PLANT TRIALS ON CHEMICAL CLEANING OF EVAPORATOR HEATING SURFACES AT UMFOLOZI MILL

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Abstract

Following successful pilot plant trials conducted as a research project by the Sugar Milling Research Institute (SMRI), full scale implementation of the process developed was begun in 1983 and continued in 1984. The process consists of a two stage treatment involving spraying a 25 to 30% w/v NaOH solution, at 100 to 105°C, over the evaporator tubes followed by spraying a 2% w/v solution of sulphamic acid at 70°C. Experiences in the practical application of this process are discussed. It has been found that no mechanical cleaning need be done and it is expected that with optimisation of the process, direct cleaning costs will become competitive with mechanical cleaning costs.

Introduction

Viable alternative methods for dealing with the scaling problem of evaporator heating surfaces have long been sought. Traditional mechanical cleaning by means of powered tube cleaning equipment is not only arduous and unpleasant work, but is also labour intensive. Rising labour costs and recent developments in industrial labour relations have led to renewed interest in chemical-cleaning methods in particular.

At Umfolozi, boiling an NaOH solution in the evaporators prior to mechanical cleaning has been practised for more than 30 years. This is done to soften the scale which is then more easily removed by mechanical means. This fact, has led to the development of an evaporator station with isolation facilities, so that small sections can be taken off-line during crushing to enable NaOH boiling to be done. A 5-vessel set of evaporators was designed so that any one of the vessels can be taken off-line while the remaining four serve as 2nd to 5th effect vessels in a quintuple effect evaporator system. This set of Fletcher evaporators, together with other necessary facilities, has provided an almost ideal plant for experimenting with chemical cleaning.

Concerted efforts to develop a totally chemical cleaning procedure were begun in 1981. These soon led to employing successfully chemical cleaning on juice heaters and to be partially successful with early effects on the evaporators. The later effects were not successfully cleaned. In 1982 and 1983 an SMRI research project was initiated to investigate chemical cleaning and, the procedure which is being used at present was developed. In 1983 after the SMRI successfully proved the method on a pilot plant basis, full scale plant trials were begun.

The Chemical Cleaning Procedure

Whether one or more vessels are cleaned, the procedure is as follows:

(1) A 30% w/v NaOH solution is prepared by adding the required amount of NaOH flakes to approximately 2 m^3 of water. To ensure that the NaOH dissolves completely, it is agitated by circulating the solution through the vessel to be cleaned or directly back into the tank.

(2) The solution is then sprayed over the calandria of the vessel at a rate of 0,5 litres per tube per minute. After flowing down the tubes the solution is returned to the tank from which it was pumped.

(3) The NaOH solution is circulated in this manner for four hours. During this time the solution is maintained at a temperature of 100 to 105°C by means of steam applied to the calandria.

(4) During the spraying, water is added to the tank, by means of a float valve. This is done to replace the water that is lost through evaporation.

(5) More NaOH is added to the solution if the concentration drops below 20%. The solution strength is determined through laboratory analysis of samples taken during spraying. One replenishment midway through the spraying is usually required.

(6) On completion of the NaOH treatment, the vessel is thoroughly flushed with water to remove remaining traces of caustic soda. This takes approximately half an hour and the pH of the water passing out of the vessel is measured to determine when sufficient flushing has been done.

(7) In the same way that the NaOH solution is prepared, a 2% w/v sulphamic acid solution also of approximately 2 m^3, is prepared in another tank.

(8) When flushing is completed, the acid solution is sprayed over the calandria in the same way that the NaOH solution is sprayed.

(9) In the case of the sulphamic acid solution, spraying is done for 1 hour and the temperature is kept at around 70°C.

(10) After acid spraying, the calandria is flooded with water which is then boiled, as vigorously as possible, for an hour. This is necessary to remove any remaining scale which, at this stage, is mostly in the form of a sludge.

(11) After the water boiling process, cold water is again sprayed into the vessel to flush scale accumulations off the saucer and to cool the vessel.

(12) The vessel is then opened for the tubes to be inspected and the calandria, to be tested. After this the vessel is put back on line.

Comments on the Procedure

The comments made arise mainly from practical observations and, as such, are not intended to serve as unequivocally valid facts, but should rather be considered as guides for implementing such a cleaning system.

Strength of NaOH solution

It has been found that the higher the strength of the NaOH solution the better is the cleaning. On early effects, solutions of 15% have been adequate, but with strengths higher than 20%, it was generally found that acid treatment could be dispensed with. The SMRI pilot plant tests, which concentrated on later effects, indicated that strengths of 20% were required[4]. Plant trials confirmed this but it is felt that 20% should be regarded as a minimum strength rather than an average.

On later effects, if scaling was light, it was found on occasions, that acid treatment was not required. This, however, occurred infrequently and on one occasion, a 38% solution strength was used on a 5th effect vessel and despite improved scale removal, acid treatment was still needed. The initial strength is set at 30% to reduce the amount of replenishing required during spraying.

Required volume of solution

Spraying the cleaning solution onto the calandria instead of the usual flooding procedure has the advantage of greatly reducing the volume of solution that is required. This reduction means that:

- Initial quantities of chemical required are reduced.
- The storage tanks can be smaller.
- The solutions are more manageable and any small losses are easily detected. This results in efficient use of the chemicals.
- When disposal of the solutions is required, the losses are considerably reduced and no real effluent treatment problem is experienced.

Umfolozi's biggest cleaning combination, consisting of three vessels of 510 m^2 of heating surface each will require 2 m^3 of solution for spraying while approximately 35 m^3 is required for flooding the calandrias. The actual solution hold-up during spraying was measured as 0,25 m^3 for one vessel and 0,69 m^3 for three vessels. Spraying, particularly in America, has been practised for many years and similar savings in solution quantities have been reported[2].

Spray nozzles and solution application rates

Information obtained from Hawaii is that the application rate should be 0,5 litre per tube per minute and that from 1 to 5 nozzles per vessel are used for spraying[3]. Only one nozzle per vessel was used at Umfolozi because it results in a much simpler installation. Details of the nozzles used are given in Table 1.

The present application rate is limited to 0,4 litre per tube per minute as the pipe to the vessels has a diameter of only 50 mm. Obviously the highest application rate obtainable should be sought, but rates much higher than 0,5 litre per tube per minute require a large pump if vessels are to be cleaned simultaneously.

TABLE 1

Spray Nozzle Details

Pipe size	Bete nozzle* reference number	Spray angle	Capacity (litres per min) at		Material
			138 kPa (gauge)	275 kPa (gauge)	
75 mm	MP 1 500W	120°	900	1 270	316 s/steel
100 mm	MP 2 000M	90°	1 600	2 260	316 s/steel

* Manufactured by Bete Fog Inc.

Duration of NaOH treatment

The SMRI pilot plant tests indicated that a three hour treatment was sufficient[4]. In plant trials a four hour treatment was thought to be necessary. This could be due to less effective spray coverage and lower application rates achieved on the plant. No real advantage was evident from extending treatment longer than four hours. On several occasions spraying was continued for up to twelve hours with no significant improvement in scale removal.

Temperature of the NaOH solution

The temperature of the NaOH solution appears to be critical. The effectiveness of the NaOH treatment was reduced drastically when the temperature of the solution dropped below about 95°C. This phenomenon has also been observed in the scale softening NaOH treatment at Umfolozi but this type of critical cut off point for the temperature of NaOH solution has not been recorded in the literature. At Amfac Sugar Company in Hawaii, temperatures of 54 to 60°C are used[3].

An interesting observation was that in some circumstances, excessive frothing during the NaOH treatment took place and was so severe, that it overflowed the storage tank and filled the vessel to levels above the uppermost sight glass. No apparent pattern or cause has yet been established, but scale removal has always been exceptionally good after frothing has occurred.

Method of heating

This was initially done as an interim measure by passing the NaOH solution through a juice heater before it went into the vessel being cleaned. This worked satisfactorily but it aggravated problems which were already being experienced with low application rates and also increased the required volume to about 3 m^3.

At present, in the Fletcher evaporators, specially installed V 1 lines to each calandria are used. In the Mirrlees set where three vessels, without separate isolation facilities, are cleaned simultaneously, V 1 is applied to the first and last calandrias. This is sufficient to keep the total solution at the required temperature.

Flushing

The water for flushing is pushed through the spray lines and with the spray nozzles, the efficiency of both the flushing and cooling of the vessels is greatly enhanced. By filling the vessel with water, as previously practised, it has been found that the process needs to be repeated at least three times. This process takes approximately an hour and a half, whereas when spray nozzles are used, the vessel can be entered after only ten minutes, but for proper flushing and complete cooling, half an hour is required.

To reduce the consumption of raw water, injection water is utilized for flushing and also for testing the calandrias. At present, this water is led into the factory drain after use, but this will be altered so that it is returned into the injection water circulating system. At present no problems are experienced with the disposal of the spent chemical solutions, since the quantities are small in relation to both the amount of effluent treated, and volumes in the plant. It is however also intended that these solutions will be disposed into the circulating water system.

Acid treatment

The acid treatment removes only a relatively small amount of the total scale. If, for some reason, the NaOH treatment is not effective then the acid treatment will not be effective. This is true when spraying is practised and a temperature of 80°C is not exceeded. However, acid boiling was practised on many occasions and when this was done, the acid treatment was much more effective. In this instance, it is not so critical that the NaOH treatment should be completely effective.

To minimise corrosion, the sulphamic acid should not exceed 80°C. However, the corrosion consequences of boiling the acid are not cataclysmic and, since it is considerably more effective, it can be used as an emergency measure if NaOH, or for that matter the whole treatment, was ineffective and if there is no time to repeat the whole process.

Screening of the cleaning solutions

Although screening to remove scale from the cleaning solutions has not yet been carried out at Umfolozi, it is considered necessary. Firstly, to reduce costs, regeneration of the solution must be practised the maximum number of times. Without some form of screening, the scale accumulation in the solutions limits regeneration to a maximum of about three times. An additional need for screening is to eliminate serious abrasion caused by spraying solutions containing scale. At the end of the 1984/85 season it was found that the impellor of the pump used for spraying was almost completely worn away. In addition, the tips of some tubes in the vessels which experienced

the most frequent chemical cleaning were honed to the sharpness of a knife-edge. The cause has been attributed to abrasion since this only occurred on the tube tips which were exposed to the spray and the rest of the tube was not affected.

No accurate information has been obtained on scale quantities in the solution but it is estimated that it could easily amount to 15% during one treatment. Most of this is disposed of during flushing but it remains in circulation during spraying.

Problems with tubes and pipes becoming blocked with scale once it has been removed are not uncommon and consideration should therefore be given to this aspect when cleaning intervals are planned so that scale build up is not too severe.

Corrosion

Because of the limited time for which the new procedure has been used and the nature of the plant trials, no information on this particular subject was gained. The SMRI is conducting tests on the corrosion of brass, mild and stainless steel by NaOH and sulphamic acid solutions. Reported results of corrosion testing of NaOH solutions in Australia "indicate the acceptability of those cleaning procedures using high concentrations of caustic soda solutions"[1]. Uninhibited sulphamic acid was used during these trials.

Costs

Details of costs for the 1984/85 season are listed in Table 2. As schedules are generally adhered to during cleaning, reference to costs on a cents per ton cane basis can be misleading e.g. Umfolozi's normal throughput is around 32 000 tons cane per week, whereas the average throughput for the 1984/85 season was only 23 000 tons cane per week. During the 1984/85 season both mechanical and chemical cleaning was carried out on a split of 73,3% and 26,7% respectively.

Costs are calculated on the whole season's cleaning, but are based on the latest prices so that they are up to date. As an example, NaOH costs were calculated on 70c per kg, while for a substantial part of the season it was obtained for 58c per kg, sulphamic acid was obtained for R1.23 per kg. Cost increases from 1980 to 1985 were:

(i) 25% for brushes used for mechanical cleaning

(ii) 32% for NaOH flakes

(iii) 100% for a Paterson grade A2 worker

At Umfolozi cleaning of filters and juice heaters is carried out with NaOH solutions. The chemical costs in Table 2 include those used for these applications. Thus the actual cost for chemicals used on evaporators is slightly lower than that shown.

TABLE 2
Details of evaporator cleaning costs for 1984/85 season

	Materials costs		Labour costs		Chemical costs		Total costs	Cents per ton of cane
	% of Total	Actual	% of Total	Actual	% of Total	Actual		
All cleaning	10,4	R6 907	41,1	R27 407	48,5	R32 313	R66 627	8,5
Mechanical cleaning	14,7	R6 907	58,7	R27 407	26,6	R12 406	R46 720	8,1
Chemical cleaning	0	-	0	-	100	R19 907	R19 907	9,6

Capital investment required for plant modifications and purchase of equipment will obviously be highly specific to each factory. To give some idea of the costs involved, details of expenditure on the equipment and plant modifications needed to date for chemical cleaning, are given in Table 3.

TABLE 3
Costs of equipment and plant modifications for chemical cleaning

Item	Comments	Cost
Spray nozzles	Purchase prices	R 3 020
Installation of spray lines	–	R10 925
Installation of steam lines	–	R 5 130
Installation of solution tanks	Redundant tanks used. Thus cost reflected is for installation and pipe connections etc	R 6 040
Installation of pump	Replacement value plus installation costs	R 3 370
Total	–	R28 485

Other Comments

(i) No real experience was gained in the chemical cleaning of a Kestner vessel, although it was done once at the end of the season.

(ii) Spraying of the NaOH solution over demister screens is practised at the Amfac Sugar Company in Hawaii[3]. It is planned to adopt a similar system at Umfolozi but since the only screens, are in the Kestners, it has not yet been tested.

(iii) Information on safety aspects of handling dangerous chemicals is readily available. It is worth noting however that standard gate valves soon develop leaks when handling NaOH solutions and either Saunders diaphragm or Amri butterfly valves are now being used exclusively. Wherever practical back-up facilities have also been provided to reduce risks of accidental spillage or contamination of juice.

Conclusion

A degree of cleaning which enabled mechanical cleaning to be dispensed with was routinely obtained with this process. Even in cases of extreme scale build-up, it was possible to remove the scale with chemical methods only. A significantly better cleaning is obtained and the subsequent redepositing of scale appears to be retarded.

The general dislike of mechanical cleaning by workers, is a significant factor weighing in favour of chemical cleaning, as it creates problems in maintaining adequate supervision and effective cleaning. Although present costs still favour mechanical cleaning, a good deal of optimisation through regeneration of solutions and determination of the most suitable cleaning intervals is possible. These should reduce chemical cleaning costs. Together with the expected increase in labour costs this should soon render chemical cleaning competitive, in terms of cost, with mechanical cleaning.

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