials were obtained from creamery supplies.

Labor and cleaning costs were calculated from quotations obtained from creamery records.

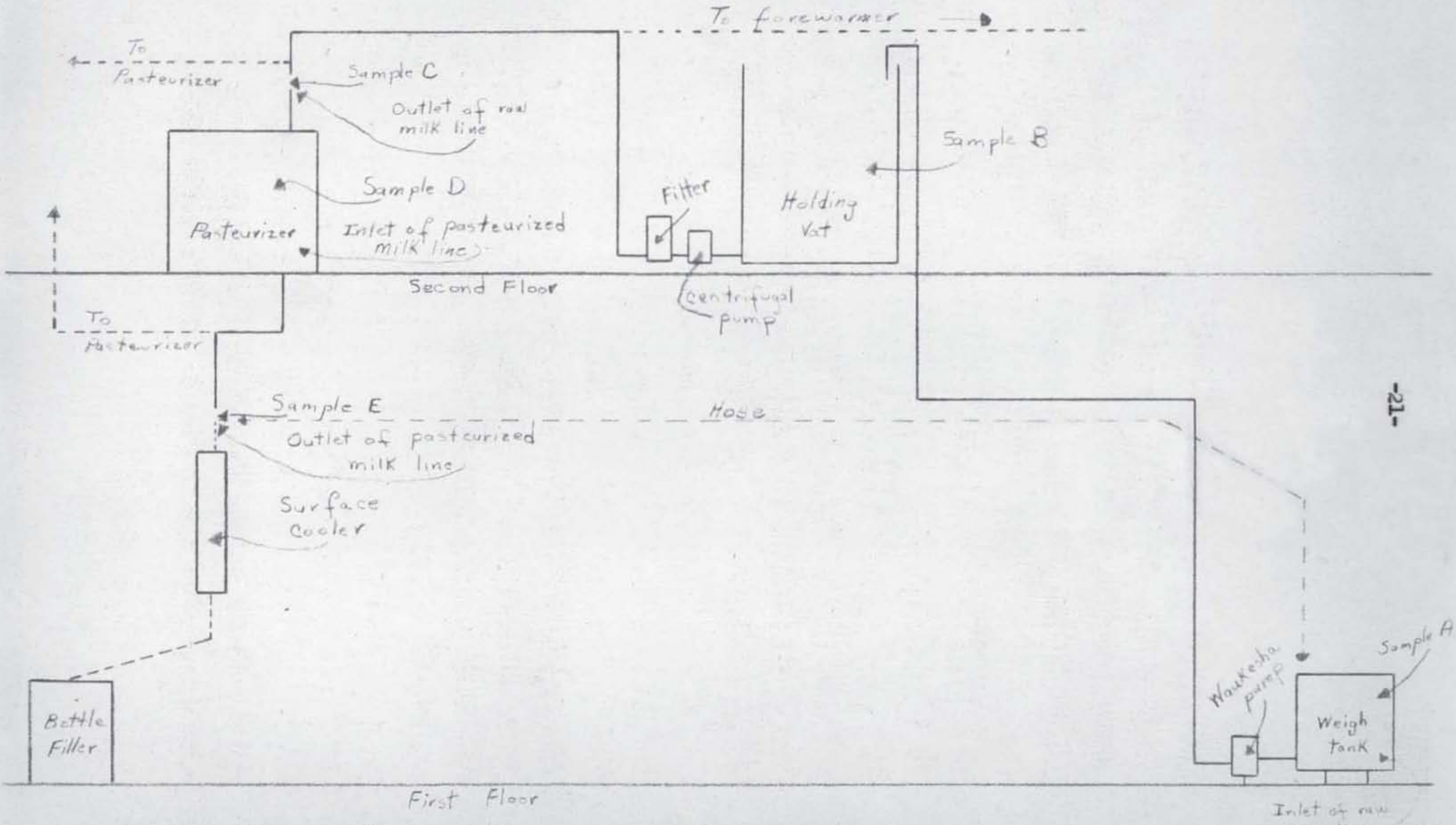


**Figure 1. Drawing of the Entire Experimental Pipe Line Installation**

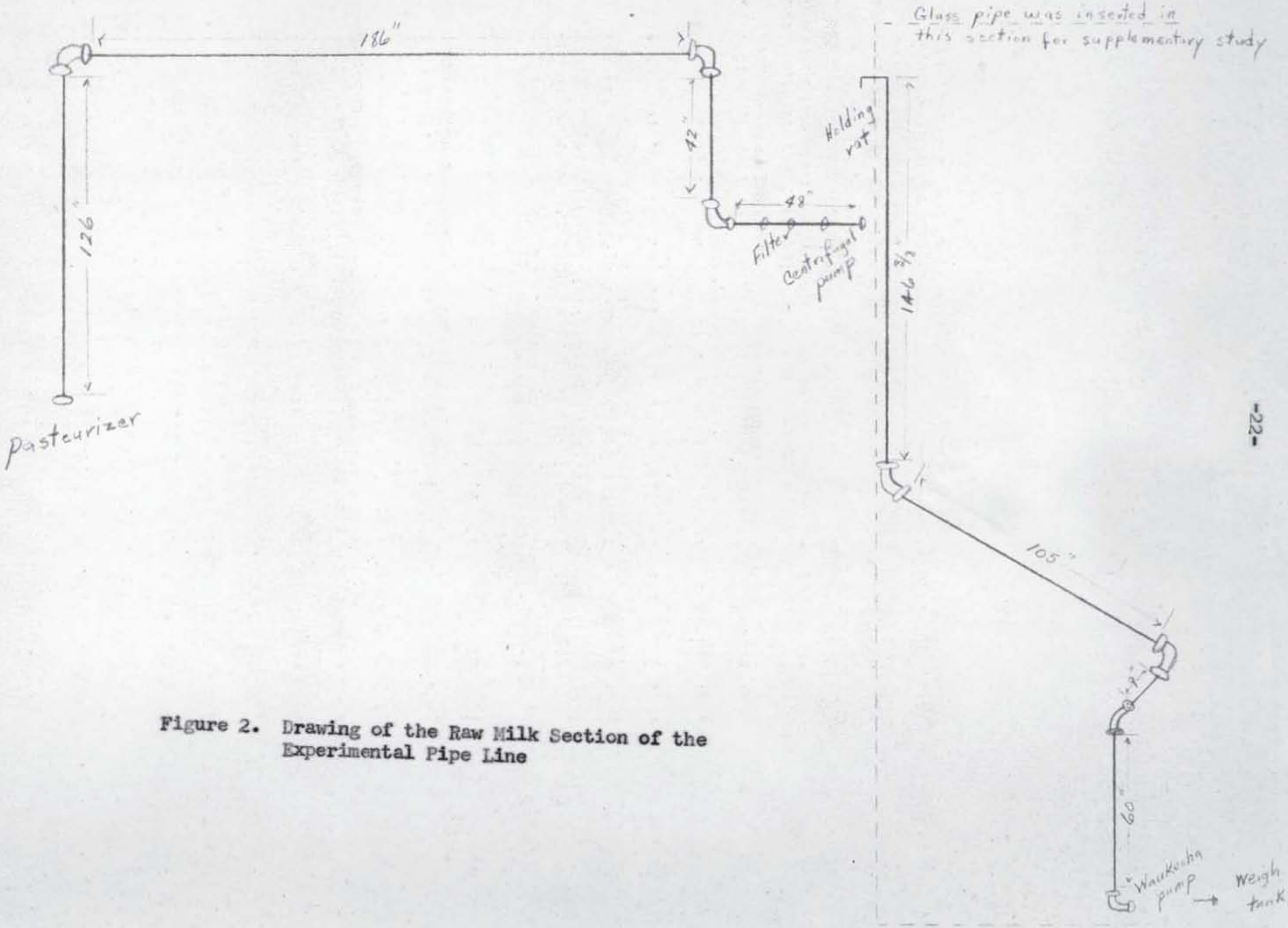


Figure 2. Drawing of the Raw Milk Section of the Experimental Pipe Line

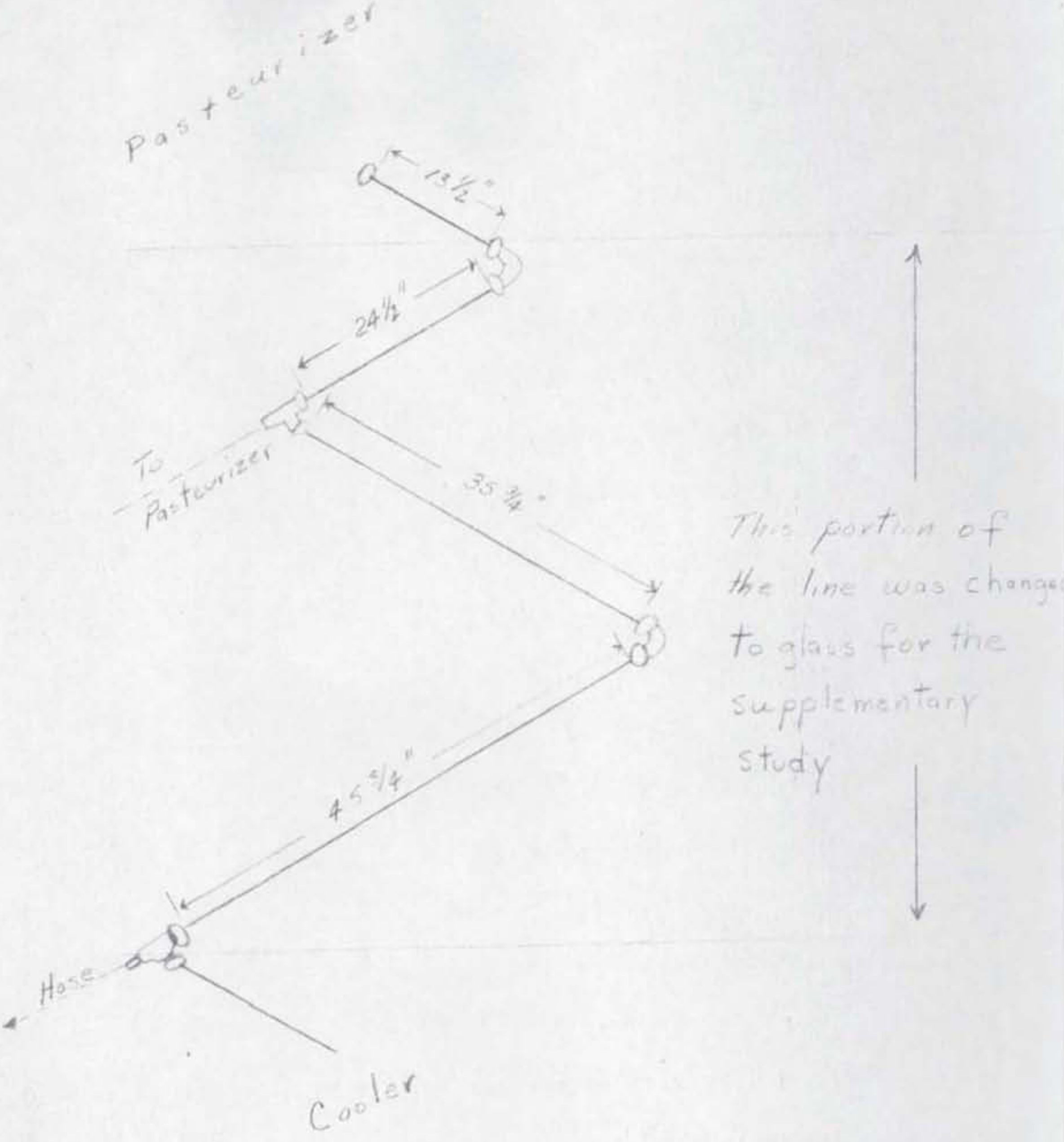


Figure 3. Drawing of the Pasteurized Milk Section of the Experimental Pipe Line

D. Methods and Procedures

1. Series I: Cleaning efficiency and cost analysis of a conventional stainless steel pipe line installation under complete daily disassembly conditions. Duration of series was 30 days.

a. Description of line

The experimental pipe line used in this series was constructed entirely of ordinary stainless steel. All tees, ells, and gaskets were of the type recommended for ordinary stainless steel. The line began at the weigh tank on the first floor of the creamery and extended a distance of twenty-six feet to join with the holding vat located on the second floor of the creamery. The milk was pumped from the weigh tank to the holding vat by means of a Waukesha positive sanitary pump. From the holding vat the line extended a distance of thirty feet to the pasteurizer also located on the second floor. A filter was located alongside the holding vat and the milk was pumped through the filter and on to the pasteurizer by means of a centrifugal pump. The pipe line extended approximately twelve and one-half feet from the pasteurizer to a valve immediately in front of the surface cooler. The total length of the line was approximately sixty-eight and one-half feet.

The inlet of the raw milk line was the weigh tank located on the first floor and the outlet of the raw milk line was a valve connected on to the line just prior to the entry of the pipe into the pasteurizer. The inlet of the pasteurized milk line was the pasteurizer and the outlet of said line was a valve connected on to the line just prior to the surface cooler.

b. Cleaning procedure

The cleaning methods and procedures employed in this series are those which are commonly employed in most dairy plants. That is, all sections of pipe line were completely dismantled every day and cleaned individually in the manner in which the men usually did their job. No effort was made to change any part of the cleaning operation for it was intended that this series should give an accurate basis for comparisons with Series II.

The general cleaning procedure employed usually consisted of (1) rinsing the entire line with lukewarm water, (2) completely dismantling the entire line and washing each section of pipe with a power-driven brush located in a tank containing a cleaning solution, (3) the individual sections of pipe were then rinsed with warm water and reassembled. The whole line was then sanitized in the morning just prior to use. The cleaning solutions were made daily by mixing alkali cleaner with water at the rate of one-half pound to fifty gallons. The cleaner used was a commercial hard water alkali cleaner.*

Records were kept of the amounts of time and materials required for the cleaning of the pipe line and also the weigh tank, holding vat, and pasteurizer which were all included within the scope of the experimental pipe line.

c. Bacterial quality of processed milk

Determinations of the bacterial quality of the milk processed through the experimental line were made by means of the standard plate count and coliform count. All standard plate counts and coliform counts were made according to rules and regulations as enumerated by Standard Methods for the Examination of Dairy Products (Ninth Edition).

The media used in making the standard plate counts was prepared in the following manner: twelve grams of Glucose Tryptone Extract agar were added to five hundred milliliters of distilled water. Skimmilk was then added to the agar at the rate of five milliliters per five hundred milliliters of agar. The prepared agar was then autoclaved for fifteen minutes at 140 °F.

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* National Dairy Products Corporation General Cleaner Type D.

The media used in making the coliform counts was prepared in the following manner: twenty and seven-tenths grams of Violet Red Bile agar were added to five hundred milliliters of distilled water. The prepared agar was then autoclaved for fifteen minutes at 140 °F.

Samples for the estimations of bacterial content were taken from five different points extending over the entire pipe line during each test run. These samples were taken aseptically, by means of sterile sampling tubes, at the inlets and outlets of the raw and pasteurized milk lines, respectively, and also one sample was taken from the holding vat. It was thought advisable to take a sample at the holding vat since all milk passing through the cold milk line had to pass through the vat. The following description will help to clarify the sampling procedure: sample A was taken from the weigh tank which served as the inlet of the raw milk line; sample B was taken from the holding vat located approximately midway along the raw milk line; sample C was taken from a valve, which just preceded the entry of the raw milk line into the pasteurizer, serving as the outlet of the raw milk line; sample D was taken from the pasteurizer which served as the inlet of the pasteurized line; Sample E was taken from a valve approximately two and one-half feet prior to the entry of the pasteurized milk line into the surface cooler. This valve served as the outlet of the pasteurized milk line. As each sample was taken, it was immediately transferred to the cold storage room located on the first floor of the creamery. The samples were held there within a temperature range of 35 to 40 °F. Shortly thereafter, never more than two hours later, the samples were taken to the dairy chemistry laboratory where representative portions were promptly plated for both the standard plate count and coliform count. The dilutions used in making the total plate count were as follows: raw milk, 1:100, 1:1000; pasteurized milk, 1:10, 1:100. The dilutions used in making the coliform count were as follows: raw milk, 1:10, 1:100; pasteurized milk, 1:1, 1:10. All dilutions were made in duplicate making a total of 44 plates required for each run.

Immediately after the required dilutions had been made and plated and the prepared media had been poured, the plates were placed in an incubator. The incubator was held at a constant temperature of 35 °C. The standard plate count plates were incubated for 48 hours and the coliform count plates were incubated for 24 hours. At the cessation of the above mentioned periods of time, the plates were promptly removed from the incubator and counted by means of a Quebec Colony Counter. Records were carefully kept of all counts.

All utensils such as sample bottles, petri dishes, and pipettes were sterilized before use by autoclaving for 20 minutes at 140 °F and then drawing five inches of vacuum for ten minutes.

In this series a total of twenty runs were made with five samples taken for each run.

d. Sanitizing efficiency

Determinations of sanitizing efficiency were made by testing for the parts per million of available chlorine in samples taken before and after circulation of the chlorine solution. These samples representing the beginning and ending of circulation were taken from the weigh tank and the valve located just prior to the surface cooler. The theory behind such a comparison is the conception that the smaller the loss of available chlorine the more sterile the pipe line should be.

Several different strengths of chlorine solutions were used but an effort was made to reach a standardization of approximately 200 parts per million at the beginning of circulation. The samples used in the chlorine determinations were tested shortly after the milk samples had been plated. All testing was done using the Wyandotte Test Kit in which each drop of the standardized thiosulfate solution represented ten parts per million available chlorine.

e. Labor costs

The determinations of the labor costs involved in the cleaning operation described in this series, were made by keeping a record of the amount of time spent in dismantling, cleaning, reassembling, and sanitizing of the pipe line and then multiplying the total number of man hours of labor by the prevailing wage paid at the creamery. Eighty-five cents per hour was used as the wage factor. Records were also kept as to the amount of time required to clean the weigh tank, holding vat, and pasteurizer. Records were kept for 30 days.

f. Cost and amounts of cleaning materials

The amounts of cleaner and sanitizing agents used were recorded for a period of 30 days. The costs of cleaning and sanitizing materials were then calculated using prevailing market quotations as to prices of materials. As an item of added interest, a record was also kept of the amount of cleaner used to clean the holding vat and pasteurizer both of which were enclosed within the piping system under consideration.

g. Durability and condition of the pipe

Just prior to the beginning of this series the investigator made a visual inspection of the pipe line to determine the condition of the pipe with reference to dents, chips, and milkstone build up. At the conclusion of the series another inspection was made in the same manner as the previous one. All changes in the condition of the pipe were noted and recorded at this time.

2. Series II: Cleaning efficiency and cost analysis of the same conventional stainless steel pipe line under in-place cleaning conditions.

a. Description of pipe line

The pipe line used in this series is exactly the same line which was used in Series I.

b. Cleaning procedure

The primary difference between Series I and Series II, is found in the method of cleaning employed. In Series I, as has been previously explained, all sections of pipe were dismantled and cleaning was done with brushes. In Series II in-place cleaning methods are employed. The pipe line was left completely intact for a period of 30 days. All cleaning and sanitizing was accomplished by means of forced circulation or flush cleaning. Circulation was made possible by making a return connection from the end of the experimental line back to the beginning of the line at the weigh tank. This connection was made by attaching a light weight hose to a valve at the outlet of the experimental line and returning the opposite end of the hose to the weigh tank. The hose was hung along the wall in such a manner that the cleaning solutions were allowed to flow by gravity from the end of the line back to the weigh tank. The Waukesha positive sanitary pump and centrifugal pump were used to propel the cleaning solutions through the line in exactly the same manner as the milk is pumped through the line.

The actual cleaning of the line was accomplished in the following manner: the line was first rinsed with warm water at 110 to 115 °F for approximately ten minutes or until such time as the discharge became reasonably clear. The rinsing water was allowed to drain and the line was then filled with an alkaline cleaner solution at 140 °F. The alkaline cleaner was circulated for 30 minutes and then allowed to drain. This cleaner was mixed in the weigh tank each day at the rate of one pound of cleaner to 60 gallons of water. The composition of this cleaner was the same as was used for Series I. After the cleaner solution had drained, the line was then rinsed again with warm water and allowed to drain dry. In the morning immediately before use, the entire line was sanitized either by circulating water at 180 °F for 10 minutes or by circulating some type of chlorine solution for five minutes. Twice weekly the entire line was cleaned with an acid rinse circulated at 140 °F for 15 minutes. This acid cleaner was mixed at the rate of 1/2 gallon of acid to 60 gallons of water. This cleaner was a commercial acid type milkstone remover.*

The cleaning operation was so set up that the weigh tank, holding vat and pasteurizer could be cleaned with the same cleaning solution as was used in the line. That is, these pieces of equipment were cleaned while the cleaning solutions were being circulated through them.

c. Bacterial quality of processed milk

Determinations of bacterial quality of processed products were made in exactly the same manner as those previously described for Series I.

d. Sanitizing efficiency

Determinations of sanitizing efficiency were made in exactly the same manner as previously described for Series I with one exception. Hot water sterilization was used for the first six runs on Series II and standard plate counts

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* Diversey Corporation's Dilac.

were made on samples of water taken from these runs. Routine chlorine test determinations were made on the remaining runs in the series.

e. Labor costs

Labor costs were calculated in exactly the same manner as previously described for Series I.

f. Cost and amount of cleaning materials

The costs and amounts of cleaning materials were calculated in the manner previously described for Series I.

g. Durability and condition of pipe

Observations of the durability and condition of the pipe were made in the manner previously described for Series I.

E. Results

1. Cleaning efficiency and cost analysis of a conventional stainless steel pipe line under daily complete disassembly conditions.

a. Bacterial quality of processed milk

The results of the standard plate count and coliform count determinations for Series I are given in Tables 1 and 2, respectively. The largest increase of bacteria per milliliter in the standard plate counts taken at the inlet and outlet of the raw milk line, was 3900. This difference occurred only once. The next largest increase was 1000, occurring only twice. The largest increase in bacteria per milliliter between plate counts taken at the inlet and outlet of the pasteurized milk line was 90. This difference occurred only one time. The next largest increase was 50. In the raw milk line the counts at the inlet of the line exceeded the counts at the outlet of the line, on the same run, in exactly one-half of the runs made. The average plate count at the inlet and outlet of the raw milk line was 2680 bacteria/ml. and 2820 bacteria/ml., respectively. Statistical analysis shows that the differences, obtained for plate counts at the inlet and outlet of the raw milk line were insignificant for all runs made in this series. The average plate count at the inlet and outlet of the pasteurized milk line was 10 bacteria/ml. and 20 bacteria/ml, respectively. Statistical analysis shows that the differences, in plate counts between the inlet and outlet of the pasteurized milk line, were slightly significant.

The largest increases between coliform counts at the inlet and outlet of the raw milk line were 180 coliforms/ml., occurring one time, and 145 coliforms/ml., occurring one time. The coliform counts on the pasteurized milk line remained negative throughout the entire series with the exception of one run in which the count increased from zero to five. In the raw milk line the coliform counts, at the inlet of the line, exceeded the counts at the outlet of the line in seven out of twenty runs. The average coliform count at the inlet and outlet of the raw milk line was 13 coliforms/ml. and 35 coliform count at the inlet and outlet of the raw milk line, was 13 coliforms/ml. and 35 coliforms/ml., respectively. The average coliform count at the inlet and outlet of the pasteurized milk line was zero coliforms/ml. and less than one coliform/ml., respectively. Statistical analysis shows that the differences, between coliform counts at the inlets and outlets of the raw and pasteurized lines, were not significant.

b. Sanitizing efficiency

The results, of the determinations of the parts per million of available chlorine before and after sanitizing in Series I, are given in Table 3. The greatest loss of parts per million available chlorine on any single run was 20 parts per million. Such a loss occurred in five of the twenty runs made. On the remaining 15 runs, the loss ranged from zero to ten parts per million. The average available chlorine strengths before and after sanitizing were 196 parts per million and 186 parts per million, respectively.

Statistical analysis shows that the differences between the parts per million of available chlorine obtained before and after sanitizing were significant.

c. Labor costs

Table 10 gives a summary of the man hours of labor required for the pipe line cleaning and the cost of this labor. The total man hours of labor required for the cleaning and sanitizing of the pipe line system in Series I was 70.5 hours for the entire 30 day period. The cost of this labor was $59.93. This figure represents approximately fifteen per cent of the total labor cost required for the cleaning and processing done in the creamery.

The time required for the cleaning of the holding vat and pasteurizer for the 30 day period was 22.5 hours. The cost of this labor amounted to $19.13.

d. Costs and amounts of cleaning and sanitizing materials

Figures for the costs and amounts of cleaning and sanitizing materials are given in Table 9. Approximately fifteen pounds of cleaner were required to clean the pipe line for the 30 day period. The cost of this amount of cleaner was $2.10.

An additional 60 pounds of cleaner was required for the cleaning of the holding vat and pasteurizer. The cost of this cleaner was $8.40.

e. Durability and condition of pipe

The results of the visual inspection of the pipe line are given in Table 8. The visual inspections made indicate that the pipe generally receives rather rough treatment during the course of daily disassembly, cleaning, and re-assembly of the line. Several indentations and scratches were observed that were not present at the beginning of the series. There was no visible build up of soil or milkstone in the line.

2. Cleaning efficiency and cost analysis of the same conventional stainless steel pipe line under in-place cleaning conditions.

a. Bacterial quality of processed milk

The results of the plate count and coliform count determinations made for Series II are given in Table 4 and Table 5, respectively. The largest increase between the standard plate counts at the inlet and outlet of the raw milk line was found to be 1200 bacteria/ml. Such an increase occurred only one time. The next largest increase was 900 bacteria/ml. This increase occurred twice during the 30 day period. When comparing the counts at the inlet and outlet of the raw milk line, it was found that in eleven out of twenty-three runs, the counts at the inlet of the line were the same as or larger than the counts at the outlet of the line.

The largest increase between the plate counts at the inlet of the pasteurized milk line was found to be 40 bacteria/ml. This count occurred only once. The next largest increase was 20 bacteria/ml. This count occurred twice during the 30 day period. When counts at the inlet and outlet of the pasteurized milk line were compared, it was found that in 13 out of 23 runs, the counts at the inlet were the same or larger than the counts at the outlet of the line.

The average standard plate count at the inlet and outlet of the raw milk line was 3139 bacteria/ml., and 3295 bacteria/ml., respectively. The average plate count at the inlet and outlet of the pasteurized milk line was seven bacteria/ml., and ten bacteria/ml., respectively. Statistical analysis shows that the differences between the standard plate counts at the inlet and outlet of both the raw and pasteurized milk lines, were very insignificant.

The largest increase between the coliform counts obtained at the inlet and outlet of the raw milk line, was found to be 20 coliform/ml., occurring twice during the 30 day period. When a comparison was made of the coliform counts at the inlet and outlet of the raw milk line, it was found that in seventeen out of twenty-three runs, the counts at the inlet were the same as, or larger than, the counts at the outlet of the line. The average coliform count at the inlet and outlet of the raw milk line was 41 coliforms/ml., and 40 coliforms/ml., respectively. The coliform counts at the inlet and outlet of the pasteurized milk line remained negative throughout the entire 30 day period. Statistical analysis shows no significant differences between coliform counts at the inlet and outlets of both the raw and pasteurized milk lines.

b. Sanitizing efficiency

The results of the determinations of parts per million available chlorine and plate counts for hot water are found in Table 7 and Table 6, respectively. Where plate counts were made of the hot water, the greatest increase in count was 40 bacteria/ml., occurring one time. All other plate counts ranged from zero to 30 bacteria/ml. Hot water was used for the first six runs of this series and chlorine was used on the remaining seventeen runs. The greatest loss in parts per million of available chlorine on any single run was 30 parts per million, occurring two times. All other losses ranged from zero to 20 parts per million. The average chlorine strengths before and after sanitizing were 202 and 185 parts per million, respectively. Statistical analysis shows the differences in parts per million of available chlorine before and after sanitizing were significant.

c. Labor costs

Table 10 gives a summary of the man hours of labor required for the cleaning and sanitizing operations under the in-place cleaning methods employed in this series. Approximately thirty-two hours were required for the entire cleaning and sanitizing operation for the 30 day period. It is impossible to divide up this time between the pipe line and the other parts of the installation since the holding vat and pasteurizer were cleaned while the cleaning solutions were circulating through the pipe line itself. The cost of the labor required for the cleaning and sanitizing operations in this series was $27.20.

d. Costs and amounts of cleaning and sanitizing materials

Figures for the cost and amounts of cleaning and sanitizing materials are given in Table 9. Approximately 30 pounds of cleaner were required to clean the entire installation, including the holding vat and pasteurizer, for the 30 day period. The cost of this cleaner was $4.20. Approximately eight pounds of sanitizer were required for 24 days in which chlorine was utilized. The cost of this chlorine was $4.80. Approximately four gallons of acid cleaner were required for the 30 day period. The cost of this cleaner was $12.00.

e. Durability and condition of pipe

The results of the visual inspection of the pipe line used in this series are given in Table 8. Visual inspections of the line show no additional indentations or scratches on the pipe which were not present at the beginning of this series. Likewise, further inspection of the line showed no visible soil build up or presence of milkstone formation in the line. All gaskets were still in good condition.

Table 1

Standard Plate Counts for Samples Taken from Raw and Pasteurized Milk Lines Used in Series I

Bacteria Count per Milliliter

| Run | Raw Milk Line | | Pasteurized Milk Line | |
|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet |
| 1 | 2100 | 1600 | 0 | 10 |
| 2 | 2200 | 1600 | 10 | 10 |
| 3 | 1700 | 2500 | 10 | 100 |
| 4 | 1600 | 1400 | 10 | 20 |
| 5 | 2600 | 2200 | 0 | 10 |
| 6 | 2700 | 2100 | 0 | 10 |
| 7 | 6700 | 5600 | 70 | 20 |
| 8 | 1900 | 2800 | 10 | 10 |
| 9 | 5600 | 4700 | 0 | 0 |
| 10 | 2000 | 1700 | 10 | 20 |
| 11 | 2100 | 1600 | 10 | 30 |
| 12 | 1900 | 1900 | 0 | 0 |
| 13 | 1500 | 2500 | 10 | 10 |
| 14 | 3300 | 4200 | 0 | 20 |
| 15 | 4700 | 4800 | 10 | 10 |
| 16 | 2800 | 3800 | 10 | 10 |
| 17 | 3600 | 3200 | 20 | 20 |
| 18 | 1200 | 1200 | 0 | 10 |
| 19 | 2300 | 2000 | 10 | 50 |
| 20 | 1100 | 5000 | 10 | 20 |
| Average | 2680 | 2820 | 10 | 20 |

Table 2

Coliform Counts for Samples Taken from Raw and

Pasteurized Milk Lines Used in Series I

Coliform Count per Milliliter

| Run | Raw Milk Line | | Pasteurized Milk Line | |
|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet |
| 1 | 0 | 5 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 |
| 3 | 10 | 5 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 |
| 5 | 5 | 5 | 0 | 0 |
| 6 | 10 | 30 | 0 | 0 |
| 7 | 40 | 50 | 0 | 0 |
| 8 | 40 | 80 | 0 | 0 |
| 9 | 10 | 0 | 0 | 0 |
| 10 | 0 | 20 | 0 | 0 |
| 11 | 40 | 20 | 0 | 5 |
| 12 | 0 | 0 | 0 | 0 |
| 13 | 30 | 5 | 0 | 0 |
| 14 | 0 | 5 | 0 | 0 |
| 15 | 5 | 150 | 0 | 0 |
| 16 | 10 | 100 | 0 | 0 |
| 17 | 10 | 30 | 0 | 0 |
| 18 | 20 | 10 | 0 | 0 |
| 19 | 5 | 0 | 0 | 0 |
| 20 | 10 | 190 | 0 | 0 |
| Average | 13 | 35 | 0 | 0.25 |

Table 3

Parts Per Million of Available Chlorine

in Sanitizing Solutions in Series I

| Run | Before Circulation | After Circulation | Difference |
|---|---|---|---|
| 1 | 70 | 70 | 0 |
| 2 | 100 | 90 | -10 |
| 3 | 290 | 290 | 0 |
| 4 | 150 | 140 | -10 |
| 5 | 200 | 190 | -10 |
| 6 | 190 | 190 | 0 |
| 7 | 190 | 170 | -20 |
| 8 | 210 | 200 | -10 |
| 9 | 200 | 200 | 0 |
| 10 | 230 | 220 | -10 |
| 11 | 220 | 220 | 0 |
| 12 | 210 | 200 | -10 |
| 13 | 210 | 200 | -10 |
| 14 | 210 | 210 | 0 |
| 15 | 200 | 180 | -20 |
| 16 | 210 | 190 | -20 |
| 17 | 210 | 200 | -10 |
| 18 | 200 | 190 | -10 |
| 19 | 210 | 190 | -20 |
| 20 | 200 | 180 | -20 |
| Average | 196 | 186 | 10 |

Table 4

Standard Plate Counts for Samples Taken from Raw and

Pasteurized Milk Lines Used in Series II

Bacteria Count per Milliliter

| Run | Raw Milk Line | | Pasteurized Milk Line | |
|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet |
| 1 | 7900 | 8800 | 0 | 0 |
| 2 | 1700 | 1600 | 0 | 10 |
| 3 | 1700 | 1800 | 0 | 10 |
| 4 | 2000 | 3200 | 0 | 10 |
| 5 | 5100 | 4900 | 20 | 40 |
| 6 | 7000 | 5600 | 0 | 0 |
| 7 | 2500 | 2500 | 0 | 10 |
| 8 | 2000 | 1600 | 0 | 10 |
| 9 | 1700 | 1600 | 0 | 20 |
| 10 | 2000 | 2200 | 10 | 5 |
| 11 | 2400 | 2500 | 20 | 60 |
| 12 | 2600 | 3500 | 0 | 0 |
| 13 | 3500 | 3100 | 50 | 10 |
| 14 | 1300 | 1900 | 30 | 0 |
| 15 | 1600 | 1600 | 10 | 10 |
| 16 | 3300 | 4000 | 5 | 5 |
| 17 | 2000 | 2300 | 5 | 5 |
| 18 | 2300 | 2900 | 0 | 5 |
| 19 | 2700 | 3200 | 0 | 0 |
| 20 | 2400 | 3000 | 5 | 0 |
| 21 | 3200 | 3000 | 0 | 0 |
| 22 | 6800 | 6600 | 0 | 10 |
| 23 | 4500 | 4400 | 10 | 10 |
| Average | 3139 | 3295 | 7 | 10 |

Table 5

Coliform Counts for Samples Taken from Raw and Pasteurized Milk Lines Used in Series II

| Run | Raw Milk Line | | Pasteurized Milk Line | |
|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet |
| 1 | 20 | 0 | 0 | 0 |
| 2 | 0 | 5 | 0 | 0 |
| 3 | 20 | 20 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 |
| 5 | 110 | 70 | 0 | 0 |
| 6 | 5 | 5 | 0 | 0 |
| 7 | 20 | 20 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 |
| 9 | 30 | 20 | 0 | 0 |
| 10 | 0 | 10 | 0 | 0 |
| 11 | 50 | 50 | 0 | 0 |
| 12 | 20 | 40 | 0 | 0 |
| 13 | 560 | 580 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 |
| 17 | 60 | 40 | 0 | 0 |
| 18 | 5 | 0 | 0 | 0 |
| 19 | 5 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 |
| 21 | 10 | 20 | 0 | 0 |
| 22 | 10 | 10 | 0 | 0 |
| 23 | 20 | 20 | 0 | 0 |
| Average | 41 | 40 | 0 | 0 |

Table 6

Standard Plate Counts for Hot Water as Used for Sanitizing in Series II

| Run | Before Circulation | After Circulation | Difference |
|---|---|---|---|
| 1 | 0 | 30 | 30 |
| 2 | 10 | 50 | 40 |
| 3 | 0 | 10 | 10 |
| 4 | 0 | 0 | 0 |
| 5 | 20 | 20 | 0 |
| 6 | 0 | 10 | 10 |
| Average | 5 | 20 | 15 |

Table 7

Parts Per Million of Available Chlorine

in Sanitizing Solutions in Series II

| Run | Before Circulation | After Circulation | Difference |
|---|---|---|---|
| 7 | 210 | 180 | -30 |
| 8 | 200 | 180 | -20 |
| 9 | 210 | 180 | -30 |
| 10 | 210 | 200 | -10 |
| 11 | 200 | 180 | -20 |
| 12 | 190 | 170 | -20 |
| 13 | 210 | 190 | -20 |
| 14 | 200 | 180 | -20 |
| 15 | 210 | 200 | -10 |
| 16 | 200 | 180 | -20 |
| 17 | 210 | 190 | -20 |
| 18 | 200 | 190 | -10 |
| 19 | 180 | 170 | -10 |
| 20 | 200 | 180 | -20 |
| 21 | 210 | 190 | -20 |
| 22 | 190 | 180 | -10 |
| 23 | 200 | 200 | 0 |
| Average | 202 | 185 | 17 |

Table 8

Results of Visual Inspections of Pipe

Lines Used in Series I and Series II

| | Scratches, Indentations | Visible Soil Build up | Milkstone Build up |
|---|---|---|---|
| Series I | Several scratches and indentations were present at the end of the series that were not present at the beginning of this series | None | None |
| Series II | There was no notable physical wear on the external portion of the pipe line | None | None |

Table 9

<u>Comparison of the Costs and Amounts of Cleaning and Sanitizing Materials Used in Series I and Series II</u>

| | Series I | Series II |
|---|---|---|
| Amount of cleaner required | 15 # (pipe line)<br>60 # (holding vat + pasteurizer)<br>75 # | 30 # (entire installation)<br>4 gallons of acid |
| Cost of cleaner | $2.10 (pipe line)<br>$8.40 (holding vat + pasteurizer) | $ 4.20 (alkaline cleaner)<br>$12.00 (acid cleaner) |
| Amount of sanitizer required | 10 # | 8 # |
| Cost of sanitizer | $ 6.00 | $ 4.80 |
| Total cost | $16.50 | $21.00 |

Table 10

Comparison of the Labor Costs Involved in the Cleaning and Sanitizing Methods Used in Series I and Series II

| | Series I | Series II |
|---|---|---|
| No. of hours required for cleaning and sanitizing for 30 days | 70.5 (pipe line)<br>22.5 (holding vat and pasteurizer) | 32.0 (entire installation) |
| Total | 93.0 | |
| Cost of labor required for cleaning and sanitizing for 30 days | $59.93 (pipe line)<br>$19.13 (holding vat and pasteurizer) | $27.20 (entire installation) |
| Total | $79.07 | |

# IV

# DISCUSSION

## A. Discussion of Results

### 1. Bacterial quality of processed milk

A comparison of the standard plate counts and coliform counts obtained in Series I and Series II reveals some very important information. Information given in the section on results and in Table 1 reveals that the average plate count at the inlet and outlet of the raw milk line in Series I was 2680 bacteria/ml., and 2820 bacteria/ml., respectively. Using these figures, the average difference between the counts at the inlet and outlet of the line was 140 bacteria/ml. Similar information obtained from Table 4 shows that the average plate count at the inlet and outlet of the raw milk line in Series II was 3139 bacteria/ml., and 3295 bacteria/ml., respectively. This set of figures gives an average difference of 156 bacteria/ml., between counts at the inlet and outlet of the line. Comparison of the average differences shows that counts made on the raw milk line in Series II increased an average of 16 bacteria/ml. more than did the counts made on the raw milk line studied in Series I. This increase is a very small one when consideration is made for the allowable bacteria count at the time of delivery of pasteurized milk to the consumer. At the present time the allowable count, at the time of delivery, is 30,000 bacteria/ml.

It is worth while to note that in Series I the counts at the inlet of the raw milk exceeded the counts at the outlet of the same line on exactly one-half of the runs made. Likewise, in Series II the counts made at the inlet of the raw milk line were the same as or exceeded those made at the outlet of the same line in 11 out of 23 runs made. The determination of the factor or factors causing such a phenomenon to occur was not within the scope of this investigation. However, it should be noted that such results do compare very favorably with results obtained by Moore, Tracy, and Ordal [18] and Hucker and Thomas [11], in circulation cleaning studies using pyrex glass and stainless steel as the component pipe line materials.

In comparing the results of plate counts on the raw milk lines studied in Series I and Series II it should be noted that the largest single increase in count on the two lines was 3900 bacteria/ml. and 1200 bacteria/ml., respectively. Although both of these increases are small when compared to allowable counts, it seems especially significant that the largest increase in Series II is less than one-third as large as the largest increase in Series I. This fact indicates a favorable report for the cleaning procedures used in Series II. It is a more or less recognized fact that individual variations are more important than average variations. Statistical analysis shows that the differences between counts taken at the inlet and outlet of the raw milk line, were insignificant in both Series I and Series II. Such information gives a sound basis for the statement that the cleaning procedures employed in Series II will permit the processing of a product which is at least equal in bacteria quality to that processed through lines cleaned by procedures used in Series I. It should be noted here that the high degree of significance given for the differences between runs in Series I and Series II for the raw milk line, refers only to the readily observed fact that the daily variations between bacteria counts are high. The daily variation in count has no direct bearing upon the counts obtained at the inlets and outlets of the two experimental pipe lines.

In general, the results obtained for plate counts on raw milk indicate that circulation cleaning methods may be used on raw milk pipe lines with an expectancy of high bacteria quality of the processed product.

Comparison of the plate counts, obtained at the inlets and outlets of the pasteurized milk pipe lines studied in Series I and Series II, indicates a slightly different situation from that observed on the raw milk lines. Table 1 shows that the average count at the inlet and outlet of the pasteurized milk line in Series I was 10 bacteria/ml., and 20 bacteria/ml., respectively.

Likewise, Table 4 shows that the average count at the inlet and outlet of the pasteurized milk line in Series II was seven bacteria/ml., and ten bacteria/ml., respectively. These figures give an average difference of ten bacteria/ml., and three bacteria/ml., respectively, for Series I and Series II. Comparison of the above figures shows that the plate counts obtained on the pasteurized milk line in Series I were, on the average, seven bacteria/ml. higher than those obtained for the pasteurized milk line used in Series II. In so far as averages are concerned, such results favor cleaning procedures used in Series II. Individual comparisons show that the largest single increase in count between the inlets and outlets of the pasteurized milk lines, was 90 bacteria/ml. in Series I and 40 bacteria/ml. in Series II. Although both of these increases are relatively small, it is worthwhile to note that the largest increase in Series II was less than half as large as the largest increase observed in Series I. Such evidence favors the use of circulation cleaning for pasteurized milk lines.

Further observation of the results obtained for the pasteurized milk lines used in Series I and Series II, reveals that in 13 out of 23 runs, the counts in Series II at the inlet are the same as or exceed the counts at the outlet of the line. Such results are in accordance with results obtained for the raw milk lines. Statistical analysis shows that the differences in plate counts at the inlet and outlet of the pasteurized milk line used in Series I, are significant. Similar analysis shows that the differences between plate counts at the inlet and outlet of the same line in Series II, are insignificant. Such results bolster the hypothesis that pasteurized milk lines cleaned by forced circulation, will give processed products with as high or higher bacteria quality as similar lines cleaned by brush methods.

In general, the results obtained indicate that circulation cleaning methods may be used satisfactorily for the pasteurized milk pipe line utilized in this investigation.

Examination of the results obtained for coliform counts at the inlets and outlets of the two experimental pipe lines gives some important information upon the effectiveness of the cleaning procedures used in Series I and Series II. Table 2 shows that the average coliform count at the inlet of the raw milk line used in Series I was 13 coliforms/ml. The average coliform count at the outlet of the same line was 35 coliforms/ml. These figures give an average difference of 22 coliforms/ml. between the inlet and outlet of the raw milk line in Series I. Likewise, Table 5 shows that the average coliform count at the inlet of the raw milk line in Series II was 41 coliforms/ml. The average coliform count at the outlet of this line was 40 coliforms/ml. This set of figures shows an average decrease of one coliform/ml. between the inlet and outlet of the raw milk line in Series II. Comparison of the average obtained for coliform counts on the raw milk line used in Series I and Series II shows that the counts on the raw milk line in Series I increased an average of 23 coliforms/ml. more than did the counts taken on the line used in Series II. When considering averages, the above increase indicates a favorable reaction toward circulation cleaning methods because of the fact that regulations on coliform counts are much more strict than those placed on plate counts. In fact, the presence of any coliform organisms at all is very undesirable and precautions should be taken to keep such counts as low as possible. This investigation is concerned only with the increases in counts and not with the counts present at the time of the receiving of the milk. Further comparison of the coliform counts obtained from the raw milk lines in Series I and Series II shows that in Series I the counts at the inlet of the line exceeded the counts at the outlet of the same line in 7 out of 20 runs. In Series II the counts at the inlet of the line were the same as or exceeded the counts at the outlet of the line in 17 out of 23 runs. These results are roughly comparable to the results observed for the plate counts on the experimental lines.

In comparing the results of coliform counts made on the raw milk lines studied, it is worthwhile to note that the largest single increase between the coliform count at the inlet and outlet of the raw milk line in Series I was 180 coliforms/ml. Similarly, the largest single increase in coliform count on the raw milk line in Series II was only 20 coliforms/ml. While any increase in coliforms is undesirable it is important to note that the largest single increase in Series II was less than one-eighth as large as the greatest single increase in Series I. In so far as daily variations in coliform counts are concerned, such evidence indicates a favorable reaction toward circulation cleaning methods for the cleaning of the raw milk lines used in this investigation. Statistical analysis shows the differences between coliform counts at the inlet and outlet of the pipe lines were insignificant in both Series I and Series II. This analysis plus other factors as previously discussed, indicates that in so far as coliform counts are concerned the raw milk sections of the experimental pipe lines used in this investigation can be cleaned effectively by circulation cleaning procedures.

Table 2 and Table 5 show that the coliform counts on the pasteurized milk lines studied remained practically negative throughout the course of this investigation. There was one exception occurring in Series I when the count increased from zero to five coliforms/ml. on one run. The coliform counts on the pasteurized line in Series II remained zero throughout the duration of that Series. There was no need for statistical analysis here. Visual observation of the results show no significant increase in counts. Such information indicates that in so far as coliform counts were concerned, the experimental pipe line used in this investigation can be very effectively cleaned by using circulation procedures.

In general, the results obtained for plate counts and coliform counts indicate that circulation cleaning methods may be used on both the raw and pasteurized milk sections of the pipe line installation studied in this investigation with an expectancy of a finished product satisfactory from the standpoint of bacterial quality.

2. Sanitizing efficiency

Information given in Table 3 shows that the average available chlorine strengths before and after sanitizing in Series I were 196 parts per million and 186 parts per million, respectively. These figures give an average loss of 10 parts per million available chlorine as a result of the sanitizing operation in Series I. Table 7 shows that the average chlorine strengths before and after sanitizing in Series II were 202 parts per million and 185 parts per million available chlorine, respectively. This set of figures gives an average loss of 17 parts per million available chlorine as a result of the sanitizing operation in Series II. Comparison of these averages shows that the sanitizing operation as performed in Series II caused an average loss of seven parts per million more of available chlorine than did the sanitizing operation performed in Series I. The average losses of available chlorine in both Series I and Series II, were relatively small when consideration is made of the fact that the average amount of available chlorine at the end of circulation was at least 180 parts per million. Further examination of the results found in Table 3 and Table 7 shows the largest single loss of available chlorine in Series I was 20 parts per million and the greatest single loss of available chlorine in Series II was 30 parts per million. These figures show that the two series compare favorably as far as individual variations are concerned. Statistical analysis shows that the differences in parts per million of available chlorine before and after sanitizing are significant in both Series I and Series II. Although statistics do show the differences to be significant, hasty conclusions should not be formed either condoning or condemning the cleaning methods used in either series. As a means of comparison, personal communication has brought to the investigator's attention the fact that many men in the dairy cleaner and sanitizer field regard a loss of 50 parts per million or even more, as evidence of satisfactory cleaning procedures. It has already been pointed out that the greatest single loss in either series of this investigation was 30 parts per million of available chlorine. The fact that a slightly greater loss of available chlorine was found in Series II compared to Series I indicates that perhaps the circulation cleaning methods used in Series II left a slightly greater amount of organic matter in the pipe line than was the case when brush methods were used in Series I. However, the previously mentioned fact that in Series II the least amount of available chlorine at the end of sanitizing was 180 parts per million indicates that the line was satisfactorily clean at the time of entry of milk into the line. In general, there was no measurable difference between the two methods of cleaning in so far as sanitizing efficiency was concerned.

Hot water sanitizing was used in place of chlorine sanitizing on the first six runs of Series II. Plate counts made on samples of the water before and after sanitizing show no appreciable pick up of bacteria. In general, the investigator observed no particular advantage in using hot water sanitizing as opposed to chlorine sanitizing or vice versa. Both methods of sanitizing indicated satisfactory results.

3. Labor costs

Table 10 gives a summary of the number of man hours of labor, and the cost of those man hours, required for the cleaning and sanitizing procedures used in Series I and Series II. The total number of man hours required for the pipe line alone for the 30 day period in Series I was 70.5 hours. The cost of the labor was $59.93. The total number of man hours required for the pipe line plus holding vat and pasteurizer for the 30 day period in Series II was 32 hours. The cost of this labor was $27.20. Comparison of these figures shows that the cleaning and sanitizing procedures used in Series II made it possible to clean the experimental pipe line in less than half the time required for Series I and at nearly one-third of the cost of the labor required for Series I. These results show that in so far as labor costs are concerned, circulation cleaning methods have a distinct advantage over daily disassembly cleaning methods. It should be emphasized that these results are valid only for the experimental pipe line used in this investigation. While this installation is a comparatively small one and the savings made may not represent any large sum of money, it seems reasonable to say that similar results would be observed on either larger or smaller installations. In all probability the larger the installation the greater the savings would be. It is worthwhile to note that in Series II the 32 hours required for cleaning includes the holding vat and pasteurizer as well as the pipe line itself. It was impossible to give a division of the time spent cleaning the pipe as compared to the time spent cleaning the holding vat and pasteurizer because of the fact that those two pieces of equipment were cleaned with the cleaning solution while it was being circulated through the pipe line itself. However, in Series I the time spent on the pipe line alone was 70.5 hours. An additional 22.5 hours were spent cleaning the holding vat and pasteurizer as these pieces of equipment were cleaned separately from the pipe line in Series I. A summary of these figures shows that the total cost of cleaning and sanitizing the entire installation, including pipe line, holding vat, and pasteurizer in Series I was $93.00. As has been mentioned, the total cost of performing the same operation in Series II was $27.20. Comparison of those figures shows that circulation cleaning reduced the labor cost to approximately one-fourth of the cost required for daily disassembly cleaning methods as employed in Series I.

In general, the analysis of the data collected in this investigation with reference to labor costs, indicates that circulation cleaning methods are definitely superior to daily disassembly cleaning procedures.

4. Costs and amounts of cleaning and sanitizing materials

Table 9 gives a summary of the costs and amounts of the cleaning and sanitizing materials required for the cleaning and sanitizing procedures used in Series I and Series II. Comparison of the costs and amounts of cleaner required for the two series shows that approximately fifteen pounds of cleaner were required for the pipe line alone in Series I. An additional 60 pounds of cleaner were required for cleaning the other pieces of equipment included in the installation. In Series II, only 30 pounds of cleaner were required for cleaning the entire installation including all pieces of equipment. Although it is impossible to determine exactly how much cleaner was required to clean the pipe alone in Series II, it is significant to note that the cleaning methods used in Series II required less than half as much cleaner as was required for Series I to clean the entire installation. When comparing the costs of the cleaner required for the two series it is found that the inclusion of the acid cleaner in Series II makes the cost of cleaner in Series II slightly greater than the cost in Series I. However, it seems quite possible that the number of times of using acid cleaner could be reduced from twice weekly to once weekly thus cutting in half the amount of acid cleaner required. Such a change would make the cost of cleaner almost exactly the same for both series. It should be emphasized that the figures given for amounts of cleaner required are only valid for the experimental pipe line studied in this investigation. The outlay of the creamery made it very easy to include the holding vat and pasteurizer in the circulation cleaning operation. This would not be necessarily true in other installations. In general, analysis of costs of cleaning materials shows very little difference between the cleaning methods used in Series I and Series II.

Comparison of the costs and amounts of sanitizing materials used in Series I and Series II shows that the cost and amount of sanitizer used in Series II was slightly less than that used in Series I. No valid comparison can be made, however, because of the fact that hot water was used on approximately one-third of the runs made in Series II whereas chlorine was the only sanitizing agent used in Series I. If only chlorine had been used in both series, the amounts and costs of sanitizer required would have been exactly the same for both series. This would have been true because the lines were sanitized in exactly the same manner in so far as chlorine was concerned.

5. Durability and condition of pipe

Table 8 gives the results of the visual inspections made on the experimental pipe lines used in Series I and Series II. In so far as physical wear is concerned, these results bear out the fact the pipe generally receives rather rough treatment as the process of daily disassembly, cleaning, and reassembly is carried through. Examination of the line at the beginning and end of Series II indicated that there had been no additional physical wear on the line during the duration of that particular period of time. It seems reasonable to say that the in-place cleaning procedures, as employed in Series II, were definitely advantageous from the standpoint of physical wear and strain on the experimental pipe line. Comparison of the results of soil and milkstone build up shows no measurable difference between the two cleaning methods employed. In general, the visual inspections made indicate that circulation cleaning methods are equally as satisfactory or possibly more satisfactory than daily disassembly cleaning procedures from the standpoint of durability and condition of the pipe itself.

B. Recommendations

In the concluding section of the discussion of results observed in this investigation, the investigator would like to make the following recommendations concerning the cleaning and sanitizing of in-place pipe line installations:

1. Be especially careful in picking the men who are responsible for the cleaning operation. Use of in-place cleaning methods required a considerably smaller number of men than would be required for daily disassembly methods. However, if effective results

are to be obtained using in-place cleaning procedures, the various factors such as temperatures, lengths of time, and amounts of cleaner, must be strictly and carefully adhered to. Such procedures necessitate the employment of capable operators for the cleaning operation.

2. All lines should be completely dismantled and cleaned thoroughly by hand at least once each week, or possibly twice within every ten-day period. Such action is recommended in spite of the fact that excellent results were obtained for the pipe line under study, without dismantling the line at all. To be on the safe side, it is felt that a careful periodic hand cleaning of the line is desirable. Such action would increase the labor cost of in-place methods by approximately 25 per cent.

3. Be sure that the pump or pumps, which are used to force the cleaning solutions through the lines, have sufficient capacity to completely fill the pipe line while circulation is in progress. Although no apparent difficulty was experienced with the pumps used in this investigation, it is felt that such a point should be given extra emphasis.

4. All sections of the pipe line should be pitched so that they will drain properly.

5. Be sure that all sections of the pipe line are properly supported and that all connections are tight so as to minimize vibration from the pumps.

6. Clean all sections of the pipe line with an acid cleaner once weekly. Although acid cleaner was used twice weekly in Series II, it is felt that once weekly would be sufficient providing all other portions of the cleaning procedures recommended for in-place cleaning are properly carried out.

V

## CONCLUSIONS

This study of the cleaning and sanitizing of the sanitary milk pipe line installation at the Virginia Polytechnic Institute, by means of both daily disassembly procedures and in-place cleaning methods, led to the following conclusions:

1. The data obtained indicate that the raw milk section of the experimental pipe line studied in this investigation can be cleaned very satisfactorily by circulation or in-place cleaning procedures in so far as bacteria quality of the finished product is concerned.

2. The data obtained also indicate that the pasteurized milk section of the experimental pipe line studied in this investigation can be claned satisfactorily by means of circulation or in-place cleaning procedures in so far as bacteria quality is concerned.

3. The data obtained indicate that there was very little difference between the two cleaning methods in so far as their effect on sanitizing efficiency was concerned.

4. Calculation of the labor costs required for the two methods of cleaning shows that the circulation or in-place method of cleaning is definitely superior to daily disassembly cleaning methods.

5. Comparison of the amounts and costs of cleaning and sanitizing materials required for the two cleaning methods indicates

that in so far as the experimental pipe line studied in this investigation is concerned, there was very little difference between the two cleaning methods.

6. The results observed indicate that circulation cleaning methods are definitely more favorable than daily disassembly methods from the standpoint of physical wear on the pipe line.

## VI

## SUMMARY

The primary purpose of this investigation was to attempt to determine whether or not the sanitary pipe line installation of the Virginia Polytechnic Institute creamery, composed of ordinary stainless steel, could be satisfactorily cleaned by circulation cleaning procedures as opposed to daily disassembly of the entire pipe line. To facilitate such a determination, two experimental periods of approximately thirty days each in duration were set up. In the first period the experimental pipe line was subjected to complete daily disassembly cleaning procedures. That is, each section of the line was disassembled, cleaned individually, and reassembled. In the second period the experimental line was subjected to in-place cleaning procedures. That is, the line was left completely intact and cleaning was accomplished by means of forced circulation of cleaning solutions in a manner comparable to the way the milk is forced through the line. The cleaning methods used in the second period necessitated the use of an acid cleaning solution twice weekly. Sanitizing in the first period was accomplished by the use of a chlorine rinse before use and in the second period both chlorine and hot water at 180 °F were used. The experimental installations consisted of fifty-six feet of raw milk line and twelve and one-half feet of pasteurized milk line.

Included within the scope of the line was a holding vat and one pasteurizer.

Samples of milk were taken from the inlets and outlets of both the raw and pasteurized milk sections of the experimental pipe line. These samples were examined for standard plate count and coliform count according to regulations as set forth in Standard Methods for the Examination of Dairy Products (Ninth Edition). Likewise, determinations were made for sanitizing efficiency in the two methods of cleaning by means of determination of the part per million of available chlorine before and after sanitizing.

Records were kept on the amount of time required to clean the pipe line, and the costs and amounts of cleaner and sanitizer required. Visual inspections of the line for physical wear and soil and milkstone build up were made.

The results obtained show that there was no measurable pick-up of bacteria in the experimental line due to the use of in-place or circulation cleaning procedures. This was true for both the raw milk section and pasteurized milk section of the line. Likewise, it was found that in-place cleaning did not have an inhibiting effect on the sanitizing efficiency for the pipe line studied.

The records kept indicate that a considerable saving in labor costs was effected by the use of circulation cleaning methods. Further examination of the costs and amounts of cleaner and sanitizer required shows very little difference between costs for materials in either type of cleaning procedure. Finally, visual inspections of the line indicated a definite superiority for circulation cleaning methods.

Under the conditions of this study it was found that the conventional stainless steel line, already in use in the Virginia Polytechnic Institute creamery, could be cleaned by in-place or circulation cleaning procedures with results that were very satisfactory both from the standpoint of bacteria quality of the processed products and also from the standpoint of economical expenditure of operation.

## VII

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## VIII

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# IX

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APPENDIX A

Tables of Statistical Analysis

Table 11

Analysis of Variance of the Differences Between

Plate Count at the Inlet and Outlet of the

Raw Milk Line in Series I

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Inlet and Outlet of Line | 1 | 20.87 | 20.87 | 0.249[x] |
| Between Runs | 19 | 5,053.64 | 265.98 | 3.170[xx] |
| Error | 19 | 1,582.67 | 83.30 | |
| Total | 39 | 6,657.18 | | |

[x] Not significant
[xx] Slightly significant

Table 12

Analysis of Variance of the Differences Between Plate Count at the Inlet and Outlet of the Pasteurized Milk Line in Series I

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Inlet and Outlet of Line | 1 | 21.272 | 21.272 | 4.38[xx] |
| Between Runs | 19 | 114.564 | 6.029 | 2.17[xx] |
| Error | 19 | 49.042 | 2.586 | |
| Total | 39 | 148.878 | | |

[xx] Slightly significant

Table 13

Analysis of Variance of the Differences Between Coliform Counts at the Inlet and Outlet of the Raw Milk Line in Series I

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Inlet and Outlet of Line | 1 | 12.6675 | 12.6675 | 1.39[x] |
| Between Runs | 19 | 250.1029 | 13.1633 | 1.44[x] |
| Error | 19 | 172.9862 | 9.1045 | |
| Total | 39 | 435.7566 | | |

[x] Not significant

Table 14

Analysis of Variance of the Differences in Parts Per Million of Available Chlorine Before and After Sanitizing in Series I

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Before and After Sanitizing | 1 | 903 | 903.00 | 26.5xxx |
| Between Runs | 19 | 78,528 | 4,133.05 | 121.3xxx |
| Error | 19 | 647 | 34.05 | |
| Total | 39 | 80,078 | | |

xxx Highly significant

Table 15

Analysis of Variance of the Differences Between Plate Count at the Inlet and Outlet of the Raw Milk Line in Series II

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Inlet and Outlet of Line | 1 | 30.6196 | 30.6196 | 2.68[x] |
| Between Runs | 22 | 410.1534 | 410.1534 | 35.78[xxx] |
| Error | 22 | 245.2147 | 11.4612 | |
| Total | 45 | 9,299.2107 | | |

[x] Not significant
[xxx] Highly significant

Table 16

Analysis of Variance of the Differences Between Plate Count at the Inlet and Outlet of the Pasteurized Milk Line in Series II

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Inlet and Outlet of Line | 1 | 4.8476 | 4.8476 | 1.66[x] |
| Between Runs | 22 | 119.8837 | 5.4492 | 1.86[x] |
| Error | 22 | 64.2561 | 2.9207 | |
| Total | 45 | 188.9874 | | |

[x] Not significant

Table 17

Analysis of Variance of the Differences in Parts Per Million of Available Chlorine Before and After Sanitizing in Series II

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Before and After Sanitizing | 1 | 2,473.4 | 2,473.40 | 83.05xxx |
| Between Runs | 16 | 2,194.0 | 137.13 | 4.60xx |
| Error | 16 | 476.6 | 29.78 | |
| Total | 33 | 5,144.0 | | |

xx Slightly significant
xxx Highly significant

# X

# SUPPLEMENTARY STUDY

# A Brief Analysis of the Possibilities of Using Pyrex Glass Tubing in Milk Pipe Lines

## A. Introduction

The introduction of pyrex glass tubing to the dairy industry was largely brought about by the shortage of stainless steel during the war years of 1941 to 1947. According to Sheuring and Henderson (24) glass has the advantages of being corrosive resistant, transparent, and light in weight. Glass will not contaminate fluids, can be used over a wide range of temperatures, and possesses hard, smooth surfaces which have poor adhesion characteristics for most fluids. They further state that at the present time there are more than forty commercial and college dairy plants in the country using permanent glass pipe lines. These lines are being used for raw cold milk, cold pasteurized milk, hot pasteurized milk, ice cream mix, skim milk, and whey.

Although it seems as though there has been quite a bit of work done with pyrex glass tubing, no great wealth of material has been published upon the subject. Therefore, to inform the dairy plant operators in Virginia, in particular, it was felt that a study of glass sanitary pipe line would be well justified. It was also felt that such a study would form a desirable supplement to data presented in the main body of this thesis. In accordance with such a belief such a study was begun and the ensuing pages present a preliminary analysis of the results obtained up to the time of the final drafting of this thesis. It is expected that this experimentation on pyrex glass will be carried on for several months.

B. Methods and Procedures

1. Description of line

The experimental pipe line being used in this study was set up to follow exactly the same route as the line used in Series I and Series II as described in the main body of the thesis. The only major change in the line consisted of the installation of pyrex glass pipes at certain points along the pipe line. In the raw milk section of the line, glass tubing was inserted at the pump connected to the receiving tank on the first floor of the creamery and extended a length of approximately twenty-six feet up to the holding vat on the second floor. This section corresponds roughtly to the distance between A and B in Figure 1. The remainder of the raw milk line extending from the holding vat to the pasteurizer consisted of conventional stainless steel pipe. In the pasteurized section of the experimental line, glass tubing extended from the pasteurizer to a valve located about three feet from the surface cooler. This was a distance of approximately twelve and one-half feet. This section corresponds roughly to the distance between D and E in Figure 1.

The glass tubing installed for this study was one and one-half inches in diameter. All connections of glass to glass were made by means of special flange sets with pure sulphur-free gum rubber gaskets inserted between the pieces of tubing. The outlay of the experimental installation required the connection of glass to stainless steel at several points. These connections were made by means of No. 10 PX adapters made especially for that purpose. In so far as was possible, all sections of the line were supported by hangers to alleviate strain on the glass connections. All fittings on the glass section of the line were standard glass tees and elbows.

2. Cleaning and sanitizing methods

The cleaning and sanitizing methods used in this study of glass tubing are the same as those used for Series II in the main body of this thesis. This line was cleaned from the viewpoint of a permanent installation as was the experimental line in Series II. The line was left completely intact and the same temperatures, amounts and types of cleaners, and lengths of time were utilized as for the circulation methods used in Series II.

3. Bacterial quality of processed milk

Bacterial quality of determinations, in the form of standard plate counts and coliform counts, were made in exactly the same manner as for Series I and Series II. Samples were again taken at five different points along the experimental pipe line. A slight change was made in the procedure of taking samples in that sample B was considered the outlet of the raw milk line in so far as the glass tubing was concerned. This was slightly different from the procedure observed for Series I and Series II. In these two series sample C was considered the outlet of the raw milk line.

4. Labor costs and material costs of cleaning and sanitizing, and sanitizing efficiency

Data concerned with the labor and material costs of cleaning and sanitizing were collected in the same manner as for Series I and Series II in the main body of this thesis. Determinations of sanitizing efficiency were made in the same manner as for the two series included in the main body of this thesis.

5. Durability and condition of pipe

Visual inspections were made and results were recorded as for Series I and Series II.

6. Initial cost of pipe line

The cost of the glass pipe line was calculated from prevailing market quotations and compared with the corresponding price for stainless steel. Costs were figured on the basis that the entire line was composed of glass.

C. Results

1. Bacterial quality of processed milk

The results of the standard plate counts for the raw and pasteurized milk pipe lines examined in this supplementary study are found in Table 18. The largest increase of bacteria/ml. between the inlet and outlet of the raw milk line was found to be 900 bacteria/ml. The largest increase of bacteria/ml. between the inlet and outlet of the pasteurized milk line was found to be 180 bacteria/ml. The average plate count at the inlet and outlet of the raw milk line was 3525 bacteria/ml., and 3867 bacteria/ml., respectively. Statistical analysis shows that the differences between plate counts at the inlet and outlet of the raw milk line were slightly significant. The average plate count at the inlet and outlet of the pasteurized milk line was 13 bacteria/ml., and 30 bacteria/ml., respectively. Statistical analysis shows that the differences between plate counts at the inlet and outlet of the pasteurized milk line were not significant.

Results of the coliform counts made at the inlet and outlet of the raw and pasteurized milk lines are given in Table 19. The largest increase between coliform counts at the inlet and outlet of the raw milk line was 10 coliforms/ml. occurring two times. The coliform counts on the pasteurized milk line remained negative with the exception of one run in which the count increased from zero to ten coliforms/ml. The average coliform count at the inlet and outlet of the raw milk line was 18 coliforms/ml., and 20 coliforms/ml., respectively. The average coliform count at the inlet and outlet of the pasteurized milk line was zero and less than one coliform/ml. No statistical analysis is required to note that the differences between coliform counts at the inlet and outlet of both the raw and pasteurized milk lines, are not significant.

2. Sanitizing efficiency

The results of the determinations of the parts per million of available chlorine before and after sanitizing are given in Table 20. The greatest loss of parts per million of available chlorine on any single run was 20 parts per million. Such a loss occurred on two runs. The loss on the remaining runs ranged from zero to ten parts per million. The average available chlorine strengths before and after sanitizing were 195 parts per million and 185 parts per million, respectively. Statistical analysis shows that the differences between the parts per million of available chlorine before and after sanitizing were significant.

3. Labor costs, material cost of cleaning and sanitizing, and durability of pipe

The data on these determinations are, of course, incomplete because the work reported here represents only the first portion of the study. However, it is to be expected that labor and material cost should be the same as for Series II since the same cleaning methods and procedures are used. In so far as the durability of the pipe is concerned, no damage has yet occurred to the line. Likewise, no visible soil or milkstone build up has been noted.

4. Initial cost of pipe line

The cost of the glass pipe, as figured for the entire installation, was $115.60. The cost of the fittings required was $238.38. The total cost of the line was $353.98.

Table 18

Standard Plate Counts for Samples Taken from the Raw and Pasteurized Milk Pipe Lines Used in Supplementary Study on Pyrex Glass Lines

| Run | Raw Milk Line | | Pasteurized Milk Line | |
|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet |
| 1 | 3400 | 3800 | 20 | 200 |
| 2 | 2000 | 1900 | 0 | 0 |
| 3 | 6400 | 6500 | 20 | 20 |
| 4 | 1400 | 1800 | 0 | 0 |
| 5 | 2100 | 2000 | 10 | 10 |
| 6 | 4000 | 4800 | 30 | 50 |
| 7 | 2600 | 3300 | 10 | 10 |
| 8 | 3500 | 3800 | 0 | 0 |
| 9 | 4900 | 5800 | 40 | 50 |
| 10 | 2200 | 2300 | 30 | 30 |
| 11 | 7000 | 7300 | 0 | 0 |
| 12 | 2800 | 3100 | 0 | 0 |
| Average | 3525 | 3867 | 13 | 31 |

Table 19

Coliform Counts for Samples Taken from the Raw and Pasteurized Milk Pipe Lines Used in Supplementary Study on Pyrex Glass Lines

| Run | Raw Milk Line | | Pasteurized Milk Line | |
|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet |
| 1 | 20 | 20 | 0 | 0 |
| 2 | 0 | 0 | 0 | 10 |
| 3 | 10 | 10 | 0 | 0 |
| 4 | 40 | 40 | 0 | 0 |
| 5 | 10 | 20 | 0 | 0 |
| 6 | 10 | 10 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 |
| 8 | 30 | 30 | 0 | 0 |
| 9 | 0 | 10 | 0 | 0 |
| 10 | 20 | 20 | 0 | 0 |
| 11 | 50 | 50 | 0 | 0 |
| 12 | 30 | 30 | 0 | 0 |
| Average | 18 | 20 | 0 | 0.8 |

Table 20

Parts Per Million of Available Chlorine in Sanitizing Solutions in Supplementary Study on Pyrex Glass Lines

| Run | Before Circulation | After Circulation | Difference |
|---|---|---|---|
| 1 | 190 | 180 | -10 |
| 2 | 200 | 200 | 0 |
| 3 | 210 | 200 | -10 |
| 4 | 190 | 170 | -20 |
| 5 | 180 | 170 | -10 |
| 6 | 200 | 190 | -10 |
| 7 | 190 | 180 | -10 |
| 8 | 190 | 170 | -20 |
| 9 | 200 | 190 | -10 |
| 10 | 200 | 190 | -10 |
| 11 | 210 | 210 | 0 |
| 12 | 180 | 170 | -10 |
| Average | 195 | 185 | 10 |

D. Discussion of Results

1. Bacterial quality of processed milk

The results given in Table 18 show that the average plate count at the inlet and outlet of the raw milk line, in this supplementary study, was 3527 bacteria/ml., and 3867 bacteria/ml., respectively. These figures given an average difference of 340 bacteria/ml. between the inlet and outlet of the line. In order to make a comparison it was felt that the data obtained for stainless steel in Series II of the main body of the thesis, could be utilized. These data were obtained under the same conditions as those which prevailed for the glass line. The only difference was the type of tubing used. Using the data obtained for Series II, it was found that the average difference between the plate counts at the inlet and outlet of that series was 156 bacteria/ml. Therefore, a comparison of the average differences shows that the counts taken on the raw milk section of the glass line increased an average of 184 bacteria/ml. more than did the counts on the stainless steel line in Series II. Although this count seems to indicate a definite increase due to the use of glass lines, it is a relatively small number when consideration of allowable counts is made. It should also be emphasized that the data obtained for the glass line represent only the preliminary stages of the glass line study and later results may show an entirely different picture. In comparing the results on the raw milk sections of the glass and stainless steel, it is worth while to note that the largest single increases in count at the inlets and outlets of the lines were 1200 bacteria/ml. for stainless steel and 900 bacteria/ml. for the glass line. Although neither of these counts is large, it is significant to note that in so far as individual variations were concerned the glass line had a smaller count.

Statistical analysis shows that the differences between plate counts at the inlet and outlet of the raw milk section of the glass line were only slightly significant. The validity of such information seems questionable. It is felt that later data may show the differences not to be significant and likewise the counts which were obtained were not very high when speaking in terms of acceptable bacterial quality. In general, the results obtained indicate that the raw milk section of the glass pipe line, installed in the Virginia Polytechnic Institute creamery, can be used with the expectancy of satisfactory results from the standpoint of bacterial quality in so far as plate counts are concerned.

Results of the plate counts on the pasteurized section of the glass pipe line are given in Table 18. The average plate count at the inlet and outlet of the pasteurized section of the glass pipe line was 13 bacteria/ml., and 31 bacteria/ml., respectively. These figures show an average increase of 18 bacteria/ml. The data obtained for pasteurized milk in Series II show an average difference of three bacteria/ml. between the inlet and outlet of the pasteurized line. Comparison of these averages shows that the counts on the pasteurized section of the glass line increased an average of 15 bacteria/ml. more than did the pasteurized section of the stainless steel line in Series II. In so far as averages are concerned, such results would not tend to favor glass over stainless steel for use in pipe lines. This does not necessarily mean that glass would not be satisfactory for this purpose.

A comparison of the individual variations shows that the largest single increase in plate count on the pasteurized section of the glass line was 180 bacteria/ml. Likewise, the largest single increase on the corresponding section of the stainless steel line was 40 bacteria/ml. Although neither increase is excessive and both are acceptable, it is worthwhile to note that the largest single increase on the glass line was more than four times as large as the largest single increase on the stainless steel line.

Statistical analysis shows that the differences between plate counts at the inlet and outlet of the pasteurized milk section of the glass pipe line were not significant.

In general, the results obtained indicate that in so far as plate counts are concerned, pyrex glass tubing can be used for both the raw and pasteurized milk sections of the experimental pipe line studied in this investigation. However, the results do not indicate that the glass line is more satisfactory than stainless steel under the same conditions of cleaning and sanitizing.

Examination of the data obtained for coliform counts indicates that very satisfactory results were obtained for both the raw and pasteurized sections of the glass pipe line. The average coliform count at the inlet and outlet of the raw milk line was 18 coliforms/ml., and 20 coliforms/ml., respectively. This gives an average increase of two coliforms/ml. while similar data for stainless steel in Series II show an average difference of one coliform/ml. Comparison of these figures shows very little to choose from in so far as coliform counts on the raw milk line are concerned. It is especially notable that in only two runs did the coliform count increase at all. Comparison of individual increases of coliform count on the raw milk sections of the two lines indicates a more favorable reaction toward glass lines.

Comparison of the coliform counts on the pasteurized milk sections of the two lines shows that both types of pipe lines were very satisfactory in that such counts remained negative throughout with the exception of one run on the glass line in which the count increased from zero to ten coliforms/ml.

In general, the results obtained indicate that glass lines are acceptable from the standpoint of coliform counts, but that glass is not superior to stainless steel in this respect.

It should be noted that on two occasions outbreaks of coliform and bacteria counts were found with the glass line. However, this trouble was traced to a valve from which samples were being taken and the trouble was easily eliminated.

2. Sanitizing efficiency

In general, the results obtained for parts per million of available chlorine before and after sanitizing the glass pipe line, are in pretty close harmony with the results obtained under similar conditions with stainless steel. Comparison of the exact figures shows that the average loss of parts per million of available chlorine in Series II was 17 parts per million. The average loss with the glass pipe line was 10 parts per million. Such a difference would tend to indicate that the glass lines had a little less organic matter left in them when compared to the stainless steel line.

Actually, there is very little difference between the two types of lines in sanitizing efficiency when comparing the losses with standards agreed upon by most cleaning experts. That is, a loss of 50 parts per million is still considered to be satisfactory.

3. Labor costs, cleaning material cost, and visual inspections of pipe line

As has already been stated, the results reported in this supplementary study represent only the beginning of the study on glass lines and, therefore, no complete set of figures is available for comparing labor and material costs with those for stainless steel. Those costs should be approximately the same as for Series II for the same length of time. This is true because the same cleaning procedures were used in both instances. As for visual inspection of the line, the only thing that can be said is that no breakage of the glass line has yet occurred and no soil build up or milkstone build up have been observed.

4. Initial cost of pipe line

The total cost of the stainless steel line used in Series II was $434.35. The total cost of the glass line was $353.98. This indicates that glass is less expensive than stainless steel on initial installations.

It should be emphasized again that the results obtained for the glass line are of a preliminary nature and do not necessarily represent a true picture of the over-all situation.

E. Conclusions

This supplementary study, using pyrex glass tubing as a substitute for stainless steel in the sanitary pipe line installation of the Virginia Polytechnic Institute creamery, led to the following conclusions:

1. The results obtained indicate that pyrex glass tubing can be used with satisfactory results in so far as bacterial quality is concerned. This is true for both raw and pasteurized lines.

2. The results obtained do not indicate that pyrex glass tubing is more desirable than stainless steel tubing.

3. The results obtained show no measurable difference between the two types of pipe line material in so far as sanitizing efficiency is concerned.

4. The calculation of pipe line costs seems to indicate that change-over from stainless steel to glass would not be particularly advantageous. However, an initial installation using pyrex glass would seem to be satisfactory.

# F

## Tables of Statistical Analysis

Table 21

Analysis of Variance of the Differences in Plate Count at the Inlet and Outlet of the Raw Milk Section of the Pyrex Glass Pipe Line

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Inlet and Outlet of Line | 1 | 41 | 41.00 | 10.02[xx] |
| Between Runs | 11 | 4,620 | 420.00 | 102.6[xxx] |
| Error | 11 | 45 | 4.09 | |
| Total | 23 | 4,706 | | |

[xx] Slightly significant
[xxx] Highly significant

Table 22

<u>Analysis of Variance of the Differences Between Plate Count at the Inlet and Outlet of the Pasteurized Milk Section of the Pyrex Glass Pipe Line</u>

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between Inlet and Outlet of Line | 1 | 6.0 | 6.00 | 2.090[x] |
| Between Runs | 11 | 220.5 | 20.04 | 7.006[xx] |
| Error | 11 | 31.5 | 2.86 | |
| Total | 23 | 258.0 | | |

[x] Not significant
[xx] Slightly significant

Table 23

Analysis of Variance of the Differences in Parts Per Million of Available Chlorine Before and After Sanitizing the Pyrex Glass Pipe Line

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | F |
|---|---|---|---|---|
| Between the Beginning and End of Sanitizing | 1 | 360 | 360.0 | 9.00 xx |
| Between Runs | 11 | 2,760 | 250.9 | 6.27 xx |
| Error | 11 | 440 | 40.0 | |
| Total | 23 | 3,560 | | |

xx Slightly significant