CLEANING AND SANITIZATION OF WELDED LINE SYSTEMS FOR HANDLING MILK[1, 2, 3]

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Commercial circulation cleaning of welded pipelines is extremely effective in removing milk solids. After normal rinsing only approximately 2.6 g of milk solids could be found in an average circuit cleaned with 165 gallons of cleaning solution. This quantity of milk solids relative to the volume of the equipment involved had little if any effect on the growth of microorganisms. The small amount of milk solids left in pipelines after cleaning was not high enough to cause any dissipation of chlorine. A new approach to sanitizing a pipeline system by leaving in the lines overnight a chlorine solution of 1.0 - 2.5 ppm concentration is discussed.

There is considerable commercial interest in the use of welded lines for conveying dairy products. Welded lines alleviate the troubles of gaskets of the conventional cleaned in place (CIP) system, and should provide a more efficient and economical system of installation and operation in a dairy plant. Such a system is less subject to the vagaries of a typical dairy plant employee. Welded lines also may have merit from a sanitation standpoint, because essentially it is a closed system of operation.

The conventional CIP system of lines with specially constructed joints has been proven satisfactory from a sanitation standpoint both by laboratory investigations *(3, 8)* and from extensive commercial use. Recent work of Kaufmann *et al. (5)* indicated the extreme effectiveness of circulation cleaning. They also showed that with the same treatment the less highly polished finishes can be cleaned bacteriologically to the same degree as the most highly polished finishes.

Welding of lines was introduced to replace as many of the clamp joints as possible. Havighorst *(4)* pointed out many of the advantages of such a system. In comparing a welded line system with a demountable system he observed that the welded system could be cleaned and sanitized satisfactorily. Olson *et al. (9)* published results on a plant employing welded lines from which the results indicated a satisfactory degree of sanitation. All of the previous work with welded lines was done on individual plants using only the general standards of sanitation as a control. Thus, additional work was undertaken to evaluate a commercial operation and to compare the results to controlled laboratory data where the conventional system could be compared to a welded system.

Experimental

A completely new commercial dairy plant of the Safeway Stores Company was used for this work. It was designed to utilize as far as possible butt welded joints in place of the conventional clamp joints. Since the acceptability of the plant from the sanitary standpoint was primarily the responsibility of the Omaha-Douglas County Health Department, the plant was permitted to utilize the welded pipelines on a temporary basis. During the construction of the plant the welding of the lines was under close observation of a representative of the health department and a representative of the Dairy Husbandry Department of the University of Nebraska. Where there was doubt as to the quality of a finished weld, it was cut out and replaced.

Natural openings at such points as plug valves and some special openings constructed in ells (Figure 1) which were welded into the system served as the inspection ports. These were examined by the swabbing technique for bacteriological cleanliness. Swabs were taken approximately once each month for a period of nearly two years in cooperation with the Omaha-Douglas County Health Department. These swabs were taken prior to sanitizing in the morning. The equipment had been washed with a 0.67% alkaline washing solution for 30 minutes at 170°F the previous afternoon. Additional swabs were taken after sanitization of the equipment. Counts were run on standard plate count agar and on a coliform count medium.

The equipment was examined visually for cleanliness at least once each month utilizing the natural openings and the specially constructed ports. In addition, some questionable welds were cut for a more thorough inspection.

For comparative effectiveness in cleanability two laboratory units were constructed. One had 18 conventional CIP joints, and the other one, similar in length, had 22 welded joints. The unit assembled with welded joints is shown in Figure 2.

Finished milk products were taken from the cold

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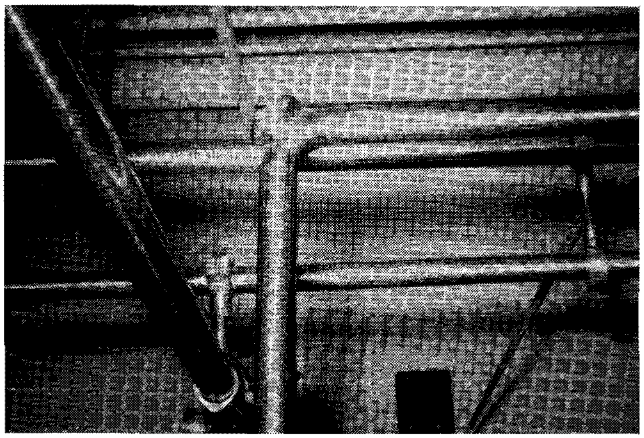

Figure 1. A Section of Piping Showing a Specially Constructed Inspection Port.

room of the producing plant for standard plate counts and for coliform counts. These counts were made according to Standard Methods *(1)*.

Quality of the Finished Product

The finished products from the plant of this study were under the surveillance of the plant laboratory, the company's central laboratory, the local health group, and approximately 25 out-city health departments where the products were distributed. The results from all these organizations were essentially the same.

For simplicity only the results of the Omaha-Douglas County Health Department are given. Furthermore, the counts are limited to milk. The results of 20 examination periods are presented in Table 1. In each period 4 or 5 milk samples were examined amounting to a total of 94 samples over a period of nearly two years. These bacteriological results indicated that a high quality product was produced by this plant with welded lines.

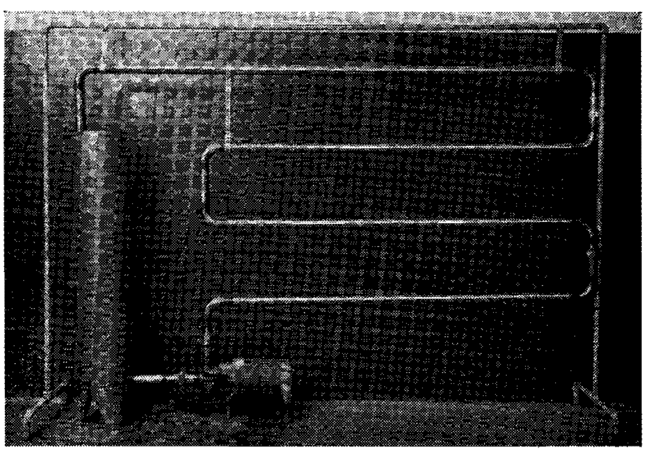

Figure 2. A Laboratory Unit with Welded Lines Used in the Comparative Study of Welded Joints and Conventional C.I.P. Joints.

TABLE 1. BACTERIOLOGICAL EVALUATION OF SAMPLES OF THE FINISHED MILK PRODUCTS FROM A COMMERCIAL PLANT WITH WELDED LINES

Date	Standard plate count		Coliform count[a]	
	<3,000 /ml	3,000 to 10,000/ml	<1/ml	1 to 10/ml
12- 5-58	4	0	4	0
1- 9-59	4	0	3	1
2- 9-59	4	0	3	1
3-10-59	4	0	3	1
4-13-59	5	0	5	0
5- 8-59	4	1	5	0
6- 5-59	2	3	4	1
7-13-59	1	4	5	0
8-20-59	5	0	5	0
9-10-59	4	0	4	0
10-12-59	3	2	5	0
11-10-59	5	0	5	0
12- 9-59	5	0	5	0
1- 7-60	5	0	3	2
2- 8-60	5	0	5	0
3- 4-60	4	0	4	0
4-11-60	5	0	5	0
5- 9-60	5	0	4	1
7-26-60	5	0	4	1
9- 1-60	5	0	3	2
Total	84	10	84	10

[a]One of the samples of 1-9-59 showed 20 coliform organisms per ml.

For comparative purposes the results of examinations of milk samples from another commercial plant are presented in Table 2. This plant is considered comparable in every important feature (size, equipment, general cleanliness, etc.) except that conventional CIP joints are used in the pipeline system. It is apparent that the bacteriological results on the samples from the plant with welded lines indicate a higher degree of sanitation than the plant with conventional CIP joints.

Bacteriological Cleanliness of the Commercial Equipment

During approximately eighteen months 335 swab counts were made on the equipment consisting of welded lines that were cleaned by circulation. The results on the total counts are given in Table 3. The average total count on 8 sq in. was 7.9 organisms before sanitization and 1.3 organisms after sanitization. The equipment had far less organisms than the interpretive suggestion of Standard Methods *(1)*. The coliform counts also were made on all the samples. They are not included in this table, however, since the results were negative in all except two cases.

For comparative purposes some equipment was

TABLE 2. BACTERIOLOGICAL EVALUATION OF SAMPLES OF THE FINISHED MILK PRODUCTS FROM A COMPARABLE PLANT WITH CONVENTIONAL C.I.P. JOINTS

Date	Standard plate count[a]			Coliform count		
	<3,000 /ml	3,000 to 10,000/ml	10,000 to 30,000/ml	<1/ml	1 to 10/ml	More than 10/ml
1- 6-59	4	2	0	4	1	1
2-10-59	5	2	0	5	1	1
3- 4-59	1	5	0	3	3	0
4- 1-59	8	0	0	5	2	1
5-12-59	4	4	0	6	0	2
6- 2-59	1	1	4	2	3	2
7- 7-59	4	2	1	0	2	4
8- 4-59	7	1	0	5	1	2
9- 1-59	6	0	0	4	1	1
10- 7-59	7	2	0	8	0	1
11-10-59	8	0	0	4	1	3
12- 8-59	6	0	1	5	2	0
1-19-60	8	0	0	4	4	0
2- 9-60	5	2	0	0	5	2
3- 7-60	5	1	1	7	0	0
4-18-60	7	1	0	5	3	0
5 -9-60	8	1	0	4	3	1
6- 8-60	8	0	0	5	3	0
Total	102	24	7	76	35	21

[a]One of the samples of 6-2-59 had 35,000 per ml.

hand washed and stored open to the air in order for it to dry before the next use. This equipment was swabbed during each inspection. The results of 26 such examinations showed an average of 17.2 colonies per 8 sq in., or more than twice as many as on the equipment cleaned by circulation cleaning.

The counts on the finished products and especially the counts on the swabs were extremely low, therefore, work was undertaken to determine the bactericidal efficacy of the cleaners used. The cleaning solution consisted of 0.67% of an alkaline commercial cleaning solution. During the course of this work a variety of commercial cleaning compounds were used. Samples of the used cleaning solution were neutralized and plated on standard plate count agar to determine the extent of microbial contamination. It was found that the cleaning solution was sterile in two out of three trials and in the third trial it had an average of only 16 organisms per milliliter. This could be expected since the temperature of the cleaning solution during use was approximately 170°F. These results corroborate the earlier work of Meyer *(7)*, who pointed out the high germicidal properties of some alkaline cleaning solutions.

Physical Cleanliness

At the time of each bacteriological examination of the equipment by swabbing a visual inspection was made of the inside of the equipment at the inspection ports. The equipment always was found to be free from objectionable accumulation of milk residues. The oxidized film on the inside of the line resulting from welding soon was removed by normal CIP cleaning. In order to pursue this evaluation further, however, both chemical and microbiological techniques for analyses were utilized.

Chemical Cleanliness

With an aim toward determining the presence within the equipment of any residue that was not visible to the eye, an indirect approach was taken. It was reasoned that the extent of removal of milk solids from the equipment could be estimated from the increase in milk solids in the cleaning solution. This estimation was made by determining the increase in nitrogen content of the cleaning solution as a result of the cleaning process.

A modified Kjeldahl test involving both micro and macro techniques was used for determining nitrogen. The sample size was 100 ml of cleaning solution. The materials for digestion and the procedure were according to A.O.A.C. *(2)*. The distillation was made into 5 ml of 4% boric acid with the indicator system consisting of brom cresol green, p-nitrophenol, and new coccine as suggested by Sher *(10)*. The entrapped ammonia was titrated with 0.01 N sulfuric acid. The standard for calculating the quantity of milk solids involved was established by testing known quantities of milk in the presence of an alkaline cleaning solution of 0.67% concentration.

TABLE 3. THE RESULTS OF SWAB TESTS ON THE INSPECTION STATIONS OF THE COMMERCIAL PLANT WITH WELDED LINES

Date	Before sanitization		After sanitization	
	No. of stations swabbed	Average count on 8 sq in	No. of stations swabbed	Average count on 8 sq in
1-20-59	11	1.9	11	.2
2-24-59	12	11.8	13	.3
4-14-59	12	.3	13	.2
6- 4-59	12	5.1	10	.5
7-21-59	11	14.6	11	1.2
8-25-59	11	3.4	11	.2
9-22-59	11	5.5	11	.7
10-27-59	11	2.0	12	.2
12- 1-59	11	12.2	12	2.0
1-12-60	12	18.0	12	.4
2- 8-60	12	6.6	13	.6
3 -8-60	10	.8	11	.1
4- 5-60	15	18.2	15	4.4
6 -3-60	14	6.2	15	5.1
	165	7.9	170	1.3

TABLE 4. MILK SOLIDS REMOVED DURING COMMERCIAL CLEANING OPERATIONS

Trial	Number of circuits cleaned	Milk solids removed per circuit in grams	Contamination of the cleaning solution in ppm of milk solids[a]
1	3	1.5	2.8
2	2	1.3	2.2
3	3	0.4	0.7
4	3	3.7	6.0
5	2	0.0	0.0
6	2	0.0	0.0
7	2	0.7	1.0
8	10	3.6	5.8
9	13	3.6	5.8
	Average	2.6	4.2

[a]The volume of cleaning solution was 165 gallons.

The above method was applied to determine the extent of milk solids in the cleaning solution from the commercial operation with the welded pipeline system. Tests were run on the cleaning solution before use and after a number of series of pipe, etc. had been cleaned. For experimental purposes, the same cleaning solution was used to clean as many as 13 circuits with 165 gallons of solution. The data are presented in Table 4. It was observed that a typical cleaning operation removed only approximately 2.6 g of milk solids per circuit, amounting to approximately 4.2 ppm of milk solids in the cleaning solution.

Rapid Chemical Test

In addition to the above tests work was undertaken to develop a more rapid method for estimating milk solids in a cleaning solution. Lowry's *(6)* colorimetric method for proteins was modified for this purpose. The method was found applicable for routine approximations of protein in cleaning solutions. The method involves digesting the protein with sodium hydroxide for 30 minutes and developing the blue color with phenol reagent. The optical density was measured at 620 mμ. To determine the reliability of the test, varying quantities of milk solids were added to a cleaning solution, and the protein content was determined by the colorimetric method. The color development was in direct proportion to the protein content. It was observed that the test had a sensitivity of approximately 4.0 ppm of milk solids. The method also was compared to the Kjeldahl method using a variety of milk samples with water dilutions as well as with cleaner dilutions. The results are presented in Figure 3. Fairly good agreement between the two methods was obtained.

Bacteriological Test for Residual Soil

The low concentration of solids as found in the lines naturally raises the question whether this small quantity would support the growth of microorganisms. Exploratory work using *Streptococcus lactis* in erlenmeyer flasks showed that concentrations of less than 5 ppm of milk solids in tap water had little or no effect on the growth rate of the organisms. However, the less fastidious organism, *E. coli,* showed a greater response to small quantities of milk solids in tap water.

As a continuation of these observations, a microbiological technique was standardized for estimating

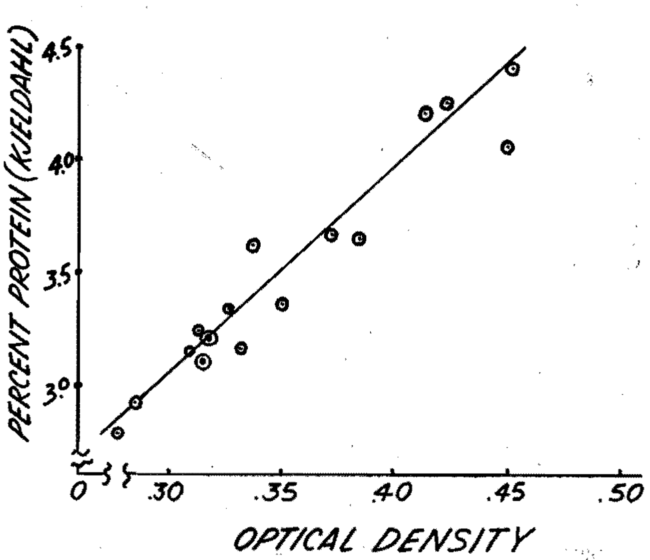

Figure 3. The Relationship Between the Kjeldahl and the Lowry Method of Determining Protein Concentration.

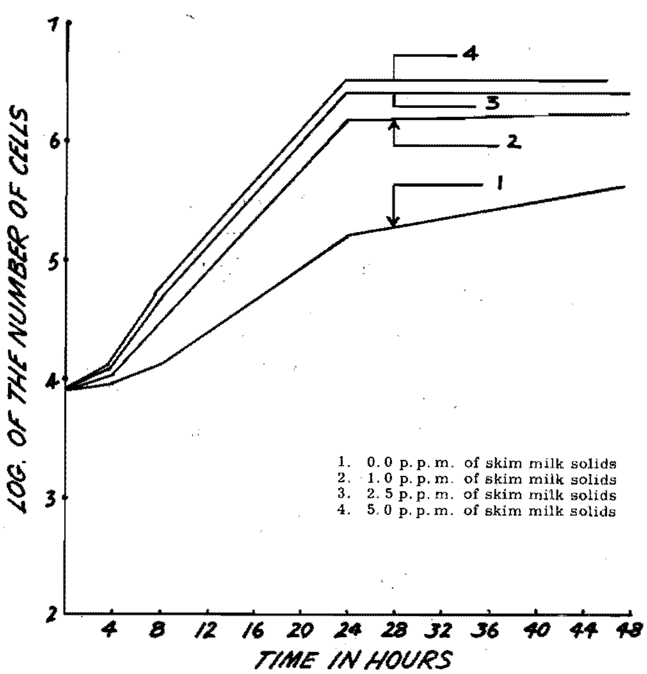

Figure 4. The Stimulatory Effect of Milk Solids on the Growth of *E. coli* in Tap Water at 30°C.

the quantity of skim milk solids in a solution of this low concentration. The procedure consisted of neutralizing the free chlorine of tap water with sodium thiosulfate in erlenmeyer flasks. Varying quantities of skimmilk solids were added to the water in the flasks before sterilization. The milk solutions were inoculated with approximately 8,000 cells of *E. coli* per ml in the medium. The flasks were incubated at 30°C for varying times and growth was determined by the standard plate count. The results are given in Figure 4. As little as 1 ppm of skimmilk solids gave a detectable stimulation to the growth of *E. coli*. The greatest response was noticed in the samples incubated 8 to 24 hr.

A similar approach was used in a pilot laboratory welded pipeline system (Figure 2). Essentially the same response to milk solids added to tap water neutralized with sodium thiosulfate was obtained with this assembly as was obtained in the erlenmeyer flasks. Thus, the technique seemed applicable for comparable studies on various laboratory assemblies to determine the residual milk solids by this microbiological technique.

The above microbiological technique and duplicate assemblies were used to compare the cleanability of the welded line system and of the conventional joint system. The systems were contaminated by circulating whole milk at room temperature continuously for five hours. The equipment was then cleaned with an alkaline cleaning solution according to generally accepted commercial practices. Tap water neutralized with sodium thiosulfate was inoculated with *E. coli* and the system was allowed to stand overnight, at approximately 86°F. The bacterial counts at the beginning of the period were compared with those obtained 17 hr later. The section of welded lines and the section of clamp joints were used on alternate days.

The comparative results are given in Table 5. The 14 trials indicated that there was no appreciable difference between the cleanability of welded lines and clip joints with these laboratory systems.

When the results of these trials were compared to those given in Figure 4, it was apparent that there was not enough milk solids left in the equipment to give a noticeable stimulus to the growth of *E. coli*.

Continuous Sanitization

The general method for handling pipelines is to sanitize with chlorine solution containing 100 to 200 ppm of available chlorine immediately prior to use. Several workers have reported that high concentrations of milk solids in the system dissipated part of the chlorine. In the present study it was observed that following the cleaning process extremely small concentrations of milk solids were left in the lines. During some of the exploratory work it was observed that the small quantities of milk solids as generally found in the lines did not dissipate even 1 ppm of chlorine. Thus, there was an apparent need for quantitative data on the quantity of milk solids required to dissipate a given quantity of chlorine.

TABLE 5. A COMPARISON OF GROWTH STIMULATING RESIDUES IN LABORATORY SYSTEMS OF WELDED LINES AND CLAMP JOINTS

	Clamp joint connections		Welded connections	
	Before incubation	After incubation	Before incubation	After incubation
	10,000	51,000	3,800	53,000
	12,000	70,000	8,400	72,000
	7,900	15,000	7,900	96,000
	8,100	144,000	6,800	100,000
	6,600	270,000	6,000	44,000
	3,400	8,700	4,600	41,000
	6,900	120,000	6,600	46,000
Arith. av.	7,800	97,000	6,300	65,000

The next phase of the study was concerned with the determination of the interaction of skim milk solids and chlorine. Varying quantities of milk solids in distilled water were reacted with different concentrations of chlorine. The reaction time was 1 hr and the temperature was 25°C. At the end of the reaction time, the residual chlorine was titrated with sodium thiosulfate and the quantity of chlorine dissipated was calculated. The results are given in Figure 5, which represents the average of three replications

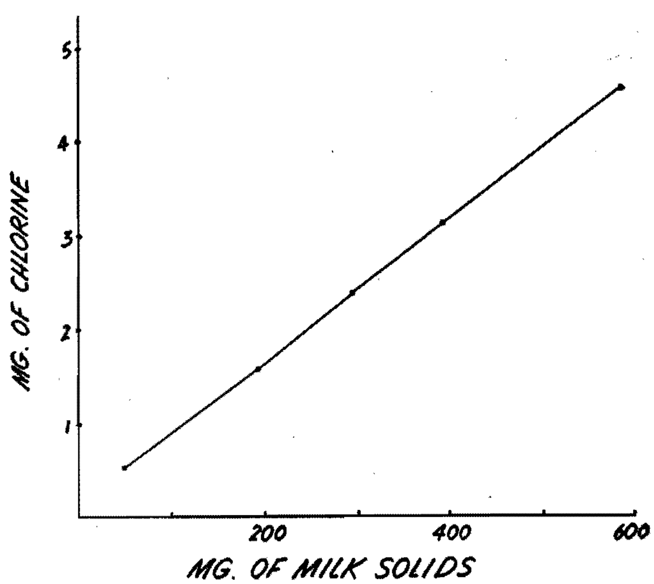

Figure 5. The Relationship of Skim Milk Solids Required to Dissipate the Chlorine of a Sanitizing Solution in 1 Hour at 25°C.

of duplicate runs. It can be seen from this graph that almost 150 parts of milk solids were required to dissipate one part of chlorine. As evidenced from the data previously presented showing that very small amounts of milk solids were present in a normally cleaned system, it is logical to conclude that the milk solids in a well cleaned CIP system would have little effect upon chlorine at any concentration.

The above observations suggested the possibility of substituting an extremely low concentration of chlorine sanitizer that could be left in the equipment overnight to achieve sanitization rather than using the 100 - 200 ppm chlorine solution. Exploratory work showed that tap water as well as solutions with added milk solids were essentially sterile after overnight storage as long as there was a residual of chlorine as indicated by the starch-iodine test. Specific instances of contamination in the pilot equipment with welded lines were set up using *E. coli* with an inoculum of approximately 12,000 per ml and chlorine content of 1.0 - 2.5 ppm in the system. The solution was examined after 16 hrs. The results showed the system was essentially sterile after overnight storage as long as there was residual chlorine.

This method of sanitizing seems to have potential merits. It should afford an added measure of safety from the public health standpoint because of the closed system of essentially sterile lines. Furthermore, this method of sanitizing may be less destructive to stainless steel equipment than the ordinary use of chlorine solutions of high concentrations. This method of sanitizing is being studied further both in the pilot operation and in a commercial plant.

DISCUSSION

A welded line system is an essentially closed system. While it cannot be inspected easily in the traditional manner, logical advantages of the closed system can be utilized. The work reported here substantiates the general belief that circulation cleaning is extremely effective in cleaning a welded line as it is in cleaning a clamp joint system, and renders the equipment essentially "chemically clean." Furthermore, from the work reported here it is apparent that an alkaline cleaning solution is essentially sterile during the cleaning operation.

Since dairy equipment cleaned under proper conditions is essentially chemically clean and sterile, it should be handled between uses in such a manner that it stays sterile. A chlorine solution could be used in much lower concentrations than now used routinely in the equipment.

The use of continuous sanitization should be less destructive to the equipment, thereby giving a longer life to the equipment and a financial saving. It would mean a better preservation of the smooth surface finish of the equipment and the maintenance of higher sanitary standards through a reduction of the use of corroded, pitted equipment resulting from the use of destructive sanitization practices.

The superivsion of the use of chlorine at this concentration should be an easy matter to control for the regulatory people as concentration could be determined accurately and rapidly.

ACKNOWLEDGEMENT

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