AIR-COOLING OF A-CRYSTALLISERS

I SINGH, H JONES and S GAYAPARSAD

Transvaal Sugar Ltd, P O Box 47, Malelane, 1320, South Africa
E-mail: singhi@tsb.co.za

Abstract

This paper examines the rationale for air-cooling of A-crystallisers at the Malelane Mill. The A-crystalliser station at the Malelane Mill comprises two banks of agitated but uncooled 42 m^3 cylindrical units connected in series. During periods of high purity brix loading and/or high volumes of refinery returns, the A-massecuite exhaustion drops off significantly. This manifests itself as a constraint on factory throughput. Various alternatives were considered to improve A-crystalliser cooling.

After a technical and economic evaluation, surface air-cooling was identified to be a quick and easy as well as cost-effective option. This short paper describes the factors considered in the design of the air-cooling fans and examines the effectiveness of the air cooling process.

Keywords: air-cooling, crystallisers

Introduction

The A-crystalliser Station at the Malelane Mill comprises two banks of uncooled, mechanically stirred 42 m^3 cylindrical vessels connected in series. During periods of high purity brix loading and/or high volumes of refinery returns, the A-massecuite exhaustion drops off significantly. Lower A-massecuite exhaustions lead to increased volumes of down-stream massecuite boilings and consequent higher rates of recycling. This manifests itself as a constraint on factory throughput, higher undetermined sugar losses and increased coal burning.

A-crystalliser cooling options

A capacity study of Malelane Mill in 1999 identified that the residence time for A-massecuite was marginal. This situation was aggravated by the absence of A-crystalliser cooling. Retrofitting of water-cooling to the existing A-crystalliser station at Malelane presented an opportunity to increase A-massecuite exhaustion with a view to accommodating a higher brix loading and thereby increasing cane-crushing capacity.

Both static and rotating cooling elements were evaluated for installation in the horizontal cylindrical shaped crystallisers. The cost of the cooling elements, the need to upgrade the drives and the need to provide a dedicated cooling tower and the complexity of the installation made this project non-viable.

Vertical crystallisers were considered as an alternative but the high cost involved with this option could only be economically justified in a later phase of the mill expansion that would involve the installation of an A-continuous pan.

Compressed air injection cooling was tabled as an option but due to a lack of established experience with this technology, it was not pursued further. Direct contact air-cooling on the other hand is a tried and tested practice in the Australian Industry (Tait *et al.*, 1998). This technique of cooling massecuites was evaluated and it was concluded that a cost-effective system could be designed for cooling of A-massecuites at Malelane Mill.

Direct contact air-cooling

Direct contact air-cooling of massecuites involves contacting the hot massecuite stream with a sizeable stream of cooler air. Figure 1 depicts the general layout of the Malelane installation. Design data used in the sizing of the fans are shown in Table 1.

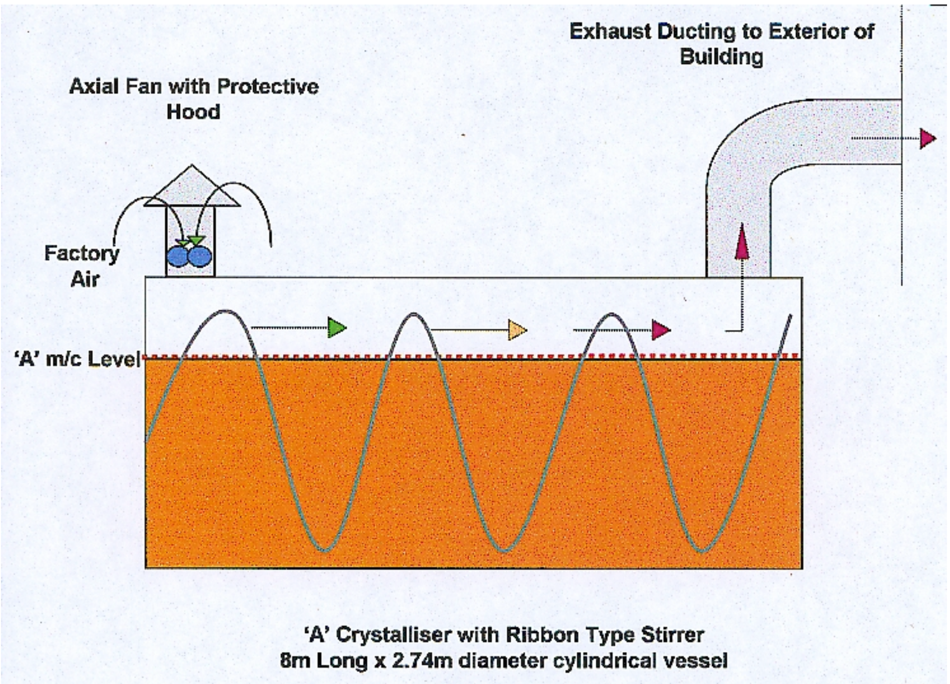

Figure 1.

Table 1. Design data.

Nominal volume of one A-crystalliser cylindrical vessel	42.5 m^3
Total A-crystalliser volume	382 m^3
Average A-massecuite flow rate	71 m^3/hr
Average A-massecuite retention time (cx only)	5.4 hrs
Average A-massecuite retention time (incl. Strike Receivers)	8 hrs
Massecuite temperature at inlet of A-crystalliser	62°C
Required massecuite temperature at discharge of A-crystalliser	<54°C
Specific heat capacity of A-massecuite at 92.2° Bx.	1.50 kJ/kg°C
Total heat load to be removed from A-massecuite	351 kW
Average heat load to be removed from A-massecuite per crystalliser	39 kW
Length of cylindrical crystalliser	8000 mm
Diameter of cylindrical crystalliser	2740 mm

Direct contact air-cooling involves two heat transfer mechanisms:

- Forced convective cooling in which the heat transfer process involves heat being exchanged between a moving air stream on the one hand and the upper surface of massecuite and the ribbon element of the crystalliser paddles on the other. This process can be likened to the heat removal in conventional water-cooled crystallisers.
- Evaporative cooling in which water is evaporated from the surface of the massecuite. The energy required for evaporation is derived from the massecuite and in so doing drops the temperature of the massecuite.

The design heat load to be removed from the massecuite in each crystalliser is shown in Table 2.

Table 2. Design heat loads.

Method of heat transfer	Surface area (m^2)	Heat load (kW)
Average heat load to be removed from each crystalliser	–	39.0
Radiation from mild steel shell of each horizontal cylindrical vessel	32	3.6
Forced convection from the upper surface of massecuite and ribbon paddle elements at 80% crystalliser level	18	25.2
Evaporative cooling from the upper surface of massecuite at 80% crystalliser level	18	10.2

Fan sizing

The required airflow for air-cooling is a function of its moisture absorptive capacity and the quantity of heat to be removed by convection from the upper surface of the massecuite. The quantity of water to be evaporated at an average massecuite temperature of 55°C was calculated to be 23.04 kg/hr.

It was estimated that a minimum air velocity of 3 m/s would be required to evaporate this quantity of water from the upper surface of the massecuite. At the cross sectional area corresponding to 80% level in the crystalliser, this air flow equates to 2.86 m^3/s. An axial flow fan with a capacity of 4.75 m^3/s was finally selected to meet the mill's requirements for standardisation, off-the-shelf availability and low noise. Due to the low capital cost of the fans and ducting it was decided to install individual cooling fans on each crystalliser rather than a single large fan. This has the advantage of eliminating complex ducting and dampers to regulate air flow to individual crystallisers. Protection against over cooling of A-massecuite has been provided for by interlocking the final crystalliser outlet temperature with the motor switchgear. If the massecuite temperature drops below 50°C the entire bank of fan motors is stopped and will only re-start when the final outlet temperature rises above 54°C.

Results

The average results for ten high throughput test runs for molasses Nutsch purity drop, temperature drop and moisture removal across the bank of four crystallisers are summarised in Table 3.

Table 3. Δ Nutsch purity, Δ temperature and moisture removal over four crystallisers (South bank).

Run	Ambient temperature (°C)	Δ Nutsch purity (%)	Δ Temperature (°C)	*Moisture removal (kg/hr)
With fans off	26 - 30	3.5	1	–
With fans on	26 - 30	7.9	7	25
Improvement	–	4.4	6	25

*Note: The mass of moisture removed has been determined from dry and wet bulb temperature readings of air into and out of each crystalliser.

A temperature drop of 6°C and an improvement of 4 units in Nutsch purity have been achieved with air cooling over the south bank of crystallisers during the test periods. The removal of approximately 25 kg/hr/crystalliser of water from A-massecuite will have a positive effect on massecuite brixes and thereby a synergistic effect on the crystallisation driving force. An additional bonus from using factory ambient air and exhausting this air externally is that some heat load within the factory building is removed and at the same time fresher cooler air enters the building at the ground floor level. For a factory with high ambient temperatures especially during summer, this has a positive effect on operator thermal comfort. Initial fears of localised encrustation on the paddle elements have not materialised.

Conclusion

The axial flow fans installed on the bank of four cylindrical A-crystallisers at Malelane have allowed the A-massecuite to be cooled by an additional 6°C during the winter months. The temperature drop is expected to be less during the summer months when the ambient temperature is approximately 10°C higher. Given these positive results, Malelane Mill has proceeded with the installation of cooling fans on the remaining A-crystallisers.

The capital cost for the crystalliser air-cooling installation at Malelane comprising fans, switchgear and ducting has amounted to R180 000 for the nine crystalliser vessels. This figure is approximately 10% of the estimated cost of retrofitting water-cooling to the entire A-crystalliser station.

The opportunity exists for this technique to be extended to the A-strike receivers where the temperature difference between massecuite and air is greater and therefore greater cooling benefit will accrue. Further enhancement in cooling is expected to be derived when the corroded cylindrical tops of the existing vessels are replaced with U-shaped upper sections, which will offer 20% more massecuite surface area contact with the cooling air stream.

REFERENCES

Tait, PJ, Hepburn, JA, Vigh, S, Rodriguez, BM and Lamarque, M (1998). Performance trials on the STG-FCB air swept crystalliser. *Proc Aust Soc Sug Cane Technol* 20: 491-497.