*Proceedings of The South African Sugar Technologists' Association — June 1991*

# CRYSTALLISER COOLING WATER TREATMENT AT FELIXTON

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## Abstract

Important factors affecting corrosion in crystalliser cooling elements are outlined, as well as possible methods of water treatment. Methods used at Felixton are outlined, including control of the treatment and its effectiveness. Requirements for good control and costs of the treatment at Felixton are given.

## Introduction

As the size of operations in the sugar industry has gradually increased over the years, more attention is being paid to cooling water treatment. Most cooling systems today operate as open recirculation systems, and cooling is achieved in natural or forced draught cooling towers. Cooling water treatment is carried out to prevent corrosion, deposition of inorganic material or scale, growth of micro-organisms and fouling. This is achieved by proper dosing of chemicals, and regular analysis to control dosing rates and cooling water chemistry.

Corrosion is an electrochemical process which occurs where either dissimilar metals (e.g. iron and steel) or similar metals under dissimilar conditions are in contact with water, resulting in the development of an electrolytic cell in which transport of electrons causes oxidation of iron. The transport of electrons is prevented by the formation of a protective film on the cathode or anode. The formation of hydrogen stops the electron transport but, as cooling water in an open system always contains oxygen, this hydrogen is removed and only the addition of corrosion inhibitors will reduce corrosion.

A large number of inhibitors which form a protective layer of iron complexes is available. This layer can be formed on the cathodic or anodic side of the corrosion cell and experience in corrosion inhibition has shown that a mixture of inhibitors is far more cost effective than the application of only one. Common cathodic inhibitors are zinc and phosphates. The latter are commonly applied as polyphosphates or organic phosphates (phosphonates) and, in addition to their corrosion inhibitor action, act as scale inhibitors due to calcium complex formation. Chromate is a traditional anodic inhibitor which due to its toxicity to the environment has been largely replaced by molybdate, often in combination with the anodic inhibitor silicate. Due to the large surface area of the anodic site in a cooling system, under-dosage of an anodic inhibitor should be avoided, even for short periods. A small area of unprotected metal will result in highly accelerated corrosion.

Instead of using protective films, corrosion can also be prevented electrochemically by fitting zinc or magnesium electrodes in galvanic contact with the equipment to be protected. In this way, a galvanic cell is formed in which mild steel is protected by the voltage difference. The zinc or magnesium gradually go into solution. This method is common in the protection of marine vessels and of underground pipelines running through aggressive soil, but is not yet commonly applied to factory equipment.

The effect of corrosion inhibition is normally measured by installing corrosion coupons in the system in coupon racks. The coupons are removed and weighed at set periods, and from the decrease in mass and time period the corrosion rate is calculated. Corrosion rates are traditionally expressed in milli-inches per year (mpy). The metric equivalent of mpy is 0,0254 mm/year. As a rough guide, corrosion control should obtain a rate of 2-3 mpy. Corrosion coupons however, can only give a value at that point under those conditions, e.g. in a cooling system in which microbial control is poor, local accelerated corrosion can occur under deposits, while at the same time coupons give an acceptable result. The cost of the protected equipment has to be taken into account and compared with the annual cost of corrosion inhibitors applied to the system.

The corrosion rate in mpy is related to the estimated useful life of mild steel pipes of various sizes in Table 1.

**Table 1**

**Estimated life of mild steel pipes under corrosive conditions (Anon, 1969)**

| Nominal size (mm) | Schedule | Wall thickness (mm) | Estimated pipe life (years to lose ½ wall thickness) | | |
|---|---|---|---|---|---|
| | | | 50 mpy | 15 mpy | 5 mpy |
| 12 | 40 | 2,77 | 1,1 | 3,6 | 11 |
| 25 | 40 | 3,38 | 1,3 | 4,4 | 13 |
| 50 | 40 | 3,91 | 1,5 | 5,1 | 15 |
| 100 | 40 | 6,02 | 2,4 | 8 | 24 |
| 150 | 40 | 7,11 | 2,8 | 9 | 28 |
| 200 | 40 | 8,18 | 3,2 | 11 | 32 |
| 250 | 40 | 9,27 | 3,7 | 12 | 37 |
| 300 | 30 | 8,38 | 3,3 | 11 | 33 |
| 350 | 30 | 9,53 | 3,8 | 13 | 38 |
| 400 | 30 | 9,53 | 3,8 | 13 | 38 |
| 450 | 20 | 9,53 | 3,8 | 13 | 38 |
| 500 | 20 | 9,53 | 3,8 | 13 | 38 |
| 600 | 20 | 9,53 | 3,8 | 13 | 38 |
| 1 000 | Standard | 9,53 | 3,8 | 13 | 38 |
| 1 000 | - | 6,02 | 2,4 | 8 | 24 |

Anon (1969). The flow of fluids through valves, fittings and pipes. Technical paper published by The Engineering Division of the Crane Company, Section B16.

Apart from using corrosion coupons, the corrosion rate can be measured electrically. Accurate determination of corrosion rate can be carried out in the laboratory but on-line measurement is not easy as the measuring cell used is complex. Commercial equipment for on-line measurement of corrosion rate does exist but its accuracy is questionable.

The prevention of scale in sugar factories is mainly confined to adequate pH control, supported by the addition of polyphosphates and organic polymers. In cooling water control it is advisable to periodically analyse TDS, pH, calcium hardness and alkalinity. From these four data and the temperature, the Langlier or Ryznar Index can be calculated as a measure of corrosiveness or scale-forming potential. The application of the Ryznar Index in drinking water treatment was recently discussed by Meadows (1990).

Microbiological control in larger installations is normally carried out by chlorination. A number of sugar factories apply HTH (granular calcium hypochlorite) for injection water treatment. The chlorination is normally applied discontinuously and supplemented by dosages of one or more non-oxidising organic biocides and a dispersant. The most cost effective method of chlorination is the application of gaseous chlorine, as carried out successfully at Gledhow since 1979. However, as gaseous chlorine lowers the pH, the treatment requires pH control, normally carried out by lime addition. Smaller cooling systems are usually treated by dispersants and organic biocides. Halogen tablets are also sometimes applied. Dispersants are as important as biocides, as the planktonic organisms do not create the major hazard to cooling systems. The deposition of micro-organisms results in under-deposit corrosion and creates anaerobic sites, where sulphate reducing bacteria develop. The sulphide produced results in accelerated localised corrosion.

Control of microbial treatment is normally carried out by determining the number of microbes per ml of cooling water. These results, however, can be misleading as the determining factor is the deposition of micro-organisms on the metal surface of the cooling system. Improved sampling methods of deposited micro-organisms do exist but require specialised equipment.

## Crystalliser layout at Felixton

Felixton operates six A crystallisers and four B crystallisers of 135 m$^3$ massecuite capacity. The 12 C crystallisers each hold 85 m$^3$ massecuite and are all of the vertical type. The total quantity of cooling water is 90 m$^3$ and the flow rate is 130 m$^3$/h. Cooling is obtained in a forced draught cooling tower. Normally, cooling water filtration is carried out as slipstream filtration in which 5-10% of the total flow is passed through a filter. Filtration in a cooling system is an important step to reduce fouling and deposition of suspended matter on surfaces in the cooling circuit.

At Felixton, not all the cooling capacity in the C crystallisers was required and over the last three years the cooling water flow through the rotors has been stopped. These rotors are filled with water and the cooling water only passes through the stators.

## Cooling water treatment at Felixton

Before 1987, corrosion inhibition was obtained by dosing zinc-polyphosphate, supported by polyacrylate. Zinc, however, has the disadvantage of becoming inoperative by precipitation at pH $> 8,0$ or stripping at pH $< 6,8$.

Before the 1987/1988 season, it was decided to ensure protection of the crystalliser system by improving cooling water treatment, and the crystalliser circuit was partially cleaned by inhibited hydrochloric acid. Since 1987, corrosion was inhibited by continuously dosing a mixture of molybdate, silicate and phosphonate. Silicate has the property of penetrating formed tubercles of iron oxide and in this way passivating them. In 1989 phosphinate was added to the treatment programme.

Microbial control has been carried out by alternating shock doses twice a week of a blend of disodium methylenebis-dithiocarbonate/sodium dimethyl-dithiocarbonate and thiazolin. Last season, the second biocide was successfully replaced by a straight chain aliphatic dialdehyde. In addition to the two biocides, a dispersant is dosed continuously.

Since 1989, cleaning of the crystalliser cooling circuit has been introduced in the form of air rumbling. On an eight week cycle, each crystalliser is treated with slugs of compressed air, forced into the circulating water. This shakes loose deposits formed in the system. The water is discharged to effluent. Where water flow through the rotors has been shut down, these rotors are separately treated. As an air space exists above the water in the rotors, a vapour phase inhibitor and a long-life biocide are added to the water. During shut-down the water is pumped out and replaced. The total cooling water circuit is specially treated during the off-crop. This is an important aspect of the treatment as the off-season periods are fairly long and serious corrosion can occur. The cooling water circuit is charged with a vapour phase inhibitor and a long life biocide and circulated before shut-down. A vapour phase inhibitor was selected because air-water interfaces occur during the off-crop.

## Control of the treatment programme

Control of the corrosion rate in the rotors can be judged from the similarly treated centre wells. Mild steel corrosion coupons have been fitted at two positions in each crystalliser centre well.

Corrosion coupons have also been fitted in a coupon rack in the return line to the cooling tower. In addition, corrosion coupons are fitted at various places in the crystallisers. These coupons are removed, inspected, cleaned and weighed at periods between 30 and 90 days.

Laboratory analysis of the level of added products and various other parameters are carried out daily by the factory. Weekly inspections are performed by the water treatment contractor and discussions are held with factory staff. If analysis shows a product to be underdosed, instant correction is achieved by slug dosing on a daily basis and, if required, the dosing rate at the pump is adjusted. The result of microbial control is judged by weekly inspections. When considered necessary, a microbial analysis is carried out in which total count and the presence and number of sulphate reducing bacteria are determined.

Quarterly review meetings are held between the water treatment company and factory staff, where a quarterly report is discussed and corrective action established.

At the end of the season an inspection of the cooling water systems, heat exchangers and pipe sections is executed and an annual review report is submitted and discussed at an annual review meeting.

## Results

Judging the results of cooling water treatment cannot be as easily expressed in figures as many other operations. Corrosion rates obtained from steel coupons can be recorded and microbial counts can be reported but, to a large extent, judgement is based on visual observations of the cooling system.

During the first two seasons of revised water treatment at Felixton, the dosage of corrosion inhibitors was erratic and the required amount of 100 ppm in the system often fell below this level as undetermined loss of water from the system frequently occurred. From Figure 1 it can be seen that there were long periods of under-dosage. Comparing the dosage of inhibitors with the measured corrosion rate demonstrated that periods of under-dosage coincided with accelerated corrosion.

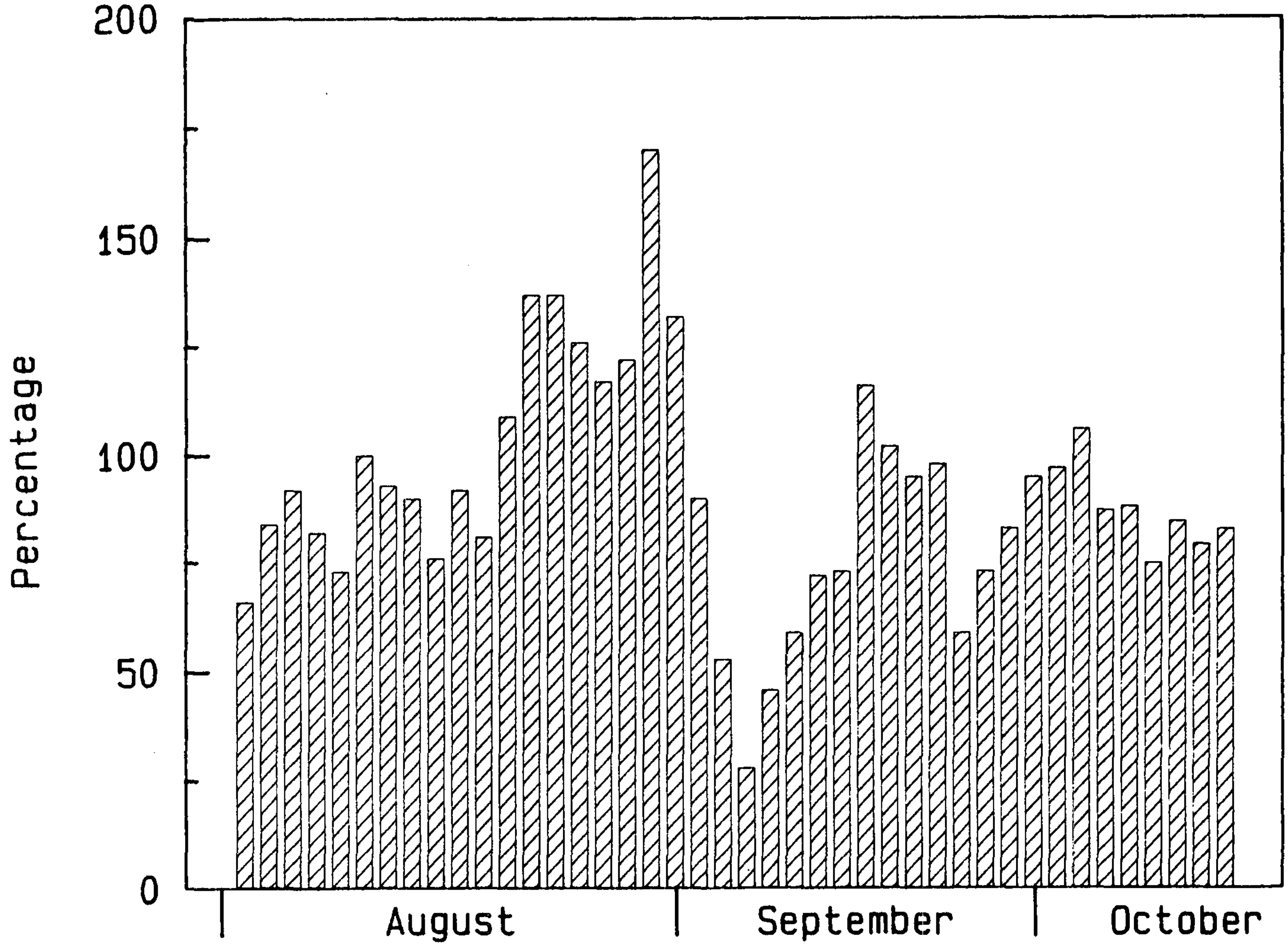

**FIGURE 1** Level of inhibitor mixture as percentage of target (1988).

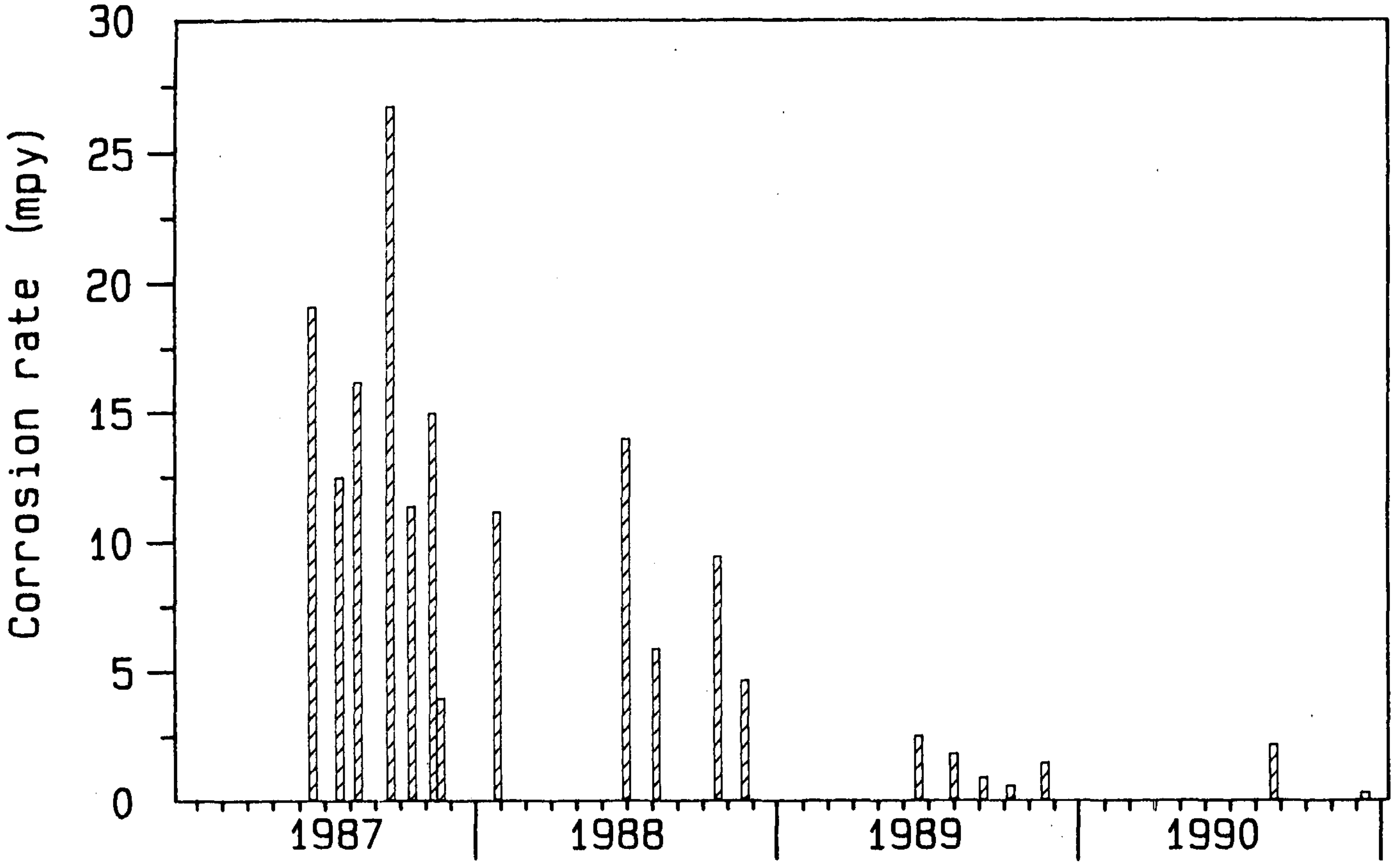

**FIGURE 2** Corrosion rate in crystalliser cooling system over four seasons.

In subsequent seasons this was overcome by increased dosage to ensure that the required 100 ppm level was maintained.

Water losses were reduced by improved control, although they still do occur. At present, the system operates at 2,5 to 3 cycles of concentration.

Corrosion rates measured by mild steel coupons since 1987 are shown in Figure 2. From this bar graph, it is clear that better control has produced improved corrosion rates.

The corrosion rate in the separately treated rotors can be compared with corrosion in the identically treated centre wells. Table 2 gives values for a few centre wells measured in 1989. From this, it is evident that corrosion control in centre wells and rotors is excellent in both wet and dry zones.

**Table 2**

**Corrosion rates in centre wells in 1989**

| Crystalliser | Position | Result |
|---|---|---|
| 2A | 5 m | 1, 2 mpy |
| 2A | Bottom | 0,9 mpy |
| 2B | 5 m | 1,3 mpy |
| 2B | Bottom | 0,01 mpy |
| 1C | 5 m | 1,5 mpy |
| 1C | Bottom | 1,6 mpy |
| 9C | 5 m | 1,6 mpy |
| 9C | Bottom | 1,3 mpy |

Figures 3 and 4 show the inside of a crystalliser stator in 1988 and 1990. The inside of the return line to the cooling tower in 1988 and 1990 is shown in Figures 5 and 6. From the photographs it is clear that corrosion is now better controlled than in the earlier years of the treatment period. In Figure 6, a protective phosphate coating can be seen. Figure 7 shows a corrosion coupon removed in August 1990. Although not entirely corrosion free, the system is controlled at an acceptable rate.

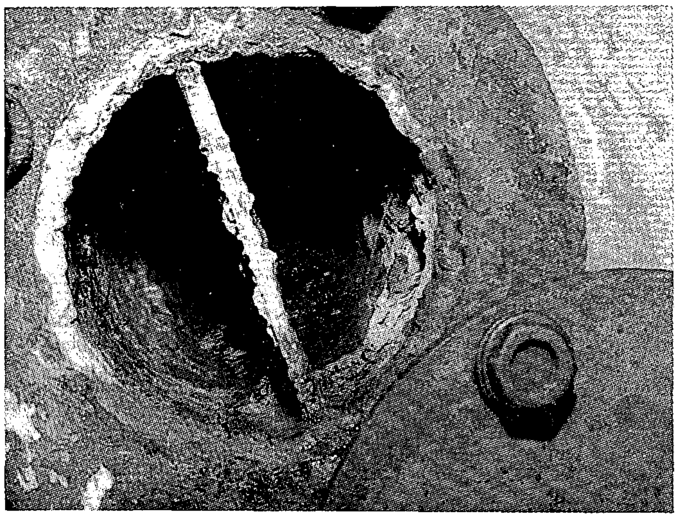

**FIGURE 4** Crystalliser stator 1990.

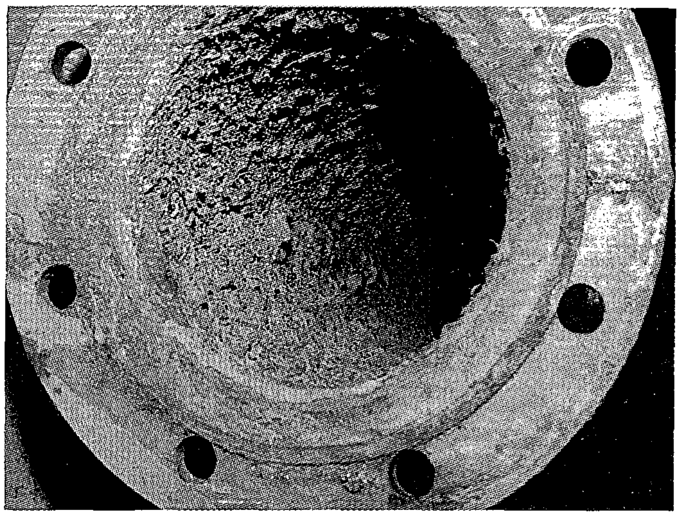

**FIGURE 5** Crystalliser return line 1988.

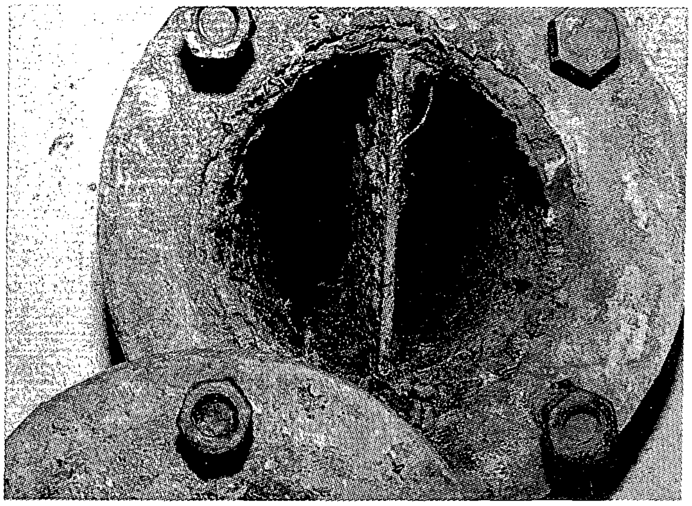

**FIGURE 3** Crystalliser stator 1988.

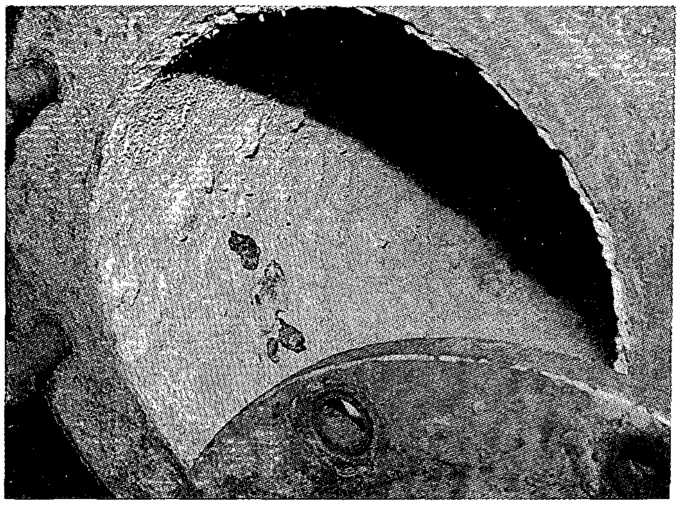

**FIGURE 6** Crystalliser return line 1990.

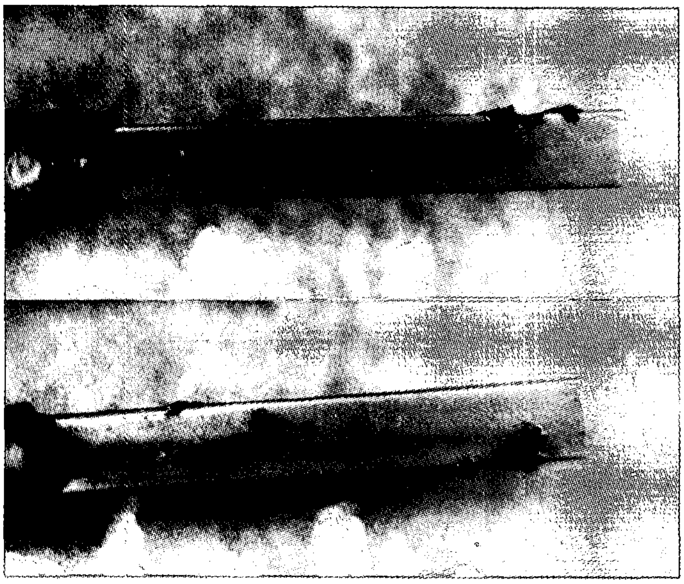

**FIGURE 7** Corrosion coupon 1990.

Good results can only be obtained if the product level is continuously maintained at 100%. In addition, good service from the water treatment company and good management of factory staff are essential.

## Costs

The treatment cost in 1990 was R55/day for corrosion inhibitors and R20/day for biocides and dispersant - a total of about R18 000 per season. The amount of make-up water averaged 42 tons per day, resulting in R1,80/ton of make-up water. The cost of cooling water treatment has to be judged against replacement costs of equipment. The estimated cost of replacing Felixton's 22 crystalliser rotors is R2 million. This is more than 100 years of treatment at today's prices.

## Conclusions

Provided good analytical control is carried out and dosing of biocides and corrosion inhibitors is adequately managed by factory staff and the water treatment contractor, a corrosion rate of < 2 mpy can be continuously maintained in a factory cooling system.

Although it is not known how long the equipment would last without any water treatment, a fair estimate indicates that the present corrosion control at Felixton mill is cost effective.

## Acknowledgements

Thanks are due to Mr J Harker of Bonchem (Pty) Ltd for the photographs and most of the data, and to Mr R Whitelaw of Felixton for additional data.

## REFERENCES

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