STEAMSIDE CHEMICAL CLEANING OF EVAPORATOR TUBES

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Abstract

Routine examination of tubes removed from evaporators at Huletts mills revealed serious steamside fouling on tubes from evaporators heated by vapour 1, exhaust steam and vapour 2. A laboratory investigation was undertaken to find a suitable cleaning formula. Chemical cleaning procedures were subsequently carried out at two mills resulting in considerable improvement in heat transfer coefficients.

Introduction

Routine examination of tubes removed from evaporators at 4 Huletts sugar mills revealed serious steamside fouling of a carbonaceous nature[1] on tubes heated by vapour 1, exhaust steam and vapour 2. Vapour 1 is also used in vacuum pans and at Bryant Sugar House (U.S.A.)[2] the vapour side of the vacuum pan tubes are cleaned annually to ensure maximum heat transfer.

Steamside fouling provides a high resistance to heat transfer — a factor which becomes very significant when a mill is short of evaporator capacity. It was decided accordingly to carry out chemical cleaning of the steamside of Amatikulu (AK) and Darnall (DL) mills' second effect vessels and Darnall's first effect vessels. The latter had an oil based vapour side fouling due to these vessels being heated by exhaust steam.

Mount Edgecombe mill had already cleaned the steamside of their 2nd and 3rd effects in February 1976. (Appendix 1).

A laboratory investigation was undertaken to find a suitable cleaning formula which gives an efficient clean and is relatively inexpensive.

Methods used

Chemical formulae for steamside cleaning were evaluated using tubes pulled from the evaporators of Huletts mills. Several tubes were pulled randomly from each evaporator to get as representative a sample of the fouling present as possible. The tubes were also pulled and handled as carefully as possible to avoid scraping the fouling off.

The fouling which covered the steamside of two of the brass tubes was scraped off and analysed (Table 1). This scraping is the reason for the high copper level in the AK 2nd effect sample.

Table 1

Fouling on the steamside of brass tubes from AK and DL

Tube	Ash	Moisture	Loss on Ignition @ 800°C	Copper as CuO	Iron (Fe_2O_3)	Phosphate
AK 2nd Effect	—	1,3%	54,3%	43,7%	0,0%	0,0%
DL 2nd Effect Blair	17,0%	—	83,0%	—	—	—

Laboratory method —

Sections of the tubes were:

(i) Weighed (W_1)

(ii) Immersed in various formulations based on a solvent and a wetting agent (Appendix 2) for a set period of time at temperatures of 25-30°C, 50°C and 70-100°C, with no stirring.

(iii) Rinsed in cold water by immersing and stirring in water.

(iv) Air dried and re-weighed (W_2).

(v) Mechanically cleaned and re-weighed (W_3).

The percentage scale removal was then estimated as —

$$\frac{W_1 - W_2}{W_1 - W_3} \times 100$$

The internal scale had been mechanically removed from most of the tubes before they were pulled. In the case of the few tubes which had not been internally cleaned the results obtained were confirmed by visual inspection.

Laboratory Results —

The most effective formulations are given in Table 2. Details of the chemicals used appear in Appendix 2.

Table 2

Steamside Chemical Cleaning Treatments

Tube	Treatment (% by mass)	Temperature	Time	Scale Removal
AK 2nd Effect brass	10% formic acid: 5% Magnus 1007: 85% water	Cold (26°C)	3 h	B
AK 2nd Effect brass	10% formic acid: 5% Magnus 1007: 85% water	Hot (90°C)	3 h	A
AK 2nd Effect brass	10% glacial acetic acid: 10% Magnus 1007: 80% water	Cold (26°C)	3 h	A
AK 2nd Effect brass	10% glacial acetic acid: 5% Magnus 1007: 85% water	Hot (55°C)	3 h	B
AK 2nd Effect brass	10% glacial acetic acid: 5% Magnus 1007: 85% water	Cold (26°C)	6 h	B
AK 2nd Effect brass	10% glacial acetic acid: 10% Magnus 1007: 80% water	Hot (90°C)	6 h	B
DL 1st Effect mild steel	10% glacial acetic acid: 2,5% NP6: 7,5% Solvesso 150: 80% water	Cold (26°C)	48 h	A
DL 1st Effect mild steel	10% glacial acetic acid: 5% Magnus 1007: 85% water	Cold (26°C)	48 h	A
DL 2nd Effect Blair brass	10% glacial acetic acid: 5% Magnus 1007: 85% water	Cold (26°C)	48 h	A
EM 2nd Effect brass	10% glacial acetic acid: 0,5% NP6: 9,5% power paraffin: 80% water	Cold (26°C)	48 h	A

A = 81 - 100%
B = 70 - 80%

Mild steel tubes proved more difficult to clean than brass. Formulae based on Magnus 1007 proved to be the best cleaners, particularly for brass tubes. They could be used either hot or cold.

Formulations using NP6 are very effective on steel tubes but are best used at high temperatures (50°C+), as they tend to thicken at ambient temperatures (20-35°C).

Cleaning procedure for a mill –
The formulae used at AK and DL are given in Table 3.

Table 3

Formulae used at AK and DL

Mill	Treatment	Time	Temperature	Present cost R/m³ of emulsion	Present cost R/m² of heating surface
AK	10% acetic acid*: 5% Magnus 1007: 85% water	12 h	25°C	82,55	0,926
DL 1st cleaning process	10% acetic acid*: 0,5% NP6: 9,5% power paraffin: 80% water	10 h	50°C	63,36	0,527
2nd cleaning process	10% acetic acid*: 2,5% NP6: 7,5% Solvesso 150: 80% water	72 h	25°C	98,23	0,818

*** Commercial grade acetic acid.**

A 5% Magnus 1007, 10% acetic acid solution proved to be the most cost effective formula – it gave a better than 80% scale removal on the tubes tested under laboratory conditions. At the time of going to press chemical costs were R82,55 per m³ of the initial emulsion.

When the formulae are made up the wetting agent should be added after the solvent and the acid last. Purified water – not raw water – should be used.

If steam is available and time is limited to 12 hours or less a hot (50°C+) cleaning procedure for a minimum of 6 hours is recommended. If time is not a limiting factor, for instance in the offcrop, a cold cleaning procedure with a residence time of 48 hours or more is recommended followed by a cold water rinse.

Exhausted solutions can be regenerated once by making up to strength again with the acid. Regeneration costs are not included in the above costs. The exhausted solutions should be disposed of by spraying into the boilers.

The normal safety precautions for handling acidic and inflammable solutions should be taken.

Cleaning procedure as carried out at Darnall –

1. Hot cleaning procedure: This was carried out during the season (Dec. 1976) on the two first effect vessels and one second effect vessel, as the evaporators were not performing very well. A sufficient quantity of the formula to be pumped round the calandria of a vessel (30m³) was made up. The formula used was – 80% water : 10% acetic acid : 9,5% paraffin : 0,5% NP6. This solution was stored in a tank, pumped to a calandria and returned via an overflow pipe. The solution was pumped round the calandria because the laboratory trials had shown that agitation improved the scale removal.

During the 10 hour cleaning process, the temperature rose from 50°C to 70°C as the reaction is exothermic. This temperature rise is good as the hotter the solution is the better.

The acid strength diminished during the cleaning process. Once the Blair vessel (a second effect vessel) was cleaned, 92% of the original acid strength remained and after the first Kestner vessel (a first effect vessel), only 38% remained.

The large amount of sludge left in the exhausted solution was analysed. It consisted of 89% carbonaceous and 3% ferrous material with negligible copper.

The effectiveness of the cleaning procedure was judged by the heat transfer coefficients (HTC). The marked improvement in the heat transfer coefficients of the Kestner and Blair vessels is shown in Fig. 1. The improvement in the HTC of the Blair 2nd effect was most marked from 1,44 to 3,25 KW/m²/°C.

2. Cold cleaning procedure: This was carried out during the 1977 offcrop as the hot cleaning procedure had concentrated mainly on the Blair vessel. The cleaning solution was made up according to the following formula –

10% acetic acid : 2,5% NP6 : 7,5% Solvesso 150 : 80% water

This was a cold (26°C) treatment with a long residence time. The solution was pumped round each vessel for 72 hours. The cleaning procedure is more effective when the solution is kept moving.

The heat transfer coefficient in the Kestners improved from 2,17 to 2,70 KW/m²/°C after the cold cleaning procedure (Fig. 1). The maximum evaporation rate achieved before the cleaning procedure was 30,26 kg of water evaporated /m²/h (270,0 tons cane crushed/hour). After the cleaning procedure the maximum rate was 34,42 kg of water evaporated /m²/h (280,8 tons cane crushed/hour) (Table 4).

Table 4

Tons cane crushed/hour and the water evaporated/hour for the 1976/77 and 1977/78 Seasons at Darnall Mill

Time	Tons cane crushed/h	Water evaporated kg/m²/h
1976		
May	256,1	27,25
June	275,9	29,74
July	270,0	30,26
August	270,4	29,23
September	260,3	30,03
October	261,8	30,31
November	257,7	29,52
December	259,2	30,70
1977		
January	252,2	30,49
Offcrop		
May	275,2	27,56
June	282,9	30,79
July	278,9	29,73
August	261,4	28,05
September	253,8	29,83
October	271,4	32,84
November	287,0	34,26
December	280,8	34,42
1978		
January	259,7	32,67

Cleaning procedure as carried out at Amatikulu mill –

AK chemically cleaned the steamside of their 3 second effect vessels at the start of the 1977/78 season. They used the formula – 10% acetic acid : 5% Magnus 1007 : 85% water. This was a cold (25°C) cleaning procedure with a short residence time of 12 hours due to the limited time available.

During the 1976/77 season, the maximum monthly rate for evaporation was 33,4 kg of water evaporated /m²/h, achieved for a cane crushing rate of 388,5 tons/h. During the 1977/78 season, the maximum monthly evaporation rate of 34,7 kg of water evaporated /m²/h was achieved for a cane crushing rate of 404,6 tons/h.

However a new flow control system was installed in the AK evaporator station during the 1977 offcrop so the improvement in evaporator station performance experienced by AK in the 1977/78 season is due to both the chemical cleaning carried out and the flow control systems.

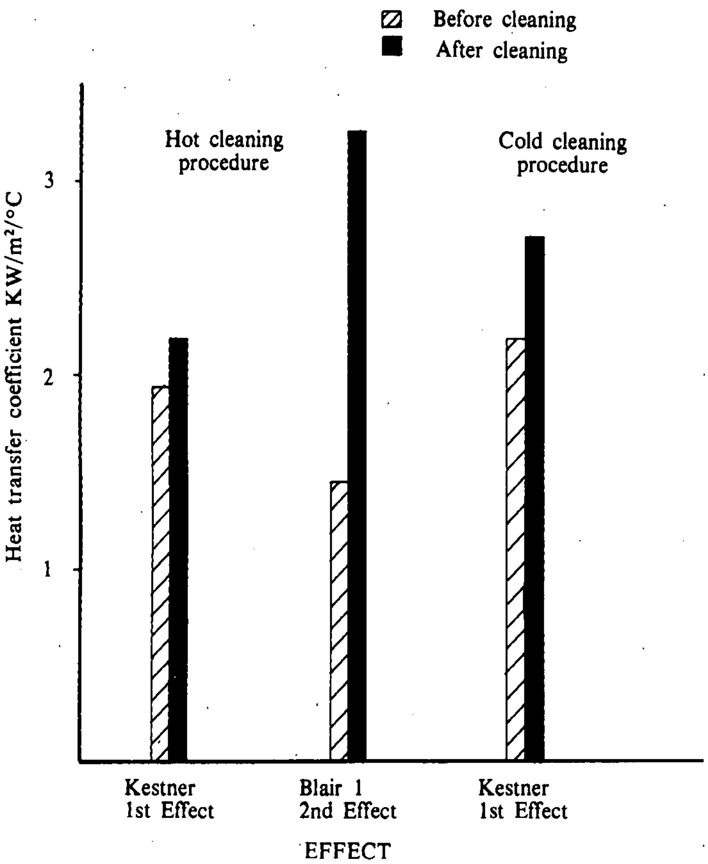

Figure 1. The effect of steamside chemical cleaning at Darnall

Conclusion

Evaporator heat transfer coefficients and thus evaporator capacity can be increased by a chemical cleaning of the steamside of evaporator tubes. The formulae by mass 10% acetic acid (commercial grade) : 5% Magnus 1007 : 85% water and 10% acetic acid (commercial grade) : 0,5% NP6 : 9,5% power paraffin : 80% water are the most effective. At R82,55 and R63,36 per m^3 of emulsion at present costs, they are also relatively inexpensive.

In the case of a vessel with very bad fouling a 100% improvement in the heat transfer coefficient is possible. In the case of a more lightly fouled vessel, a 12% to 25% increase in the heat transfer coefficient can be achieved.

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Appendix 1

Mount Edgecombe Mill (ME)

ME chemically cleaned the steamside of the second and third effects in February 1976. The formula used was –
10% formic acid : 5% Magnus 1007 : 85% water at 25°C
The heat transfer coefficient for the second effect improved from 1,08 to 1,95 KW/m^2/°C and from 1,42 to 1,84 KW/m^2/°C for the third effect (measured when 'Crustex' was not operating).

Evaporation rates cannot be compared as 'Crustex' – an ultrasonic device for preventing internal scale formation – was installed on all the evaporators after the steamside of the 2nd and 3rd effects were cleaned.

Appendix 2

Chemical Suppliers and costs:

Chemical	Supplier	Price at time of press
NP 6	I.C.I.	103 c/kg 1-5 drums (200 kg drums) 99 c/kg > 5 drums
Magnus 1007	Chemserve	R171,35 per 200 litres SG 0,83
Solvesso 150	Esso Chemicals	38,6 c/litre 200 litre drum SG 0,88
Acetic acid (commercial grade)	Holland Electric	47 c/kg 25 kg drum (with rebate)
	Protea Holdings	61 c/kg 25 kg drum (with rebate)
Formic acid (commercial grade)	B. Owen Jones	58 c/kg 25 kg drum (with rebate)
Power Paraffin		R27,24 200 litres SG 0,87

NB.: 'rebate' refers to a customs duty rebate and makes a significant difference to the price. It is not granted automatically, it has to be applied for.

The active portion of any cleaning solution is the wetting agent or detergent. A solvent is also needed for the wetting agent. In the case of Magnus 1007 formulae, no solvent is needed as the Magnus 1007 contains both the detergent and the solvent.

Formulae based on NP6 however do require a solvent. NP6 dissolves in the aromatic portion of power paraffin or Solvesso 150. The NP6 should not exceed 3% of the power paraffin.