A REVIEW OF THE MECHANICAL CLEANING OF EVAPORATORS

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Abstract

Although many sugar factories in Southern Africa still clean their evaporators mechanically**,** this topic is not well documented in recent literature. This paper describes the basic procedures used by Tongaat-Hulett factories, and highlights some of the practical steps that have been found useful. The equipment used is described, and cleaning rates in terms of tube area cleaned per operator is given. General costs are estimated.

Introduction

In a review of evaporator tube cleaning, Walthew (1994) points out that the two main options are chemical methods, and physical methods that include mechanical cleaning. Over the past eight years chemical cleaning has been discussed in five SASTA papers (Walthew *et al.,* 1998, 1997, 1995; Peacock *et al.*, 1999; Chetty *et al.*, 2002). Although mechanical cleaning is used in a number of sugar factories in southern Africa, papers on this option are more rare.

The mechanical cleaning of evaporator tubes should be quick, effective and of a reasonable cost. The latter will depend mostly on the availability and cost of labour, which is usually of a contractual nature.

Basic procedures

The following basic procedures are common to most mechanical cleaning systems.

Cooling of vessels
Once the boil-off has been completed the vessels are washed and the water drained. The vessels are then filled with cold raw water, to a level about 0.5 m above the manhole. This water is then drained to a level just below the top tube plate. At this stage the vessel should be sufficiently cool to allow entry by workers. An extractor fan may be used. If the vessel is not cool enough, a second fill and drain process can be used. The time between boil-off and entry of workers is about two hours.

Basic equipment
The cleaning equipment consists of an electric motor, a flexible shaft and descaling tools as shown in Figure 1.

Usually there is a wooden clamp on the flexible shaft, which is positioned to match the tube length. The operator must hold the flexible shaft above this clamp to ensure that the shaft enters to its full length and the tube is scraped right down to its end.

Figure 1. An example of the equipment used in mechanical cleaning of evaporators in a sugar factory.

The descaling tools consist of cutters and of brushes, as shown in Figure 2. In South Africa the cutters are always necessary in evaporator cleaning. Brushes may be present, behind the cutter, as an additional tool.

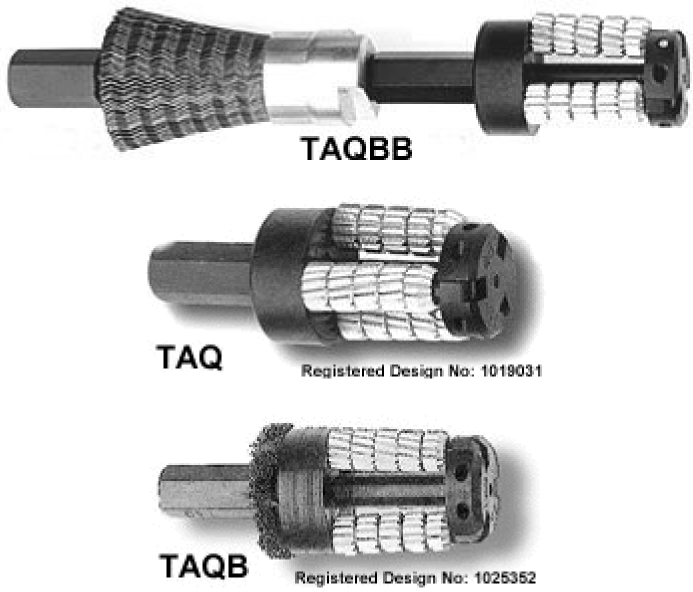

Figure 2. Tool heads: cutters and brush used in the South African sugar industry for cleaning evaporators.

Flooding of tubes

The scraping is usually done under flooded conditions. The water provides lubrication, softens the scale and washes away the dislodged scale. At some factories water is added by using hoses, rather than through flooding, to save water.

Tool movement
Generally two passages of the tool (top to bottom and bottom to top) are necessary, but this is a function of the amount and hardness of the scale. Leaving a rotating tool stationary inside the tube can cause severe damage, even in stainless steel tubes, particularly at high rotational speeds under dry conditions. An example of tube damage can be seen in Figure 3, where the tool was run at 4500 rpm in a dry tube, for about five minutes.

Figure 3. Tube damage caused by the cleaning tool being run at high speed under dry conditions.

Visual inspection
At the end of the cleaning session the tubes are inspected visually for cleanliness. This can be a subjective process and experience is needed to arrive at a correct judgement.

Specific procedures

Rate of cleaning
Some of the data obtained during this survey are shown in Table 1. Labour for evaporator cleaning is usually paid on a task rather than time basis. This is represented in Table 1 under the ‘m^2/operator/session’ heading.

Table 1. Rate of mechanical cleaning.

Source of data	Type of vessel	Cleaning rate	
		m²/operator/h	m²/operator/session
Amatikulu mill	Kestner	170	520
	Robert	50 - 100	270 - 400
South African factories	Kestner	70 - 110	270 - 440
	Robert	25 - 70	125 - 370
BWI (1966)	Robert	~	160
Hugot (1960)	Robert	10 - 35	~

These data are approximate and depend on local conditions. Clearly, the quality and type of scale has a major influence.

Speed of rotation
Common evaporator tube diameters in southern Africa are 38, 41 and 51 mm, and most of the tubes are made of stainless steel. Under these conditions, rotational speeds are 2800 and 4500 rpm. Two pole motors run at about 2800 rpm, and for this speed no gearbox or pulleys are required. The faster speed is preferred when the scaling is heavy or when the scale is hard. Some older systems use 3900 rpm, with pulleys.

Hugot (1960) gives a range of 3500 to 4000 rpm. Knights and McDonald (1966) give a range of 2800 to 4500 rpm, and state that the speed also depends on the type of tool head used.

At the higher speeds the cables, shafts and tools require more maintenance, wear more, and breakages occur more frequently. The handling of the flexible shaft is more difficult at the higher speeds.

Shear pins
A shear pin is installed between the motor and the flexible shaft. At one factory the diameter of this pin has been reduced from 7.5 to 7.0 mm.

Tool heads and brushes
All systems use tool heads of the type shown in Figure 2 or Figure 4.

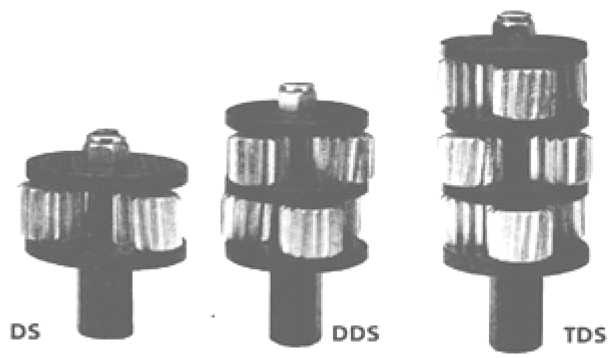

Figure 4. Tool heads: cutters. The DS and DDS cutters are not used frequently in the sugar industry.

The tool head must be of the correct diameter for the tube. The cutter wheels on the tool head are ridged, either in a straight line, or in a left or in a right hand direction. When they are mounted on the tool head it is important to combine the three types on each spindle. This helps to prevent ridges or ripples being formed on the tube surface, and improves scale removal. It also reduces the possibility of the tool head being jammed in the tube.

Some factories use a brush behind the cutter in a tool head, similar to the TAQBB arrangement in Figure 2.

An end piece is fitted between the flexible shaft and the tool head. Two types are used; the first is long and rigid, which gives increased rigidity to the tool head system. The second has a shorter end piece, and is used mostly with smaller tubes of around 38 mm diameter.

Tool heads can jam inside the tubes, particularly when old and hard scale is present. These can sometimes be dislodged by inserting a tube of smaller diameter and tapping the jammed tool. Where the tool head cannot be dislodged, it has to be abandoned inside the tube.

Flexible shafts
Flexible shafts, of the type shown in Figure 1, are used universally. At one factory, the thrust bearing was replaced with a bush, thus reducing costs. At another factory the flexible shafts are kept well oiled to prevent corrosion when not in use for long periods. Water can penetrate between the cover and the rotating shaft when operating under flooded conditions, resulting in increased maintenance.

Inspection of tubes
A number of cleaned tubes were removed from the evaporators at one factory, and cut into short lengths. These were then cut open longitudinally to expose the insides of the tubes. This was done so that the inside surfaces could be inspected more thoroughly. Some of the opened sections are shown in Figure 5. This approach also allows the scale to be removed and sent for analysis.

Figure 5. Inside sections of cleaned evaporator tubes.

It is evident that not all the tubes were cleaned totally successfully. The middle section of the top tube for example, shows the presence of a thin layer of scale which was not removed; this is illustrated in Figure 6.

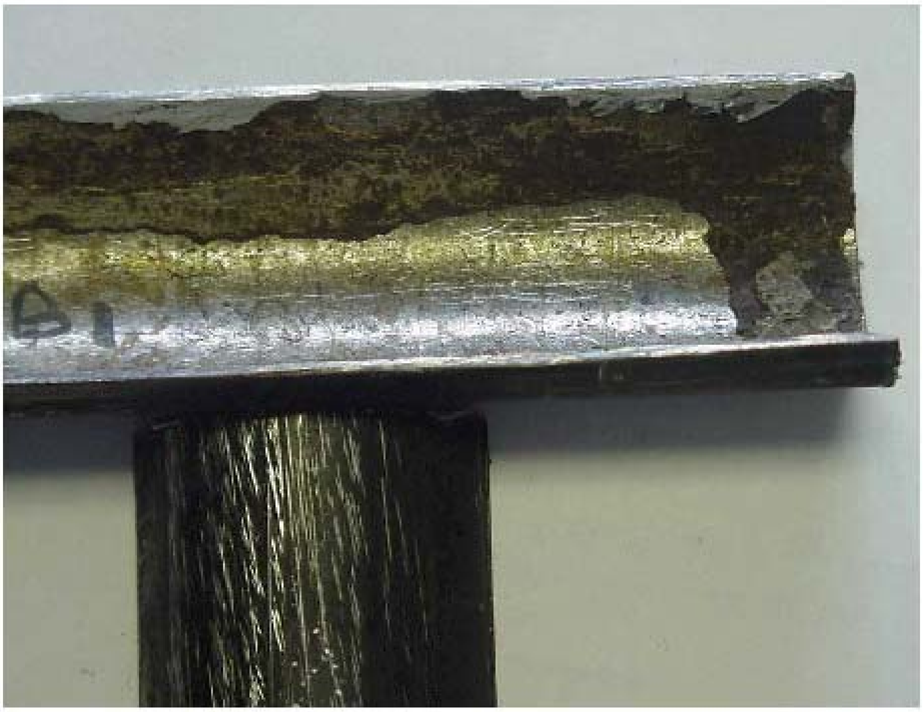

Figure 6. A section of tube showing scale that was not removed by mechanical cleaning.

Descaling of bottom tube plate

Scale adhering to the underside of the bottom tube plate needs to be manually removed during the offcrop, using a descaling tool. If this is not done, scale can build up to the extent that it starts to obstruct the bottom of the tube during the following season. This prevents the cleaning tool from working efficiently in that area, which in turn causes more scale to build up. The tube can finally become blocked with a plug of scale.

Costs

Simple cost analyses done at two factories yielded the following costs. The cost of disposables, for example brushes, cutters, spindles and cables, ranged from R12 to R17 per m^2 of tube area, for the past season. In addition, a maintenance worker is needed; the proportion of his time that will be spent on mechanical cleaning will depend on the size of the evaporator station. In a factory cleaning about 13 000 m^2 of tube area, such a worker was found to spend two to three days per week on this duty. No attempts have been made here to obtain labour costs for the operators doing the cleaning; if local labour costs are known, the data in Table 1 can be used to obtain a rough estimate of this cost.

Conclusions

The mechanical cleaning of evaporator tubes is a disagreeable job. It can cause wear in the tubes, and there have been cases (Whitelaw, 1988) when this technique has not been able to restore the heat transfer coefficient to its clean tube value, mainly because of large heating surface area and exceptionally hard scale. In such cases the factory throughput has had to be reduced. If costs are not overriding, chemical cleaning then becomes an option.

In many cases, however, mechanical cleaning is sufficient to restore evaporator performance to acceptable levels, and the cost is not prohibitive.

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REFERENCES

Chetty S, Gwegwe B and Davis SB (2002). Caustic recovery via membrane micro filtration. *Proc S Afr Sug Technol Ass* 76: 582-585.

Hugot E (1960). *Handbook of Cane Sugar Engineering*. Elsevier, New York.

Knights AG and McDonald DA (1966). Brevity: Evaporator cleaning. *Proc British West Indies Sug Technol* pp 328-329.

Peacock SD, Walthew DC, de Beer TH and Neel P (1999). The use of sequestering agents for chemical cleaning. *Proc S Afr Sug Technol Ass* 73: 219-224.

Walthew DC (1994). Evaporator fouling literature review. Communication No. 159, Sugar Milling Research Institute, University of Natal, Durban, South Africa. 83 pp.

Walthew DC, Khan F and Whitelaw RW (1998). Some factors affecting the concentration of silica in cane juice evaporation. *Proc S Afr Sug Technol Ass* 72: 223-227.

Walthew DC, Whitelaw RW and Mohabir R (1997). Chemical cleaning of evaporators. *Proc S Afr Sug Technol Ass* 71: 199-206.

Walthew DC, Whitelaw RW and Peacock SD (1995). Preliminary results from a long tube climbing film pilot evaporator. *Proc S Afr Sug Technol Ass* 69: 132-137.

Whitelaw RW (1988). Chemical cleaning of the evaporators at Felixton. *Proc S Afr Sug Technol Ass* 62: 34-38.