COOLING WATERS - THE UNSEEN PROBLEMS

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Abstract

Open and closed circulating cooling water systems are installed at most sugar mills on applications such as evaporator and pan condensers, crystalliser cooling, massecuite reheating and liquid ring vacuum pumps. Despite increasing attention being paid to corrosion control in these systems, the dangers and costs that can be incurred from inadequate treatment may not be sufficiently appreciated. Some of the potential damage that can occur in such systems is highlighted with reference to experiences at Amatikulu. An illustration to determine the economic level of expenditure of water treatment corrosion control is highlighted.

Introduction

As with most industries, sugar manufacturing relies for many of its processes on the principle of heat exchange. The usual means of heat transfer is often through the medium of circulating water. Three principal types of cooling water systems are found:

- **Once-through systems**, which require large quantities of readily available water at a reasonable cost from a primary source such as a dam or river. With limited water resources available in South Africa, these systems are not common in the sugar industry.
- **Open recirculating systems**, which are frequently used because they not only provide economic heat removal but by recycling also conserve limited supplies of water and substantially reduce costs for water. The circulating waters used for the condensing of vapours from evaporators, filters and vacuum pans are usually sourced from an open recirculating system. A number of types have been developed for the evaporative cooling of water including cooling ponds, spray ponds and cooling towers. The most widely used of these devices is the cooling tower and it is the peculiar problems associated with circulating waters contained in cooling towers that will be discussed.
- **Closed recirculating systems** are mainly used as an example for cooling compressors or heating purposes such as massecuite reheaters. Experiences with the reheater system at Amatikulu will be related in this text.

Cooling Water Monitoring

Test heat exchanges, scale measuring devices, metal coupons and corrosion rate probes are often used to monitor deposition and corrosion. The use of this monitoring equipment may only provide indirect information about the corrosive tendencies of the circulating water. These monitoring devices are merely tools and it is necessary to understand the conditions of each monitoring run in order to relate the results to actual operating conditions. Most monitoring methods merely simulate and do not duplicate actual system conditions.

Information needs to be gathered wherever possible from both sides of the heat exchange system but should be determined preferably from the hot side which usually contains the more aggressive waters.

Figure 1 illustrates a typical open corrosion rack system containing metal coupons. Corrosion rates as an average penetration in mils per year (mpy) are calculated from these coupons after a period of exposure (usually 30, 60 or 90 days) according to the formula:

$$\text{Corrosion Rate} = \frac{22{,}3.W}{d.a.t}$$

Where W = weight loss in milligrams.
d = density of the metal in grams per cubic centimetre.
a = exposed area of coupon in square inches.
t = time in days.
mil = 0,001 inches.

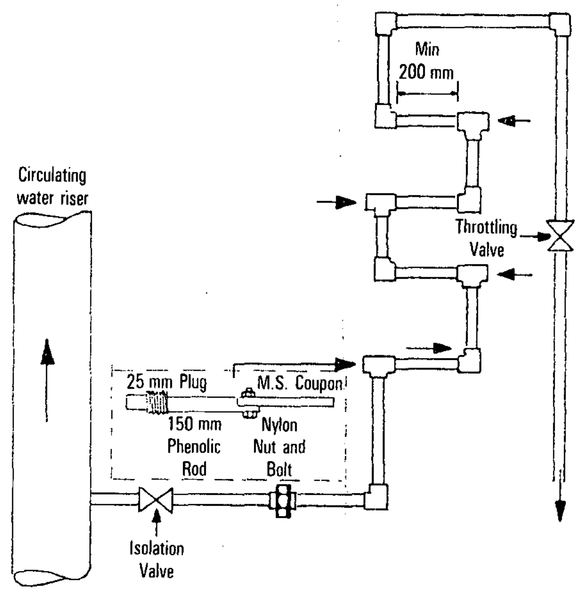

FIGURE 1 Corrosion test rack

Condenser Water Cooling Tower

The operation of a sugar mill cooling tower is adversely influenced by contamination through sugar, leading to slime, scale, corrosion and other problems. These factors can cause major losses in the efficiency of the cooling system (through slime build-up of the air passages) and can lead to the rapid deterioration of the materials of construction used in the cooling tower, pumps, pipelines and associated equipment. Control of the bleed-off and pH is helpful in reducing these problems and often is the only control means used by a mill. Experiences at Amatikulu have shown these measures to be insufficient in limiting corrosion to acceptable levels.

A nine cell, induced draught cooling tower with a recirculation rate of 5 500 m^3/h and total water volume of 2 000 m^3 was installed at Amatikulu in 1965. During the first twelve seasons of operation, slug dosing with milk-of-lime and natural water bleed through overflow were the control measures adopted. Rapid deterioration of the piping was noticed and between the 8th and 10th season the entire pipe circuit was lined internally with a 3 mm layer of cement.

Despite steps taken towards introducing chemical and microbiological corrosion control from 1977, by the off-crop of 1979/80 it was necessary to replace about 75% of the injection water reticulation system at a cost of R187 000 (1980 prices).

Intensive monitoring has since taken place and a number of corrosion control products have been utilised to reduce the extent of aggressive attack on the piping (Table 1).

TABLE 1

Yearly corrosion rates Amatikulu injection water system

Year	Corrosion rate (mpy)		Treatment
	Cold	Hot	
1980	18	—	Filming Amide + Dispersant + Biocide
1981	25	—	Filming Amide + Dispersant + Biocide
1982	19	63	Dimethylamide + Biocide
1983	10	35	Dimethylamide + Biocide
(2 mths.) 1983	7	24	Zinc Phosphonate + Biocide

Results for the four year period were not satisfactory and calculations indicated a predicted pipe life of only ten years at the average corrosion rate for this period of 28 mpy. The product change in the latter part of the 1983/84 season showed some promise and this treatment basis was continued in 1984. Monthly results for this season appear in Table 2. Results for the first five months of operation were encouraging as corrosion rates of this low magnitude had not previously been obtained for the waters from the cold side of the tower.

TABLE 2

1984 Corrosion rates Amatikulu injection water system

Month	Corrosion rate (mpy)		Comment
	Cold	Hot	
April	4	10	
May	3	38	
June	2	25	
July	6	30	
August September	4	33	Extensive erosion of coupon on hot side
October	15	26	Cold side zinc Residuals not maintained
November	18	—	
December January February	15	—	
	23	24	Hot side corrosion rack flow not continuous

Corrosion rates obtained from the coupons on the hot water return were different. These coupons exhibited extensive erosion and may have been erroneous. The cause was traced to the milk-of-lime injection into this return water reticulation system for the purposes of pH control. It was not until November 1984 that diversion of this lime directly into the tower sump was possible. Corrosion rates did not improve thereafter however, as a result of the tower having to be drained and flushed through extensive sludge and bagacillo build-up in the tower sump. Consequently zinc residuals were not maintained and corrosion rates were high.

These results are still far short of the target of a corrosion rate below 5 mpy if pipelife is to be economically maintained. There are indications from the early part of the season that this can be achieved.

Crystalliser Cooling Water System

In common with many mills, Amatikulu has the facility of a separate cooling tower for use on crystalliser cooling. This circulating water system is also coupled as the service water for the liquid ring vacuum pumps. Periodic sugar contamination plagues this system through lowered pH's and aggressive waters. The principle control measure on this system at Amatikulu was the adjustment of pH usually through the addition of caustic soda or soda ash.

The system installed at Amatikulu is an induced draught cooling tower of 65 m^3 capacity with a recirculation rate of 100 m^3/h serving 26 water-cooled 45 m^3 crystallisers and 14 liquid ring vacuum pumps.

Historical records indicate (amongst other reasons) that crystalliser cooling elements had to be replaced after about ten years due to the extensive corrosion of these paddles. By the 1982/83 off-crop a further programme had to be introduced to replace the crystalliser shafts - after 18 years of service. Further, the paddles also required replacement - after 8 years operation (Table 3).

TABLE 3

1984 Corrosion rates Amatikulu crystalliser cooling water system

Month	Corrosion rate (mpy)
April	15
May	13
June	16
July	16
August September	24
	23
October	28
November December	46
January	45
February	

Corrosion control of this system has not been successful due to the inability to control pH as a result of contamination from the vacuum pump source. The magnitude of the replacement cost of crystalliser cooling elements (R12 000 per crystalliser at 1985 prices) makes it imperative that a solution should be found to enable corrosion rates below 5 mpy to be achieved and the mild steel components of this system to achieve prolonged lives. It is proposed in the current shut-down to divorce the two circuits (viz crystalliser cooling and vacuum pump service) in view of the sucrose recovery and economic benefits of cooling massecuites to maximum advantage.

Reheater Circulating Water System

This system was introduced into Amatikulu with the installation of a 1858 m^2 heating surface C massecuite reheater in 1972. This closed circuit reheating water system of 20 m^3 capacity and 80 m^3/h circulation rate is in Figure 2.

By 1980, after eight years when no monitoring of corrosion rates took place, leaks were evident in the massecuite heat exchange system. Because of the reheater's strategic importance in the process, repairs could only be effected in the succeeding off-crop.

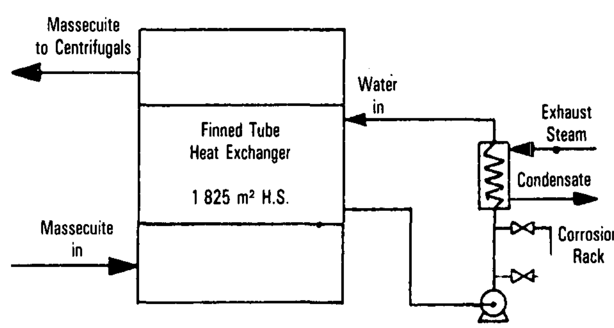

FIGURE 2 Amatikulu Reheater Circulating System

During the shut-down of the 1983/84 season an extensive examination of the heat exchanger revealed that the majority of the finned tubes were badly corroded on the water side. Replacement at a cost of R72 000 was necessary.

Table 4 illustrates the corrosion results obtained using a Nitrite-Borate treatment together with microbiological control once repairs had been effected.

TABLE 4

1984 Corrosion rates Amatikulu reheater system

Three months ended	Corrosion rate (mpy)
June	0,005
August	0,213
November	0,500
February	0,500

Economics of Cooling Water Treatment

From the foregoing it can be seen from experiences at Amatikulu that the life of the materials of construction in untreated recirculating water systems does not extend much beyond eight years on average. From Table 5 it can be deduced that by reducing corrosion rates to less than 5 mpy, dramatic increases in pipe-life and heat exchanger life are possible. It is necessary, however, to determine whether corrosion rates of this low magnitude are economically justified.

TABLE 5

Estimated life of mild steel pipe under corrosive conditions

N.B. pipe (mm)	Schedule	Wall thickness (mm)	Estimated pipe life (years)			
			50 mpy	35 mpy	15 mpy	5 mpy
25	40	3,38	1,3	1,9	4,4	13
50	40	3,91	1,5	2,2	5,1	15
100	40	6,02	2,4	3,4	7,9	24
150	40	7,11	2,8	4,0	9,3	28
200	40	8,18	3,2	4,6	10,7	32
250	40	9,27	3,7	5,2	12,2	37
300	30	8,38	3,3	4,7	11,0	33
400	30	9,53	3,8	5,4	12,5	38
500	30	9,53	3,8	5,4	12,5	38
600	30	9,53	3,8	5,4	12,5	38
900	30	9,53	3,8	5,4	12,5	38
1200	30	9,53	3,8	5,4	12,5	38

Estimated pipe life = loss of 50% wall thickness

If non-treatment is opted for, sufficient capital (at current prices) would have to be accumulated to replace piping etc every eight years. However, if a similar or slightly lesser amount is spent on corrosion control then pipe-life would be extended considerably.

Assuming that materials replacement will be necessary every eight years if non-treatment (other than pH correction) is adopted, and that replacement will be necessary every 35 years with treatment, Table 6 indicates the savings attributable to chemical treatment at Amatikulu based on the expenditure necessary to achieve corrosion rates less than 5 mpy.

TABLE 6

Comparison of costs of treatment versus non-treatment

System	Condenser	Crystalliser	Reheater	Total
Replacement Cost	360 000	312 000	72 000	744 000
Non-treatment Cost				
(i) Chemical	12 000	1 000	500	
(ii) Piping	45 000	39 000	9 000	
	57 000	40 000	9 500	106 500
Treatment cost				
(i) Chemical	46 000	5 000	1 500	
(ii) Piping	10 000	9 000	2 000	
	56 000	14 000	3 500	73 500
Savings	1 000	26 000	6 000	33 000

Conclusion

Periodic and frequent replacement of the materials of construction associated with cooling towers such as pipelines and crystalliser cooling elements and with closed circuit systems such as massecuite reheaters is necessary if sufficient corrosion inhibition measures are not introduced.

Expenditure on corrosion control should be allocated in accordance with replacement cost and anticipated life of the unit as if non-treatment were adopted. The products used for material preservation depend on each system and are not within the scope of this paper.

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