# CLEANING STAINLESS STEEL SANITARY LINES IN-PLACE[1]

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(Received for publication December 20, 1954)

**Cleaning-in-place (C.I.P.) procedures have been compared with dismantling and brushing techniques. Various times, temperatures, velocities and cleanser compositions were studied to determine the combination which was between that which would yield a satisfactory and that which would yield an unsatisfactory condition. Bacteriological and physical examination of C.I.P. lines cleaned at 150°F. or above for 20 min. indicate that C.I.P. procedures are as effective as, or better than dismantling and brush cleaning.**

Until recently the method of cleaning stainless steel and other lines used in dairy plants was to dismantle and brush-clean them. Health departments and other regulatory bodies in the United States believed that brush cleaning was the only satisfactory method. However, World War II brought about a shortage of stainless steel lines, and glass lines were substituted. Since the glass line did not lend itself to dismantling without the probability of considerable breakage, a procedure was instituted whereby cleaning solution was recirculated through the line. Adoption of recirculation cleaning did not occur commercially until trials which indicated its adequacy were completed and then it was permitted only on a tentative basis by some regulatory agencies. As a result, the possibility of a new and better method for cleaning sanitary lines became apparent, and many studies were initiated in experiment stations and industrial plants. One such study was undertaken at Iowa State College. The purpose of the study reported herein was to determine the effects of velocity, time, temperature and types of cleaners on in-place cleaning. Data on hand cleaning also were obtained for the same lines, since it was reasoned that results obtained by recirculation cleaning should be evaluated in the light of those by hand cleaning.

Several workers have published papers concerning velocities, time, temperatures and types of cleaners that should be used for cleaning by recirculation. Holland *et al.* (5) suggest a minimum velocity of 5 ft./sec. through the largest pipe diameter yet state that velocities from 2 to 8.5 ft./sec. give satisfactory cleaning. Parker *et al.* (10) found velocities of 3.4 and 4.3 ft./sec. to give satisfactory results. The time of the recirculation period varies depending upon the type of lines being cleaned. Some workers recommend from 10-15 min. (1, 2, 3, 5, 8, 10). Temperatures used for recirculation cleaning also depend upon the type of line being cleaned. Low temperatures (120-150° F.) (5, 10) are used on most cold milk lines while higher temperatures (150-170° F.) (5, 10) are used for hot milk lines and HTST (High-Temperature, Short-Time) pasteurizers. Cleaners employed for cleaning by recirculation vary widely in their composition but most of them used contain an alkali source, a polyphosphate and a wetting agent. Recently the use of chelated caustics has come into the picture; these seem to do a satisfactory job of cleaning.

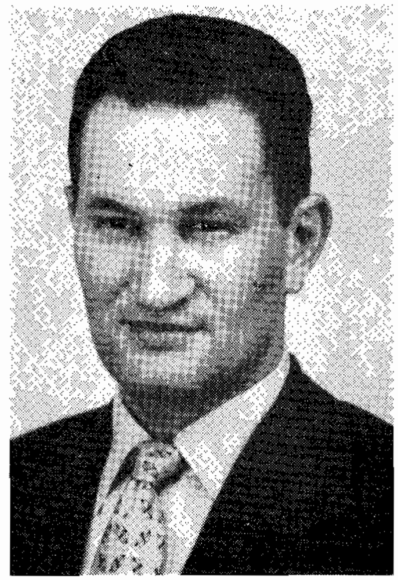
## Experimental

### *Hand cleaned lines*

Facilities in the Iowa State College market milk laboratory were used to make this study. Hand cleaning procedures consisted of dismantling, brush washing in a pipeline wash tank, sanitization and reassembling with new fiber gaskets. The reassembled lines were then examined for bacteriological and physical cleanliness. Bacteriological examination consisted of opening the union aseptically, removing the gasket with sterile forceps and swabbing the bevels and internal surfaces of the union.

After the gasket was removed it was placed in 20 ml. of a sterile 0.02 per cent (w/v) "azolectin" solution in a 4-oz. screw cap jar and shaken vigorously 50 times. Azolectin solution was used to neutralize the quaternary ammonium compound used in sanitization (7). Samples that were not plated within 0.5 hr. were placed in ice water and were so held until plated. One ml. aliquots were plated in duplicate on T.G.E. (tryptone, glucose, beef extract) agar for standard plate counts; 1-ml. portions were plated on V.R.B. (violet red bile) agar for coliform counts. All plates were incubated at 35.5° C. The former plates were counted after 48 hrs. while the latter were counted after 18 hrs.

To determine whether or not some organisms had penetrated the surface of the paper and fiber gaskets, a number of gaskets were plated subsequent to the washing technique. They were cut into small sections with sterile scissors and transferred aseptically, with the remaining 17 ml. of the azolectin suspension, to a sterile blendor cup. Ninety-nine ml. of sterile buffered distilled water were added and the gasket was blended (Waring blendor) for three minutes. A 12-ml. portion of the gasket suspension was divided among 3 petri dishes for standard plate counts



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[1]Journal Paper No. J-2589 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1206.

and a like amount for the coliform counts. These plates were incubated, counted and the results recorded as the number of colonies per gasket.

The bevels of the lines were examined by the swab technique. The swab employed was a wooden applicator stick (2.75 in. long) with non-absorbent cotton twisted on it to a length of 0.75 in. Before use, the swabs were sterilized in 4 oz. screw cap jars at 250° F. in an autoclave for 20 min. During use, the swab was removed from the jar and wetted by placing in a sterile 13 x 80 mm. screw cap vial containing 5 ml. of sterile azolectin suspension. Excess azolectin suspension was removed by pressing the swab against the side of the vial. Both the male and female bevels were swabbed by running the swab over the surface 10 times, reversing the direction after 5 revolutions. After swabbing, the swab was returned to the vial of azolectin suspension by breaking the applicator stick at a point below that touched by the fingers. The vial was shaken vigorously 50 times and aliquot portions were plated. If samples were not plated within 0.5 hr. they were immersed in ice water until plated. One-ml. aliquots were plated in duplicate on T.G.E. agar and 1-ml. portions plated on V.R.B. agar for total and coliform counts, respectively Plates were incubated, counted and counts recorded as the number of colonies per 8 sq. in.

The internal surfaces of the pipes were sampled by the swab technique after the gaskets were removed and the bevels swabbed. Approximately 8 sq. in. of surface was swabbed by running the swab over the inner surface 10 times, reversing the direction after 5 revolutions. The same plating, incubation and counting techniques were used as for the bevels. Results were recorded as the number of colonies per 8 sq. in.

*Cleaned in-place lines*

The circuit employed for cleaning by recirculation consisted of 85 ft. of 1.5 in. diameter and 20 ft. of 2 in. diameter, 18-8, beveled stainless steel line. All horizontal lines were sloped at 0.5 in. per 10 ft. Included in this system were raw, hot pasteurized, 136° F. and cold pasteurized milk lines. These lines were arranged so that with short connections they formed a complete system among themselves when the HTST pasteurizer was included. Short sections of 320-grit, 500-grit and electropolish lines were installed in the raw milk section while a 10-ft. section of 1.5 in. diameter pyrex glass line was installed in the cold pasteurized milk line.

To control the temperature of the recirculating fluid, an automatic solenoid steam valve[3] was employed. When the HTST pasteurizer was in the system a velocity of 2 ft./sec. was attained but when it was excluded a velocity of 7 ft./sec. was attained.

The cleaning problem in this plant was similar to that in most dairy plants of medium size, the only exception to this being the processing of fresh concentrated (3:1) milk.

The method of recirculation used was:

1. All lines not in the continuous system were disconnected and the continuous system and circulating unit connected.

2. The lines were flushed with water at 110-120° F. until the effluent was clear.

3. All valves were dismantled and brush-cleaned with detergent, rinsed, and replaced.

4. Acid solution was recirculated at 150° F. for 20 min.

5. The acid solution was rinsed from the system with water (90-120° F.).

6. Alkali solution was recirculated at 150° F. for 20 min.

7. Alkali was rinsed from the system with water (90-120° F.).

8. The lines were opened at drainage points, allowed to drain and dry. At 3, 7 and 10-day intervals, unions were opened, the lines were examined for physical cleanliness and swab tests were made.

9. Hot water sanitization (180° F. for 10 min.) was employed immediately after the alkali was rinsed from the lines until results obtained by swab tests, before and after sanitization, indicated that this treatment was not necessary.

10. Before use the next day a hypochlorite solution of 200 ppm. (inlet concentration) was passed through the system to sanitize the lines.

The time-temperature combination (150° F. for 20 min.) selected for the majority of the work was based upon preliminary data. The combination desired was one which was just about between that which would yield a satisfactory and that which would yield an unsatisfactory set of lines. During this preliminary phase of the work *Dilac* ($H_3PO_4$ plus corrosion inhibitor) was employed at the rate of 0.015 per cent (w/v) and cleaner A was used at the rate of 0.04 per cent active alkalinity (as $Na_2O$). The series of runs for the preliminary work consisted of two week recirculation periods at 130° F. for 10 and for 20 min., 140° F. for 10 min., 150° F. for 20 min. and 170° F. for 20 min.; all at 2 ft./sec.

After establishing the time-temperature combination (150° F. for 20 min.) each of three cleaners (A, B, and D) were used for a two week period at 2 ft./sec. in a system including the HTST pasteurizer and all the milk lines. Comparative runs were made at 7 ft./sec. with only the raw milk and cold pasteurized milk lines. Upon completion of the above series, one run of 4 days was made with cleaner A, during which swab tests were made 12 hours after cleaning rather than immediately after cleaning. In all other runs swab tests were made at 3, 7 and 10 day intervals immediately after cleaning.

Additional 4-day runs were made at 120° and 140° F. for 20 min. with cleaner A at 2 ft./sec. to determine whether or not these temperatures gave results equivalent to those obtained at 150° F. for 20 min. at 2 ft./sec.

Cleaner concentrations used after completion of the preliminary runs were 0.015 per cent (w/v) *Dilac* and 0.08 per cent active alkalinity for all alkali cleaners.

The cleaners used in this study had the following compositions:

*Cleaner A*

| | |
|---|---|
| Trisodium phosphate ($Na_3PO_4$ . 12 $H_2O$) | 60% |
| Sodium tripolyphosphate ($Na_5P_3O_{10}$) | 38% |
| Santomerse No. 1 | 1% |
| Sterox | 1% |

[3]General Control Magnetic valve. K-15-C. 3/8 in. pipe size, 7/16 in. port size. 115 v, 60 cycle, No. 225 solenoid for 150 psi, steam with class H coil.

*Cleaner B*

Soda Ash ($Na_2CO_3$) ....................11.9%
Sodium metasilicate ($Na_2SiO_3$)........11.4%
Sodium tripolyphosphate ($Na_5P_3O_{10}$) ....................66.4%
Nonionic wetting agent ....................1.3%
Nacconol ....................1.0%

*Cleaner C*

Soda Ash ($Na_2CO_3$) ....................56%
Sodium metasilicate ($Na_2SiO_3$)........34%
Sodium tetraphosphate ($Na_6P_4O_{13}$)....9%
Nacconol ....................1.0%

*Cleaner D*

Chelated caustic....Composition not known

The examination procedures, plating methods, etc. were the same as those used for hand cleaning except that sterile buffered distilled water was used in place of the azolectin solution because no quaternary compounds were employed. In later work rubber gaskets were substituted for paper or fiber gaskets in the cleaned-in-place (C.I.P.) system; these were plated by the washing technique only.

Since the quality of the final product is the criterion for good cleaning procedures, the first bottle of each product from the filler was plated for total plate and coliform counts. This was done for both the hand cleaned and C.I.P. lines. However, when trouble was experienced with high coliform counts in the first bottle of product, sterile sampling cocks were installed in the cold pasteurized line. These cocks were placed approximately 20 ft. apart so that samples of the first product through the line could be taken, and plated for total plate and coliform counts.

## RESULTS

*Product quality*

The following table is a resume of the results obtained by plating the first bottle of the products through hand cleaned (H.C.) lines.

At first glance these data would indicate that the product quality of the milk through H.C. lines was better than milk that passed through C.I.P. lines. This is not the case, however, for line samples taken through the sterile sampling cocks show that the high coliform counts of milk passed through C.I.P. lines came from sources beyond the recirculation system.

With this in mind, the data indicate that the product quality of milk put through C.I.P. lines is equal to that of milk put through hand cleaned lines.

*C.I.P.-vs-H.C.*

In Table 2 the results obtained by recirculation and hand cleaning are summarized. These results generally indicate that if the recirculation solution was above 150° F. for 20 min. the internal surfaces, bevels and gaskets of all lines were cleaned better by recirculation with cleaner A than they were by hand-cleaning procedures. At 140° F. for 10 min. the raw and cold pasteurized milk lines were cleaned satisfactorily by recirculation. However, when the recirculation solution was below 140° F. for 10 min. hand cleaning was more nearly satisfactory than recirculation cleaning. These are exceptions to the above statements. At higher temperatures (150°-170° F.) of recirculation, unsatisfactory conditions were encountered much less frequently with recirculation than with hand cleaning. At lower temperatures of recirculation (130-140° F. ) there was no consistent advantage of recirculation as measured by bacteriological and physical examination. At these temperatures results secured by recirculation were erratic. A comparison of H.C. and C.I.P. on internal surfaces, bevels and gaskets indicates that there was a smaller difference between the condition of internal surfaces than there was between bevels and gaskets. The data obtained by swabbing the bevels of hand cleaned lines indicate that they were frequently missed when brush cleaned. The gaskets taken from hand cleaned lines frequently showed contamination that most probably came from highly contaminated bevels. H.C. lines at times showed evidence of high coliform contamination, whereas no coliform contamination was found with C.I.P. lines. The bevels and gaskets from C.I.P. lines were consistently satisfactory bacteriologically, although at times they were physically unsatisfactory.

The above comparisons were made from data obtained in runs with cleaner A. Data obtained from runs IV, V, VII and VIII, with either cleaner B or D, comparing H.C. and C.I.P. lead to the same conclusions.

Gaskets in H.C. lines were subjected to possible contamination from the handlers and uncleaned bevels while gaskets from C.I.P. lines were subjected to temperatures which for the most part were in excess of pasteurization exposure, which may account for their better condition.

*Effect of recirculation time on cleaning efficiency*

The time of recirculation at 130° F. (Table 2–XII, XIII) with cleaner A did not significantly affect the bacteriological results obtained on the internal surfaces and bevels of the raw or cold pasteurized milk lines. The 136° F and hot pasteurized milk lines were not cleaned

TABLE 1—DISTRIBUTION OF STANDARD PLATE AND COLIFORM COUNTS OF THE FIRST BOTTLE OF EACH PRODUCT RUN THROUGH H.C. AND C.I.P. LINES

| Type of count | Cleaning method | Distribution ranges (counts/ml.) | Per cent of total no. of samples: Homogenized milk | cream line milk | Skim milk |
|---|---|---|---|---|---|
| Standard plate | C.I.P.[a] | <10,000 | 100.0 | 100.0 | 100.0 |
| | | <1,000 | 92.6 | 50.0 | 71.4 |
| | | <300 | 35.2 | 11.1 | 15.4 |
| | Total samples | | 54 | 34 | 26 |
| | H.C.[b] | <10,000 | 98.9 | 93.5 | 100.0 |
| | | <1,000 | 98.0 | 43.5 | 73.8 |
| | | <300 | 78.5 | 6.53 | 57.9 |
| | Total samples | | 98 | 46 | 14 |
| Coliform | C.I.P.[a] | >10 | 14.8 | 14.7 | 7.7 |
| | | 1-10 | 27.8 | 30.6 | 34.6 |
| | | <1 | 59.3 | 56.0 | 57.7 |
| | Total samples | | 54 | 34 | 26 |
| | H.C.[b] | >10 | 1.02 | 6.52 | 5.27 |
| | | 1-10 | 10.2 | 30.4 | 52.7 |
| | | <1 | 89.8 | 69.6 | 47.3 |
| | Total samples | | 98 | 46 | 19 |

[a]Cleaned-in-place lines.
[b]Hand cleaned lines.

TABLE 2—PERCENTAGE OF COUNTS WHICH LIE IN THE DISTRIBUTION RANGE 1 TO 100 COLONIES, CALCULATED AS OF 8 SQ. IN. OF SURFACE

| Run No. | | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|
| Temperature and Time | | 170-20 | 150-20 | 150-20 | 150-20 | 150-20 | 150-20 | 150-20 | 150-20 |
| Velocity, ft./sec. | | 2 | 2 | 2 | 2 | 2 | 7 | 7 | 7 |
| Cleaner | | A | A | A | B | D | A | B | D |
| % Act. Alk. as $Na_2O$ | | 0.04 | 0.04 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| *Raw milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 100 | 55.7 | 88.9 | 88.9 | 88.9 | 88.9 | 77.8 | 100 |
| | | (9) | (9) | (9) | (9) | (9) | (9) | (9) | (9) |
| | Bevels | 89 | 44.5 | 75.0 | 88.9 | 66.7 | 100 | 88.9 | 88.9 |
| | | (9) | (9) | (8) | (9) | (9) | (9) | (9) | (9) |
| | Gaskets | 37.5 | 22.2 | 50.0 | 33.3 | 11.1 | 33.3 | 37.5 | 44.5 |
| | | (8) | (9) | (8) | (9) | (9) | (9) | (8) | (9) |
| *136° F. milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 100 | 66.7 | 85.8 | [a] | 100 | [a] | [a] | [a] |
| | | (8) | (9) | (7) | | (8) | | | |
| | Bevels | 87.5 | 100 | 85.8 | [a] | 100 | [a] | [a] | [a] |
| | | (8) | (9) | (7) | | (8) | | | |
| | Gaskets | 0.0 | 33.3 | 28.6 | [a] | 12.5 | [a] | [a] | [a] |
| | | (8) | (9) | (8) | | (8) | | | |
| *Hot pasteurized milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 100 | 100 | 55.6 | [a] | 66.7 | [a] | [a] | [a] |
| | | (9) | (9) | (9) | | (9) | | | |
| | Bevels | 89 | 55.6 | 66.7 | [a] | 88.9 | [a] | [a] | [a] |
| | | (9) | (9) | (9) | | (9) | | | |
| | Gaskets | 33.3 | 66.7 | 33.3 | [a] | 0.0 | [a] | [a] | [a] |
| | | (9) | (9) | (9) | | (9) | | | |
| *Cold pasteurized milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 87.5 | 100 | 100 | 100 | 100 | 62.5 | 87.5 | 77.8 |
| | | (8) | (7) | (9) | (9) | (9) | (8) | (8) | (9) |
| | Bevels | 87.5 | 85.8 | 87.5 | 77.8 | 100 | 75.0 | 62.5 | 88.9 |
| | | (8) | (7) | (9) | (9) | (9) | (8) | (8) | (9) |
| | Gaskets | 57.2 | 57.2 | 28.5 | 62.5 | 44.5 | 12.5 | 25.0 | 11.1 |
| | | (7) | (7) | (7) | (8) | (9) | (8) | (8) | (9) |

| Run No. | | IX | X | XI | XII | XIII | XIV | XV | XVI |
|---|---|---|---|---|---|---|---|---|---|
| Temperature and Time | | 150-20[b] | 140-10 | 140-20[c] | 130-20 | 130-10 | 130-10 | 120-20 | Hand cleaned lines |
| Velocity, ft./sec. | | 2 | 2 | 2 | 2 | 2 | 7 | 2 | |
| Cleaner | | A | A | A | A | A | A | A | |
| % Act. Alk. as $Na_2O$ | | 0.08 | 0.04 | 0.08 | 0.04 | 0.04 | 0.04 | 0.08 | |
| *Raw milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 88.9 | 100 | 100 | 77.8 | 66.7 | 89.0 | 100 | 93.1 |
| | | (9) | (9) | (9) | (9) | (9) | (9) | (9) | (44) |
| | Bevels | 77.8 | 88.9 | 100 | 44.5 | 55.6 | 66.7 | 66.7 | 36.4 |
| | | (9) | (9) | (9) | (9) | (9) | (9) | (9) | (33) |
| | Gaskets | 75 | 12.5 | 22.2 | 33.3 | 42.8 | 33.4 | 0.0 | 0.0 |
| | | (8) | (8) | (9) | (9) | (7) | (9) | (8) | (11) |
| *136° F. milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 77.8 | [a] | [a] | 66.7 | [a] | [a] | [a] | 80.5 |
| | | (9) | | | (9) | | | | (41) |
| | Bevels | 77.8 | [a] | [a] | 66.7 | [a] | [a] | [a] | 83.0 |
| | | (9) | | | (9) | | | | (41) |
| | Gaskets | 12.5 | [a] | [a] | 25.0 | [a] | [a] | [a] | |
| | | (8) | | | (8) | | | | |
| *Hot pasteurized milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 33.3 | [a] | [a] | 22.5 | [a] | [a] | [a] | 82.5 |
| | | (9) | | | (9) | | | | (40) |
| | Bevels | 77.8 | [a] | [a] | 44.5 | [a] | [a] | [a] | 67.5 |
| | | (9) | | | (9) | | | | (40) |
| | Gaskets | 0.0 | [a] | [a] | 12.5 | [a] | [a] | [a] | 70 |
| | | (8) | | | (8) | | | | (10) |
| *Cold pasteurized milk lines* | | | | | | | | | |
| Per cent and total no. of counts | Surfaces | 100 | 88.9 | 66.7 | 67.5 | 88.9 | 100 | 88.9 | 93.0 |
| | | (9) | (9) | (9) | (8) | (9) | (8) | (9) | (43) |
| | Bevels | 100 | 88.9 | 100 | 67.5 | 100 | 100 | 100 | 76.7 |
| | | (9) | (9) | (9) | (8) | (9) | (8) | (9) | (43) |
| | Gaskets | 100 | 44.5 | 55.6 | 14.3 | 37.5 | 71.5 | 0.0 | 25 |
| | | (8) | (9) | (9) | (7) | (8) | (7) | (9) | (8) |

[a]Samples not taken because lines not physically clean.
[b]Data taken 12 hrs. after cleaning.
[c]Four day runs.
( ) Total samples.

physically with either a 10 or 20-min. recirculation. The same physical results were obtained at 140° F. for 10 min. (Table 2–X) on the 136° F. and hot pasteurized milk lines as were obtained at 130° F. for 20 min. (Table 2–III) the hot milk lines as were obtained at 130° F. for 10 to 20 min. On the other hand, at 150° F. for 20 min. (Table 2–III) the hot milk lines and the pasteurizer were cleaned. These data indicate that temperature is an important or more important than time for proper cleaning.

*Effect of recirculation temperature on cleaning efficiency*

Data in Table 2–I, XII, XIII and XVI indicate that more nearly satisfactory results were obtained at the higher temperatures (170° F. for 20 min.) than at the lower temperatures (130° F. at 10 or 20 min.). Two possible reasons for this are, effect of high temperatures on microorganisms and effect of high temperatures on chemical activity during the cleaning process. The difference in the results obtained on the internal surfaces at the different temperatures were not as definite as the difference in results obtained on the bevels and gaskets. This suggests that one advantage of the higher temperature is the heat penetration.

*Effect of velocities on raw and cold pasteurized milk lines*

The data in Table 2–III through VIII obtained on the internal surfaces of the raw milk lines indicate that there was slight but not consistent difference in cleaning efficiency when solutions were recirculated at 2 or 7 ft./sec., respectively, with either cleaner A, B or D at 150° F. for 20 min. The data on the internal surfaces indicate no significant difference in cleaning efficiency.

There was no difference in bacteriological conditions of either bevels or gaskets for raw milk lines cleaned at 2 or 7 ft./sec. Bacteriological conditions were slightly more satisfactory at 2 ft./sec. than at 7 ft./sec. with the bevels and gaskets of the cold pasteurized milk lines. Velocity of recirculation should not affect the bacteriological condition of the bevels and gaskets, since they are not in the flow stream. This may explain the similarity of results on bevels and gaskets cleaned at 2 and 7 ft./sec.

These data also indicate that internal surfaces are more easily cleaned than bevels, and bevels are more easily cleaned than gaskets.

A velocity of 7 ft./sec. gave better results than 2 ft./sec. on the internal surfaces of raw and cold pasteurized milk lines at 130° F. for 10 min. (Table 2–XIII, XIV). At either velocity the bevels on the cold pasteurized milk lines were cleaned more effectively than those on the raw milk lines. A comparison between the results obtained when the above velocities were employed and those obtained by hand cleaning indicates that the internal surfaces are cleaned equally well, but that the bevels and gaskets are cleaned better by recirculation than hand cleaning.

*Effect of cleaners on lines and H.T.S.T. pasteurizer*

The bacteriological condition of the internal surfaces of the raw, 136° F., hot pasteurized and cold pasteurized milk lines were similar for cleaners A and D (Table 2–III, IV, V). Data obtained with cleaner B for the raw and cold pasteurized milk lines were similar to those obtained with cleaners A and D. The hot milk lines and the H.T.S.T. pasteurizer were not cleaned physically by cleaner B at the same concentration (0.08 per cent active alkalinity as $Na_2O$) as was effective with cleaners A and D; during additional studies with cleaner B these lines and the pasteurizer were excluded from the system.

Results obtained with the bevels and gaskets indicate no significant difference in cleaning efficiency among the cleaners used.

The H.T.S.T. pasteurizer was satisfactorily cleaned most of the time with cleaners A and D at 0.08 per cent active alkalinity (as $Na_2O$). When the pasteurizer was not cleaned satisfactorily a loose deposit of milk residue remained on the upper corner of the first raw milk plate in the regenerator section opposite the hot milk outlet from the holding tube. This deposit occurred most frequently on days when the amount of milk processed was greatest. Cleaner B in no instance cleaned the pasteurizer or the hot milk lines. Since this cleaner did not give satisfactory results with the pasteurizer and hot milk lines, these were excluded from the system when further work was done with this cleaner.

*Effect of cleaner composition*

Cleaner C was used only to study the effect of alkali cleaning without prior acid recirculation. Cleaners A, B and D were studied only with accompanying acid recirculation.

As stated previously, cleaners A and D gave a satisfactory physical condition in all the lines and H.T.S.T. pasteurizer but cleaner B cleaned only the cold milk lines. Cleaners A, B and D were used at the rate of 6, 3 and 0.6 lbs./60 gal. of water, respectively or 4,930, 2,460 and 494 ppm. respectively. Since the active alkalinity (0.08 per cent as $Na_2O$) was the same for all cleaners the amount and type of constituents may have caused the difference in cleaning efficiency. A solution of cleaner A had a higher polyphosphate concentration (1,870 ppm.) than a solution of cleaner B (775 ppm.) which may account for the better cleaning by A. Assuming the soil to be composed of calcium caseinate and calcium phosphate according to Brandsaeter *et. al.* (1), the polyphosphate would sequester and remove the calcium and allow the casein to be peptized and "dissolved" by the alkali. Cleaner B had a lower concentration of polyphosphate (775 ppm.), perhaps too low to accomplish this same effect. Another explanation may be the different types of alkalies used in each cleaner; cleaner A contained $Na_3PO_4$, cleaner B, $Na_2CO_3$ and $Na_2SiO_3$ and D, NaOH. The calcium concentration required to precipitate $Ca_3(PO_4)_2$, $CaCO_3$ and $CaSiO_3$ and the amount of alkali present may affect the efficiency of cleaning. The effect of the concentration of calcium is shown in Table 3. The amount of calcium required to precipitate $CaSiO_3$ is much less than for $CaCO_3$ or $Ca_3(PO_4)_2$. This may explain why the milk residues were not removed with cleaner B which contained $Na_2CO_3$ and $Na_2SiO_3$; whereas, cleaners A and D which contained only NaOH and $Na_3PO_4$ did remove them. Thus, the polyphosphate concentration of cleaner A (1,870 ppm.) may have been high enough to sequester the calcium in the water and in the milk residue while the polyphosphate concentration of cleaner B (775 ppm.) may not have been high enough to sequester all the calcium.

Cleaner D, a chelated caustic, may act in the same manner as A but the bonding of the calcium would be different.

*Other studies made*

Data obtained from the lines of different degree of polish indicated no difference in cleaning efficiency with difference in finish.

Comparison of the data from glass and stainless steel lines indicated that there was no significant difference in the bacteriological condition when cleaned in the same system.

A study also was made to determine the cleaning efficieny of the various cleaners without the use of acid. Cleaners A, B and C were used in 6 runs, 3 of which were made at 130° F. for 20 min. and the other 3 at 155° F. for 20 min. The same recirculating procedure was used as mentioned previously except that no acid was circulated prior to the alkali recirculation. The bacteriological data indicate that cleaners A and B used at 155° F. for 20 min. gave more nearly satisfactory results than when used at 130° F. for 20 min. Cleaner C was not studied bacteriologically because a water stone build-up occurred in 2 days. Cleaners A and B permitted water stone formation in 10 and 5 days, respectively. This water stone formation may be explained on the basis of the calcium concentration as mentioned previously. The main source of calcium in this instance came from the 17 g.p.g. water used for recirculation fluid.

The data obtained from lines held twelve hours after cleaning before swab tests were made indicate that the cold milk lines were satisfactory while the hot milk lines were unsatisfactory (Table 2–II, IX) when compared to data obtained by sampling immediately after cleaning. Hot water sanitization was not used subsequent to acid and alkali circulation for only the efficiency of cleaning was to be measured.

Data obtained from lines cleaned by recirculation at low temperatures, 140 and 120° F. for 20 min., (Table 2–XI,XII) indicate that the internal surfaces of the cold milk lines were satisfactory while the gaskets and bevels were unsatisfactory when compared to data from lines cleaned at 150° F. for 20 min. (Table 2–III).

## DISCUSSION

Much of the information obtained from this study agrees substantially with that of other workers in the field. However, there are certain exceptions. The results from this study should be compared with results involving other stainless steel lines because data obtained with glass is limited.

The temperatures of recirculation (120-170° F.) used in these studies were essentially the same as those (130-170° F.) which had been used by other workers (5, 9, 10). Results obtained on hot milk lines at lower temperatures (120-140° F.) indicate that the bacteriological condition was poor, while at higher temperatures (150-170° F.) these same lines indicate a more nearly satisfactory bacteriological condition. Cold milk lines generally were satisfactory at high and low temperatures of recirculation.

Results obtained by other workers (5, 10) show that velocities did not affect the cleaning efficiency of pipe surfaces. They did not report data relative to bevels and gaskets.

Results on studies of velocities indicate that speeds of 2 and 7 ft./sec. gave equivalent cleaning on internal surfaces of cold milk lines when cleaned at 150° F. or above. However, a velocity of 7 ft./sec. gave better cleaning than 2 ft./sec. when a temperature of 130° F. for 10 min. was used. The data show that velocity is not related to the effectiveness of cleaning of the bevels and gaskets. They indicate that temperature is more important than velocity in the bacteriological cleanliness of bevels and gaskets.

Results obtained in these studies indicate that no build-up of microorganisms occurred during the two week recirculation period. This agrees with the finding of other workers, (6, 8, 9, 10).

There has been some question as to build-up of toxigenic micrococci occuring in C.I.P. lines, especially as regards gaskets. Observations made in these studies, based upon colony characteristics (color, size, shape, microscopic examination, etc.), indicate no such build-up. This is admittedly incomplete evidence of the absence of micrococci, but with few exceptions there were few colonies of any type. In cases in which a considerable number of colonies appeared they were characteristic of sporeformers rather than micrococci.

Cleaners used in these studies were similar to those used by other workers in the sense that most of them contained alkali, sequestering agent and wetting agents. Holland *et al.* (5) stated that cleaners with less than 10 per cent wetting agent did not give proper cleaning while Parker *et al.* (10) stated that those cleaners with less than 10 per cent wetting agent give good cleaning. Results obtained in this study agree with those of Parker *et al.* (10). The above workers also stated that higher concentrations of cleaners are required to clean hot milk lines than cold milk lines. Findings in this study indicate that at higher temperatures the chemical activity is greater and cleaning more efficient, for hot milk lines were cleaned with 0.08 per cent active alkalinity at 150-170° F. while at 130-140° F. they were not cleaned.

In the 1953 Milk Ordinance and Code (11) it is proposed that C.I.P. lines should have a standard plate count not greater than 100 colonies/8 sq. in. of milk contact surface in three out of four samples. If this proposed standard is to be applied to milk contact surfaces it should include the surfaces of bevels and gaskets as well as the surfaces of the pipe, for regardless of how they were assembled, some unions would tend to leak and allow milk to contact the surfaces of the bevels and gaskets. This then would be considered a portion of the milk contact surfaces.

A comparison of the results from hand cleaning made with the proposed standard indicates that the internal surfaces of the lines were satisfactory but that the majority of the bevels and gaskets were unsatisfactory. The hand cleaned lines were satisfactory judged from the usual sanitation standards in that they were physically clean and the milk passed through them met Grade A standards.

A direct comparison of results between C.I.P. (150° F. or higher

TABLE 3—RELATIONSHIP AMONG THE CONCENTRATION OF CALCIUM, THE TYPE OF WASHING COMPOUND AND THE FORMATION OF WATER STONE.

| Alkali | Compound formed | Calcium concentration[a] (mols./liter) | Solubility products[a] (mols./liter) |
|---|---|---|---|
| $Na_2SiO_3$ | $CaSiO_3$ | $9.05 \times 10^{-6}$ | $7.33 \times 10^{-9}$ |
| $Na_2CO_3$ | $CaCO_3$ | $1.20 \times 10^{-4}$ | $1.44 \times 10^{-8}$ |
| $Na_3PO_4$ | $Ca_3(PO_4)_2$ | $3.78 \times 10^{-4}$ | $3.43 \times 10^{-18}$ |

[a]Taken from chemical handbooks.

for 20 min.) and hand cleaned lines indicates that most of the internal surfaces and all of the bevels of the C.I.P. lines were more nearly satisfactory than the internal surfaces and bevels of hand cleaned lines. Gaskets from C.I.P. cold milk lines were more nearly satisfactory than H.C. lines. Regardless of the cleaning temperature the gaskets from hot milk lines, cleaned-in-place, were unsatisfactory when compared to gaskets from H.C. lines.

A comparison of the results from C.I.P. lines (150° F. or higher for 20 min.) with the proposed standard indicates that the majority (75 per cent or more) of the internal surfaces and bevels were satisfactory despite the fact that all the gaskets were unsatisfactory. At lower temperatures of recirculation (130-140° F.) the majority of the bevels and gaskets were unsatisfactory. Also at these lower temperatures the hot milk lines were not cleaned physically.

If hand and recirculating cleaning as used in these studies are to be judged in the light of the proposed standard of 100 colonies/8 sq. in., neither of the two cleaning methods appears to be fully satisfactory; indicating that the proposed standard may be too rigid. The reason for neither method being satisfactory was that the bevel and gasket surfaces generally exhibited a poorer bacteriological condition than the internal surfaces. Since the bevels and gaskets appear to be the limiting factor in both methods of cleaning it poses a question as to whether a bacteriological standard should be established for bevels and gaskets without considerably more study as to a logical number of organisms per 8 sq. in. Sufficient data have not been presented in this paper to warrant the proposal of a new standard.

## SUMMARY AND CONCLUSIONS

The bacterial quality of the milk products passed through cleaned-in-place lines is equal to the quality of products passed through hand cleaned lines.

Higher temperatures in C.I.P. cleaning generally give better physical cleaning than lower temperatures in so far as hot milk surfaces are concerned.

Higher C.I.P. temperatures generally did not give better bacteriological cleaning than lower temperatures for surfaces of cold milk lines.

The internal surfaces of sanitary lines were cleaned more easily than either bevels or gaskets. This was true for both H.C. and C.I.P. lines.

Of the cleaners tested, which contained polyphosphates, cleaner A, which contained the highest concentration of polyphosphate in solution, gave the best physical cleanliness. Cleaner D, a chelated caustic, gave results similar to A.

Bacteriological results from C.I.P. lines (150° F. or higher for 20 min.) were consistently lower than those of H.C. lines and showed no coliform contamination; H.C. lines showed erratic results and spotty coliform contamination.

Microorganisms did not penetrate into the interior of the paper or fiber gaskets when used for a period up to 3 weeks in C.I.P. lines.

Velocities had no effect upon the cleanliness of bevels and gaskets at the temperatures employed. A velocity of 7 ft./sec. at 130° F. for 10 min. did show better results on internal surfaces of cold milk lines than a velocity of 2 ft./sec. at the same temperature.

The recirculation procedure used to collect the data in this paper is given in the experimental section.

Temperature in C.I.P. procedures has more effect upon cleaning efficiency than either time or velocity, when the recirculating time is 20 min. or longer.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to the Bowman Dairy Co. of Chicago, Ill. and the Carnation Co. of Los Angeles, Calif. for partial support of this project, and to Professor W. S. Rosenberger for his cooperation and the use of the facilities in the Market Milk Department.

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designed for the production of high quality cream for manufacture yet it will give excellent milk for bottling. Even though the principal emphasis is on cream for manufacture the program in some areas must be co-ordinated with the sanitary control program for fluid milk.