AIR POLLUTION CONTROL – PRACTICAL EXPERIENCE AT TONGAAT

By B. St. C. MOOR
The Tongaat Group Ltd

Abstract

Experiences at the Tongaat Factory with six high efficiency wet type flue gas scrubbers are described. The experiences relate to three different types of scrubbers and to both single fuel (bagasse) and dual fuel (coal/bagasse) boilers. Aspects covered include pollution control equipment selection, operation and performance, materials of construction, wet and dry fans, smuts dewatering and conveying and the disposal of the smuts. Several of Tongaat's solutions to problems in these areas could find application in other factories.

Purpose

After some thirty years' experience with ineffectual spray chambers and six years' with efficient flue gas scrubbers on bagasse fired boilers and four years' experience of scrubbers on dual fuel (coal/bagasse) boilers, Tongaat has pioneered enough disasters and spent sufficient money on apparently good ideas which have failed in practice to know that smut removal from sugar factory smoke can be a costly and complex operation. However, much has been learned from these experiences, and this paper is presented in the hope that it will indicate to others some short-cuts on the road to air pollution control, and perhaps also advise against some particularly rough detours.

Type of pollution control equipment

Basically, Tongaat decided on wet flue gas scrubbers in preference to dry cyclones because of their much higher smut removal efficiencies, and in preference to electrostatic precipitators because of their lower capital costs and because the latter are unreliable on flue gases with moisture levels as high as those resulting from bagasse combustion.

Five scrubbers have been operated at Tongaat thus far, and a sixth will be in service by the time this paper is presented. Details of these are tabulated below (Table 1).

As is shown in the table, all three types achieve emission rates well below the present permissible maximum, even for new boilers in the South African sugar industry, of 400 mg/normal m^3 at 12% CO_2, and all do so with a relatively low pressure drop across the scrubber and droplet elimination equipment (less than 100mm water gauge). The characteristic of a low pressure drop is regarded as an important requirement (*a*) because of the saving in induced draught fan power, and (*b*) because a lower pressure loss permits a lower fan speed and consequently less fan wear.

Operationally all three types of scrubber in service at Tongaat are simple and generally satisfactory. Experiences with the different types include:

The Peabody scrubber installation (Fig. 1) has been previously described (Moor[5]). It is liable to blockages between the perforated plate and target plates and in the spray nozzles if the circulating water is not well screened. Blockages can also develop from a build up of fine material on the droplet eliminator and the 250 mm diameter drain from the scrubber has very occasionally choked. The spray nozzles suffer from erosion.

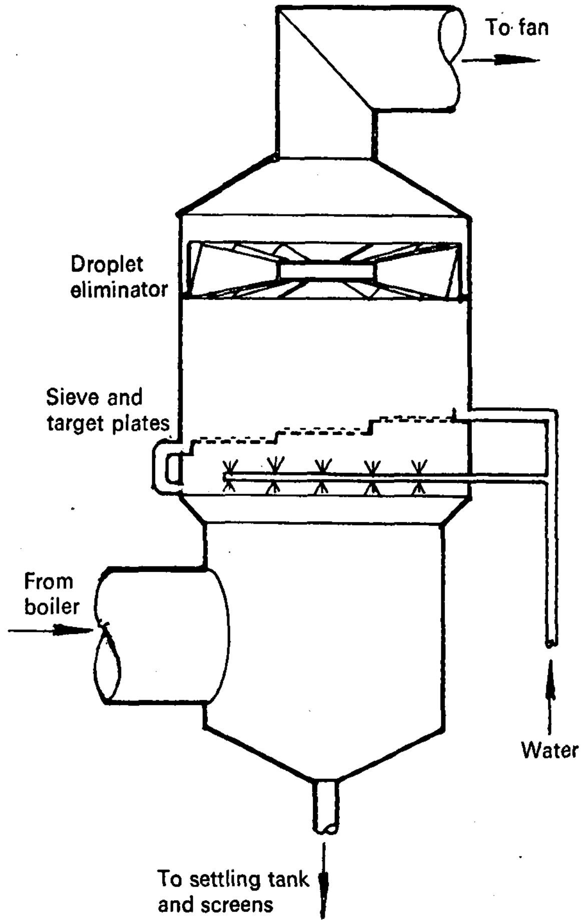

FIGURE 1 Peabody Scrubber.

TABLE 1
Scrubbers at Tongaat Sugar Mill

No. off	Make	Type	Year installed	Fuels fired	Boiler MCR (tons/hr)	Approx. emission (mg/m^3)	Pressure drop (mm water)	Circulating water (m^3/ton steam)
1	Peabody . .	Perf. plate with targets .	1970	Bagasse	40	40–50	70–90	4,5
2	Brandt-Ducon	Multivane	1973	Bag./coal	30	70–110[1]	60–80	1,5
2	Tongaat . .	Irrigated sieve	1973	Bagasse	30	100–150[2]	65–80	4,5
1	Tongaat . .	Irrigated sieve	1977	Bag./coal	120	untested		4,5

Notes: 1. Emission from Brandt scrubbers at Tongaat not measured, but estimated from tests on pilot plant and similar installations at Umzimkulu.
2. Test on irrigated sieve plate scrubber was incomplete as five of nine samples taken were destroyed before final measurement. Remaining samples indicated an emission range of 90–120 mg/m^3 in lower velocity areas of the stack, from which the overall estimate of 100–150 was inferred by the method of Hawksley, Badzioch and Blackett[4]. This method may not be entirely valid for bagasse smuts.

The Brandt-Ducon scrubbers (Fig. 2) also occasionally choke at the 250 mm outlet pipe, but the single spray nozzle has never choked and the scrubber does not require such careful screening of the circulating water as does the Peabody.

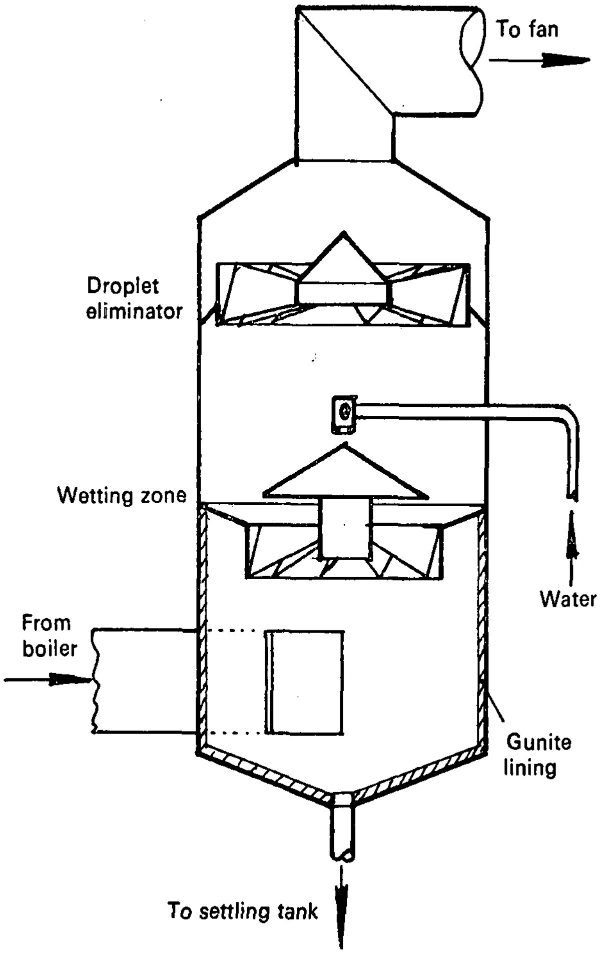

FIGURE 2 Brandt-Ducon Scrubber.

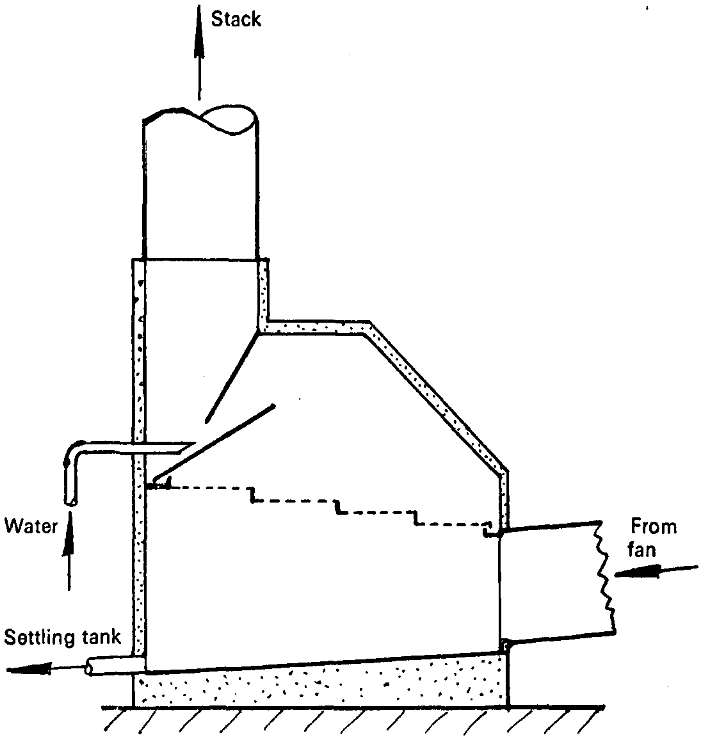

FIGURE 3 "Tongaat" Scrubber.

The flue gas enters the scrubber tangentially at a fairly high velocity, and this causes erosion of the body in the entry zone. This erosion can be countered by gunite lining or by fitting sacrificial wearing plates in this zone. Erosion of the spray nozzle and dispersion cone are not so easily countered, but these are relatively low cost items. The two most important advantages of the Brandt scrubber are its low circulating water requirement (which correspondingly reduces the size of settling tank and pump required) and the fact that its droplet eliminator vanes are subject to negligible fouling as the centrifugal flow up the scrubber separates most droplets and solids before the eliminator.

The Tongaat scrubbers (Fig. 3) are of the irrigated sieve plate type described by Ravnö and Judd[6]. They require no screening of the circulating water, are completely choke-free and have no parts subject to severe erosion. They do however require more circulating water than the Brandt scrubbers and require some device for droplet elimination from the scrubbed gases. This device can be fairly simple, and both centrifugal separation and an abrupt change in direction into a low velocity chamber have been successfully used. Impingement baffles can also be used. In order to avoid re-entrainment the gas velocity through the eliminator should not exceed 1,5ms^{-1} to 2ms^{-1} in most simple designs. Useful information on velocities, pressure drops and efficiencies of various types of scrubber entrainment separators is included in a report by Calvert, Jashnani and Yung[1].

Wet or dry fans

Initially wet fans (i.e. after the scrubber) were favoured because the higher density (lower temperature) of the gases after the scrubber would allow use of a smaller fan and the scrubbed gases should result in negligible wear. However, wet fans at Tongaat have failed from three completely different causes.

The first failure occurred on the two ASA grade 316 stainless steel fans installed after the Brandt scrubbers on the dual fuel boilers. The eye-rings on both these fans "crystallised" and disintegrated as a result of chloride stress corrosion. Chloride concentrations of up to 10 000 ppm were measured in the circulating water while burning bagasse — presumably derived both from the make-up water and from the flue gases from bagasse combustion. The stresses in the eye-rings were the result of cold-rolling a double radius (circumferential and axial) in this part of the fan during fabrication. The ferritic stainless steels (ASA grade 430) are not subject to chloride stress corrosion failure in this way, but grain growth in highly stressed weld zones render them unsuitable for fan construction. The stainless steel fans were therefore replaced with mild steel fans, but within a few months one of these disintegrated as a result of sulphide stress corrosion of the structural welds. The sulphides resulted from burning coal containing approximately 1,5% sulphur. After this failure, the other fan was removed, the welds all increased to more generous proportions and the whole fan stress relieved. Both this fan and a similarly reinforced mild steel replacement for the disintegrated fan have now served three seasons without further mishaps.

The third cause of failure has been a combination of rapid corrosion and erosion of mild steel impellers resulting from carry-over of droplets from both the Peabody and one of the Tongaat perforated plate scrubbers. In both cases the damage has been almost completely arrested by improving the droplet elimination.

Following these failures, a dry or "hot" fan arrangement was decided upon for the new boiler, with a low pressure drop coarse grit separator before the induced draught fan. This double separation (coarse grit followed by scrubber) is obviously wasteful of power, but was regarded as worthwhile because of the savings in fan erosion. Fan erosion is variously estimated to be proportional to between the third and fifth powers of the speed of the fan, and experience at several factories indicates increasing wear with increasing sand in bagasse, especially on spreader stoker fired boilers.

In summary, the experiences at Tongaat thus far do not lead to a clear preference between wet and dry fans. Wet fans suffer from various forms of corrosion and, especially if high efficiency backward-curved impellers are used, from a build up of smuts on the vanes, which in turn can lead to imbalance and vibration. Dry fans need to be larger (higher volume of hot gas) and, unless pre-arrestors and/or very slow fan speeds are used, suffer from severe erosion wear. Experience with each during the next two seasons may perhaps lead to a clear preference for one type.

Materials for scrubber construction

On boilers firing only bagasse a number of conventional materials will provide satisfactory service. Amongst these are either type 430 or the 300 series stainless steels, concrete, brickwork and gunite lined mild steel. The scrubber water contains carbonic acid and chloride ions, but even in a closed system the pH does not normally drop below about 5,0.

On boilers where coal is fired the choice is severely limited. The Natal coal supplied to Tongaat has a total sulphur content of about 1,5%, so that the products of combustion include considerable quantities of SO_2 and SO_3. Consequently sulphurous and sulphuric acid are formed in the scrubbers, and the pH in an untreated closed circulating water system rapidly drops to 3,0 or even lower. Hot dilute sulphuric acid is a notoriously difficult product to handle. In most scrubbers, this dilute sulphuric acid is present in zones intermittently subject to temperatures of over 200°C and often also to mechanical erosion. This imposes stringent requirements on the materials of construction for the scrubber.

For Tongaat's first two coal-fired boiler scrubbers, Tongaat initially specified type 430 stainless steel, and it is of interest to note that none of the nine firms who quoted on scrubbers for the purpose queried this specification. Within two weeks of start up, parts of the 5 mm thick casing and some of the 3 mm thick swirl vanes of the first scrubber had eroded/dissolved away completely. At this stage the casing was patched and the entire inner surface of the body protected by a gunited 50 mm thick reinforced fondu cement lining. Deterioration was slower on the second boiler, which had been fired mainly on bagasse, but its scrubber was similarly gunited shortly afterwards.

Because it was feared that the pH would be too low even for the fondu guniting to survive long, an alternative material of construction was sought and, on the advice of a consultant metallurgist, a replacement for the most severely damaged scrubber was ordered, to be fabricated entirely from Incoloy 825 (an alloy containing approximately 45% nickel). This very costly unit was installed at the end of the season (April 1974), and is still giving satisfactory service. Problems did arise initially in two areas of the Incoloy scrubber.

Firstly, Incoloy has no better resistance to wear than the 300 series (austenitic) stainless steels. When sacrificial 12 mm thick ASA grade 410 (martensitic) wearing plates in the inlet zone wore through, the Incoloy shell behind them also suffered fairly rapid wear. Guniting this zone appears to have now solved this problem.

Secondly, in the droplet elimination (upper) zone of the scrubber severe localised crevice corrosion even of the Incoloy occurred. This apparently resulted from high sulphuric/sulphurous acid concentrations developing under deposits of fine smuts which had remained undisturbed for weeks or perhaps months. The corrosion initially perforated the 2 mm Incoloy shell in 10 or 12 small pin-head sized holes, and by the time it was detected, two of these holes had increased in size to about 5 mm in diameter. The most obvious indication of the corrosion was a white scale-like product of the corrosion which proved to be high in sulphates. The metallurgist who had advised the use of Incoloy recommended cleaning off the carbonaceous deposit and removing a 70 mm wide skirt behind which the deposit was building up. This simple remedy has proved entirely effective and no further perforation has occurred.

As an additional precaution to protect the scrubbers on both the coal-fired boilers, it was decided to neutralise partially the circulating water by alkali dosing. The cheapest product for this purpose would have been lime, but it was considered that its effect would be very shortlived as insoluble calcium salts would precipitate out and be lost from the system together with the smuts. Caustic soda was therefore decided upon, and caustic dosing has proved a simple and not too costly means of maintaining the pH of the circulating systems above 5,0 provided some bagasse is fired together or alternately with the coal. However, if coal alone is fired for long periods (say 12 hours or more) the caustic requirement is greatly increased and becomes prohibitively expensive. It is presumed that the products of combustion from bagasse burning serve to buffer the circulating water solution.

In summary, Tongaat's experience results in recommending concrete, acid resisting brick or fondu gunite lined scrubber vessels for coal fired boilers with Incoloy 825 or, better still, Inconel 625 used for working parts such as the cone and vanes of the Ducon scrubber. Type 430 stainless steel can be used with boilers firing only bagasse.

Rubber lined pumps and valves have proved satisfactory on the water systems of all scrubbers, and PVC piping can be used in all areas not exposed directly to the hot flue gases. Provided the pH is kept above say 4,5 stainless steel (preferably type 316L if coal is fired) piping can be used inside the scrubbers. Type 430 stainless steel settling tanks have lasted very well, even on the coal fired boilers, presumably because the water temperature does not rise above about 80°C and they are not exposed to the hot flue gases.

Smuts separation from scrubbing water

Even in dry type arrestors the flyash has generally to be wetted for final removal and disposal. With wet scrubbers the smuts must be separated from the scrubbing water.

Over the years, Tongaat have tried various devices for screening smuts from water. These include a stainless steel woven wire belt, Sharples circular vibroscreens, Link Belt vibrating screens and DSM wedge-wire screens. All proved costly to maintain on this duty. All except the woven belt broke up much of the smuts into fines and none effectively separated the fines and sand. The result in all cases was a build up of recirculating fine sand and smuts, severe pump, pipe and nozzle erosion, and eventually blockages. Hydrocyclones were tried in conjunction with screens but these were only partially successful and also suffered from erosion.

Smuts dewatering on all the scrubbers at Tongaat is now done by simple settling tanks with slow drag scraper solids removal systems. Several different configurations are in use, depending on factors such as available space, but a few general design principles for successful operation have been determined. The most important are:

(*a*) The settling tank dimensions should allow an average settling period of preferably 10 minutes but not less than 5 minutes, provided the water depth is not greater than 1 m. (Cullen and Sawyer[2] found slightly longer settling times necessary, recommending 15–20 minutes. Tongaat's experience of quicker settling may be due to flyash size grading or concentrations or to the caustic soda used and its effect on the pH.) A small tank area cannot be compensated for by increased depth as a deeper tank requires a longer settling period because of the greater settling distance.

(*b*) Areas of localised high velocities or short circuiting must be avoided, especially where the slats emerge from the water.

(*c*) The water outlet should either be from a pipe below the surface leading to a weir box or over a weir with a scumming baffle ahead of it to prevent "floaters" being carried over.

(*d*) As long a "beach" as possible should be provided for the slats above the water line to allow surplus water to drain from the separated smuts.

(*e*) A wide slat assembly travelling very slowly (1,5 to 2,0 metres per minute) is preferable to a narrower assemby travelling faster.

(*f*) A stainless steel or synthetic (nylon, fibre-glass) chain should be used if long life is required. A rayon rope instead of a chain was tried at Tongaat without success.

Smuts conveyors

Four methods have been tried for transporting the smuts to an ultimate disposal point.

First attempts involved pumping the scrubber water and smuts to a separating device (screens or settling tank) situated at the disposal point. This was discarded because—

(*a*) pumping before the separation stage broke up the smuts and made the separation more difficult,

(*b*) pump and pipe maintenance was high and blockages occurred on the line carrying the unseparated smuts, and

(*c*) there was very limited area available for separating devices in the vicinity of the disposal point.

The second method tried was to position the separating devices (settling tanks) at the scrubber with a gravity feed from the scrubber to the settling tank, using a belt conveyor to transport the wet smuts to the disposal point. This conveyor was very messy and although conventional belt conveyor idlers, "Diabolomatic" idlers and Joy "Limberoller" idlers were tried, none stood up to the duty. All suffered bearing damage and severe corrosion of any exposed steel components from smut-bearing water.

The third conveying system tried was a chain and slat drag conveyor, using a grade 430 stainless steel conveyor trough. This also proved maintenance intensive as the wooden slats wore rapidly, the chain stretched due to wear from the abrasive smuts and the stainless trough wore through at the welds.

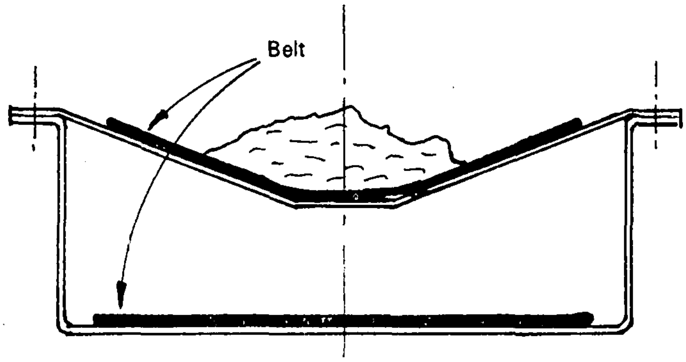

FIGURE 4 Cross-section of Drag Belt.

Finally, almost in desperation, a slowly moving dragged belt conveyor of generous width was tried. This appears to have solved all the problems — it is clean, virtually maintenance free and simple to construct, although the initial cost is a little higher than for a conventional belt conveyor of the same width. The construction comprises a double trough pressed from 4,5 mm type 430 stainless steel, a cross section of which is shown in Fig. 4. Either PVC or rubber covered conveyor belting can be used and belt speeds of between 10 and 20 metres per minute have proved satisfactory. In practice a layer of fine smuts and sand tends to build up between the trough and the belt and the wear on both trough and belt is, perhaps surprisingly, almost negligible. The first such conveyor was installed at Tongaat in 1973 and the original trough and belt are still in service and in satisfactory condition. The total factory smuts (estimated, at approximately 3,5% on cane, to be 12 tons per hour wet mass) are handled by a conveyor fitted with a 1 200 mm wide belt travelling at 15 metres per minute.

Smuts disposal

The smuts from the settling tanks are very wet and messy and contain as much as 75% to 88% by mass of water. Further dewatering of this product is difficult and costly — Huletts R and D Department have tested, and are continuing to test, devices such as vacuum belt filters, hydroclones and rubber decked vibrators, and workers such as Flood, Honey and Munro[3] and Cullen and Sawyer[2] have reported on Australian experiences in this field. Tongaat have tried perforated plate and wedgewire drainage zones in slat conveyors but these were unsatisfactory. Finally, a very simple solution was found for the mess problem — a small quantiy of bagasse is dribbled onto the smuts conveyor and this acts as a sponge which soaks up the surplus moisture.

All the smuts at the Tongaat factory are mixed in with the filter cake. The Tongaat agronomists are satisfied that the smuts have no detrimental effects on canefields, and have in fact welcomed the small quantity of extra "mopping up" bagasse which is now added.

Disposal of the filterpress and smuts mixture has not been a problem, as the company's agricultural department now uses considerable quantities of the product to achieve germination in winter planting.

Acknowledgements

Special acknowledgement is due to those of the Tongaat staff who have spent many hours under hot, dirty and often frustrating conditions gathering the experience which is the basis of this paper.

REFERENCES

1. Calvert, S., Jashnani, I. L. and Yung, S. (1974). Entrainment separators for scrubbers, Journal of the Air Pollution Control Assn, Vol 24 No 10, 971–975.
2. Cullen, R. N. and Sawyer, G. M. (1975). Dewatering of flyash from bagasse-fired boilers. QSSCT Proc **15**, 311-317.
3. Flood, B. W., Honey, A. S. and Munro, B. M. (1974). Emissions from bagasse-fired boilers, ISSCT Proc **15**, 1680–1687.
4. Hawksley, P. G. W., Badzioch, S. and Blackett, J. H. (1961). Measurement of solids in flue gases, Leatherhead, British Coal Utilization Research Assn, 105–133.
5. Moor, B. St. C. (1972). First impressions of a wet type scrubber on a bagasse-fired boiler, SASTA Proc **46**, 100-101.
6. Ravnö, A. B. and Judd, M. R. (1973). A preliminary report on a new sieve plate scrubber for bagasse fired boilers, SASTA Proc. **47**, 49–50.