A PROGRESS REVIEW OF AIR POLLUTION CONTROL IN THE SOUTH AFRICAN SUGAR INDUSTRY FROM 1972 TO 1981

By G. N. ALLAN
Sugar Milling Research Institute

Abstract

A listing of current boiler and smut collector installations is given illustrating the reduction from 59 to 19 boilers without smut collectors. Maximum boiler size has increased from 57 to 147 th^{-1}. Irrigated perforated plate type scrubbers have been the most numerous units installed but some dry multi-cyclone collectors have also been used. Smuts dewatering systems are examined, some problem areas are considered, particularly the 400 mg m^{-3} standard for multi-cyclone collectors, and overall capital cost figures for two large scrubber installations are given.

Introduction

The control of air pollution in the Republic of South Africa falls under the Atmospheric Pollution Prevention Act of 1965. This Act is divided into six parts and is very briefly summarized below :

1. Formation of a National Air Pollution Advisory Committee.
2. Control of offensive gases emitted by industries. This falls under the Chief Air Pollution Control Officer. Industrial processs which are affected are defined as "scheduled processes" and the "incineration of bagasse" is covered under this section. (Power station operation is also a "scheduled process").
3. Smoke emission. Most industries fall under this section which is controlled by local authorities.
4. Dust control. This concerns mainly mine dumps or coal stockpiling and control is exercised by the Chief Air Pollution Control Officer.
5. Vehicle fume emission. Control falls under local authorities.
6. General provisions.

An initial meeting with representatives of the Department of Health and the SA Sugar Millers Association led to the formation of the SA Sugar Millers Air Pollution Study Group to act as a liaison body between the Chief Air Pollution Control Officer and the various factories. The inaugural meeting was held on May 26, 1970 with the broad objective of reducing air pollution created by the industry.

Since its inception this group has co-ordinated the action by industry in a variety of ways. A number of these are listed below :

1. Organised pilot plant trials of wet collectors e.g. Joy at ME, Bateman at UF and the Brandt trials at NB, the last being very successful.
2. Arranged an initial survey of the typical air pollution burden from various types of bagasse fired boilers and from this data established a particle size distribution curve for the collected dust.
3. Measured fall-out levels around some factories.
4. Negotiated emmision standards in collaboration with the Chief Air Pollution Control Officer.
5. Drew up a plan of action whereby all mills agreed to install smut collectors over a period of eight years to eliminate air pollution by the sugar industry.
6. Monitored progress and technical difficulties associated with the installation of smut collectors and ash settling plants.
7. Negotiated with the Chief Air Pollution Control Officer on separate occasions for the declaration of moratoria on the implementation of the agreed plan of action owing to:
   (a) Excessive corrosion problems encountered in wet scrubbers in conjunction with coal firing in some boilers.
   (b) Financial reasons, associated with low export prices and control of production.
   (c) Financial reasons due to severe drought conditions.
8. Arranged tests by the Council for Scientific and Industrial Research on a multi-cyclone dry collector to measure inlet and outlet burdens and particle size distribution characteristics.
9. Reviewed all applications for new boiler plant with regard to the acceptability of the proposed smut collection plant before submitting these plans to the Chief Air Pollution Control Officer for the issue of the requisite permit.

Review of Progress

It must be stressed that the action which has been taken and the tempo of activity has been determined separately by each milling company. In this respect the prompt response by the Tongaat Group in its implementation programme merits special mention.

In 1972 (Allan *et al*[1]) a table of boiler plant and smut collection equipment was published and this has now been updated in Table 1 to provide a basis for comparison and hence an indicator of the progress made over the past 9 years.

The brief summary of Table 2 indicates trends which have taken place in the last nine years.

The number of installed boiler units has been reduced since 1972 but the unit size has increased over the past nine years. Ten boilers of between 80 to 147 th^{-1} have been installed since the initial survey at which time the largest units listed were 57 th^{-1} boilers at UF and SZ.

The number of Dutch Oven furnaces has halved and their departure from the scene is of regret only to the suppliers of firebrick arch blocks. Their emission potential was high, their control was difficult and the accumulation of ash in the combustion chambers of these boilers was in some cases sufficient to force a boiler off range before the full week's run was completed. The physical working conditions faced by the cleaning labour squads were intolerable.

The application of fluidized bed grates directly under the tube banks poses an interesting area of research and

TABLE 1

Factory	Boilers No.	Furnace Type DO	SS	T/E	Smut Collectors W	PP	MC	Total	Boilers not covered
ML	4	–	4	–	1	–	3	4	–
PG(*a*)	8	–	8	–	1	–	4	5	–
UF	6	–	6	–	–	1	5	6	–
EM(*b*) ..	7	5	2	–	1	1	–	2	–
FX(*c*)	4	2	2	–	1	–	2	3	–
EN	5	3	1	1	–	–	2	2	3
AK	5	–	5	–	–	1	4	5	–
GD	4	2	2	–	–	1	–	1	3
DL	6	3	3	–	–	2	1	3	3
GH	7	3	4	–	–	4	3	7	–
NB	4	–	1	3	–	1	1	2	2
UC	5	3	2	–	2	–	1	3	2
TS	6	2	3	1	2	3	–	5	1
ME	6	4	2	–	–	4	–	4	2
IL	5	2	3	–	2	–	1	3	2
SZ(*d*)	5	–	4	–	–	4	1	5	–
UK	5	4	1	–	3	–	1	4	1
	92	33	53	5	13	22	29	64	19

(*a*) PG multi-cyclone covers 4 boilers.
(*b*) EM spray chamber covers 6 boilers.
(*c*) FX spray chamber covers 2 boilers.
(*d*) SZ 1 chain grate boiler on coal only.
DO = Dutch Oven SS = Spreader stoker T/E = Thomson/Eisner
W = Wet scrubbers PP = Perforated plate MC = Multi-cyclone

TABLE 2

	No. of Units	Furnace Type DO	SS	T/E	Collectors No.	Boilers with no collector
1972	113	61	47	5	34 (*a*)	59
1981	92	33	53	5	64 (*b*) (*c*)	19

(*a*) EM, FM, TS and RN had spray chambers covering several boilers. SZ and UF had dry collectors covering several boilers.
(*b*) EM and FX have spray chambers covering 6 and 4 boilers respectively. (Two FX boilers also have cyclone separators.)
(*c*) PG has a multi-cyclone collector covering 4 boilers.
DO = Dutch Oven SS = Spreader Stoker T/E = Thomson Eisner

this may eventually do away with the enormously tedious and costly job of renewing hanger block arches. By operating with continuous ash discharge this would even obviate weekend cleaning.

The most creditable statistic shown up by the new survey is that only 19 boilers are now not covered by any collector whatsoever whereas in 1972 some 59 units had no smut removal capacity. Of the 19 units currently shown with no collectors, 8 are on standby duty and will not normally be on range and all are relatively small units, from 7 to 23 th^{-1}. The remaining eleven boilers are scheduled to be fitted with scrubbers by the 1983 season (3 at DL, 2 at ME) or with dry collectors by 1984 (2 at NB). GD and EN have still to finalize their planning.

Another factor which contributes to the improvement which has taken place is that in 1972 the 34 dry collectors then installed were probably operating at a fairly low efficiency whereas currently in 1981 the 35 wet collectors are all capable of bettering the 400 or 450 mg m^{-3} emission standard and the 27 dry collectors should all in practical terms be within a 750 mg m^{-3} limit.

Implementation of Plan of Action

Table 3 shows the tempo at which the plan of action has been carried out despite considerable financial problems from 1976 onwards. In 1976 over one million Rand were spent on the installation of smut collection equipment. Despite the previously mentioned periods of moratoria of the plan of action not a single year has gone by since the commencement of the programme in 1972 that the industry has not achieved some further progress in reducing the emission created by its bagasse fired boilers.

TABLE 3

Year	Factory				Total
1972	SZ	TS			2
1973	UK	GH	TS(2)	UF	5
1974	GH	TS(2)			3
1975	AK	PG	UC	ML	4
1976	ME	DL	SZ	PG	
	UK(2)	GH(3)	IL	NB	
	UF				12
1977	DL	SZ	PG	NB	
	TS				5
1978	ME	EM	TS	SZ(2)	
	EN	GD			6
1979	SZ	PG	TS		3
1980	ME	UK			2
1981	IL	PG			2
					44

Smut Collector Plant

Initially the majority of smut collectors were multi-cyclone dry collectors together with a few spray chambers either as back-up or as primary devices. As a result of the development work carried out in the last few years, wet collectors or scrubbers now far outnumber the multi-cyclone units. Both types will be discussed in more detail.

Multi-Cyclone Dry Collectors

In terms of the agreement with the Department of Health these units should be able to meet the 450 mg m^{-3} emission limit. It is well known that multi-cyclone units, if not maintained in a good state of repair, lose efficiency very sharply. For example, an air leak could cause a drop in efficiency from 92% to 71%, which would increase emission level by a factor of five.

This is particularly applicable to the older units, some of which are by now reaching the end of their useful working life of around 15 years.

Of these older multi-cyclone units ML will replace 3 with a single scrubber unit, AK will replace 4 with two scrubbers, GH will renew 2 with new multi-cyclones and at other factories units will fall away with the installation of new, bigger boilers.

Scrubbers

Of the scrubbers installed, twenty-two have been of the irrigated perforated sieve plate type and these have operated well without major difficulties. Tests indicate levels of around 100 mg m^{-3} under the standard conditions given in Appendix 1.

In 1973 Professor Judd of Natal University conducted tests on a perforated plate type scrubber at GH and obtained emission results of less than 100 mg m^{-3}.

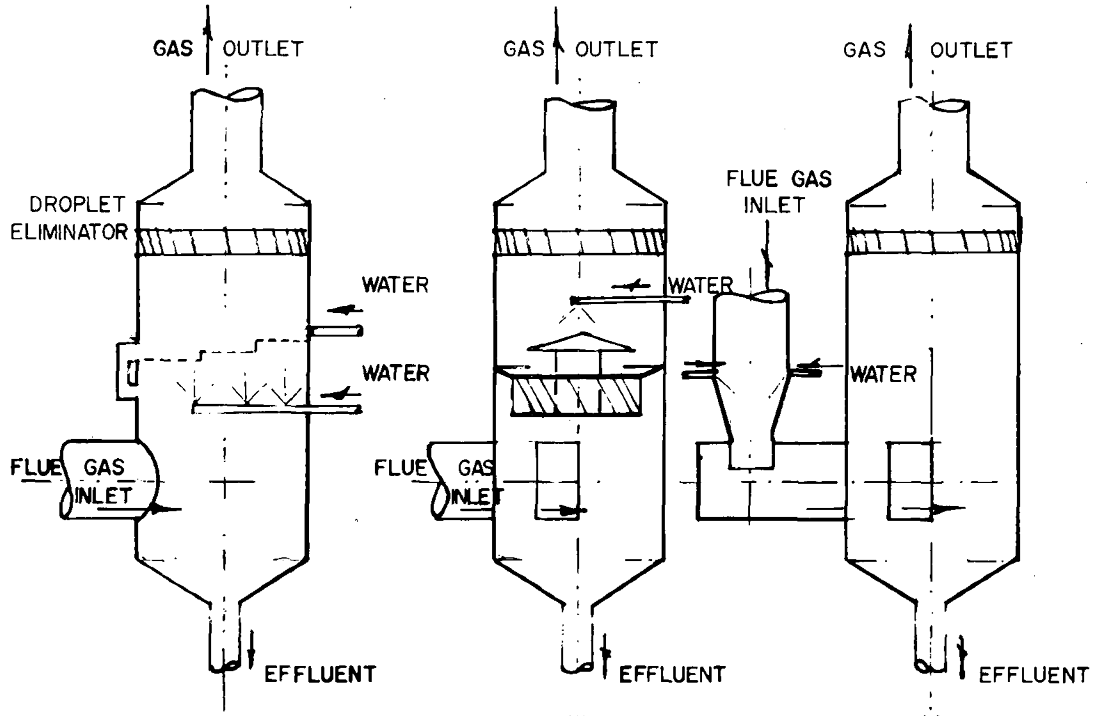

FIGURE 1 Typical scrubbers.

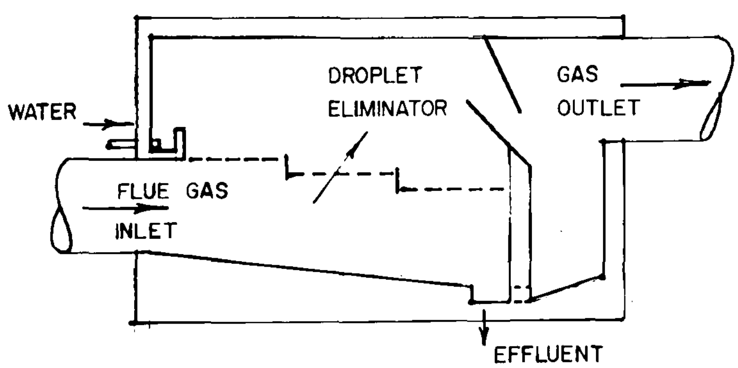

FIGURE 2 Perforated plate scrubber in brick housing.

In 1979 MJ Winkler Electronics ran tests on the UC flooded throat venturi scrubber and emission levels of 86, 80, 107 and 98 mg m^{-3} were reported.

Design parameters developed by Ravno and Judd[2] have proven to be very stable over a wide range of flue gas and inlet water conditions. Successful operation has been achieved with perforated plate of 23% open area (12 mm diameter holes on 25 mm pitch). Typically with the above hole configuration a hot gas (250°C) superficial velocity (measured across the full plate area not only the perforated area) of 3 m s^{-1} would result in a pressure drop of 50 mm WG. This low value helps to keep down the required induced draught fan power.

In order to reduce the overall diameter of the perforated plate type scrubbers a test was carried out at DL using a 28% open area plate but conditions on the plate were unstable and it was not possible to maintain a clear stack. The plate was replaced with the conventional 23% open area material and the problem disappeared.

The perforated plates have been arranged in two main configurations :

1. In a cylindrical vessel with a droplet eliminator above it. (Figure 1a).
2. In a rectangular duct or housing where the plates have been in a "stepped" arrangement with the gas flowing upward through the plates to a system of baffles mounted downstream, to eliminate carryover. (Figure 2).

The other two wet designs successfully used have been the "flooded throat" venturi designs by Howden and the fixed centrifugal impeller Ducon design by Brandt. (Figures 1b and 1c). The latter type has been used in Australia at Victoria mill with six chambers in parallel on a 277 th^{-1} boiler, probably the largest bagasse fired unit in the world.

This season two variable wetted throat box section venturis are being installed at IL and PG.

Smuts Separation and Dewatering

The removal of the smuts from both the circulating and sealing water is another problem area with high maintenance costs.

The SMRI has examined four different systems currently in use and further work will be done this season. Most factories use the settling tank with scraper approach and these work well enough but deliver a very wet product (21% dry suspended solids) which is not easy to handle or transport. (Figure 3).

The tank examined at ME was operating with hydraulic loads of between 96 and 121 litre min^{-1} m^{-2} during the tests. The solids loading of the circulating water was high and varied from 0,06 to 0,032% but the scrubber still produces a clean stack (Moult[3]).

GH uses a landfill system of roughly 28 000 m^2 which is an economical solution but a suitable site is not always available. The effluent is particularly clear with 0,01% solids content. Costs depend upon distance and elevation of the site, together with initial earthmoving costs (Moult *et al*[4]).

SZ has installed a system consisting of a subsider and filter and this system also produces a clear effluent, 0,02% solids content and dry cake of about 50% moisture. The capital costs of such a plant is high but a reduction of 50% in the mass of the material to be transported, compared with the conventional scraper system is reported to justify this expense (Kedian[5]). (Figure 4).

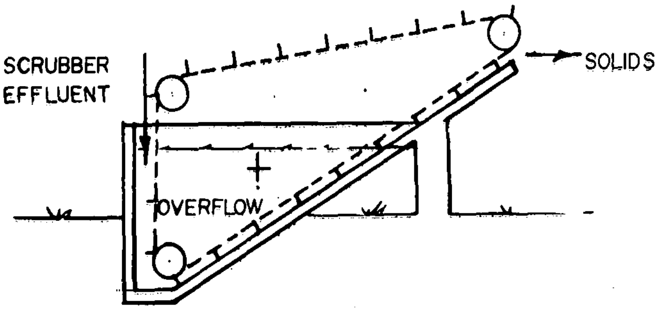

FIGURE 3 Settling tank and scraper.

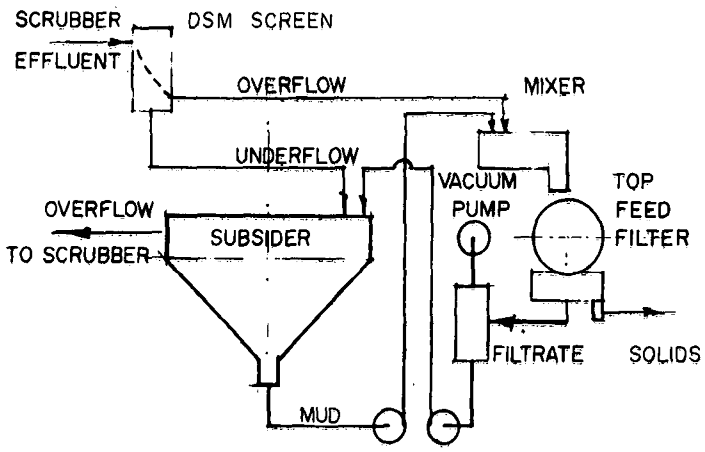

FIGURE 4 Subsider and filter.

Most smut mud is mixed with filter cake and returned to the fields by road transport.

Problem Areas

Incombustible Material

As the 1980 crop was exceptionally poor, the 1979 season data will be examined to estimate the quantity of non-combustible material fed to the boilers during that season. Based on a crop of 18,4 million tons of cane some 5,9 million tons of wet bagasse were produced and, estimating that 500 000 tons of wet fibre (detailed figures are not available) were used in by-products, 5,4 million tons of bagasse were burnt as fuel in the boilers.

With an ash % bagasse of 2,26% some 122 000 tons of incombustible material was eventually removed from the furnaces either as grate ash or as fly-ash. About half this material is natural silica in the plant, but the remaining half is in the form of silt or grit still attached to the bagasse after crushing.

Coal is used as standby fuel by the industry but as it is only used for short periods at a time no provisions were laid down by the Department of Health for SO_2 emission. In Australia, despite similar conditions of short stopgap use of oil as emergency fuel (with maximum sulphur content of 3%) the authorities forced the factories to erect 65 m high stacks to conform with ground level SO_2 emission requirements[6].

Particle Size Distribution

In connection with the efficiency of the multi-cyclone collectors, density and particle size play an especially important role. The question of particle size grading has been the cause for much discussion for some time as there was a marked discrepancy between the Australian and South African size grading curves, as determined in 1972.

In order to clarify this question the Council for Scientific and Industrial Research was requested to perform flue gas burden measurements on a new multi-cyclone collector installation and at the same time analyse the collected material. Accordingly, a new 45 th^{-1} spreader stoker boiler with multi-cyclone smut separator was selected at NB and the tests were carried out under steady load conditions.

The results of the test were published (de Reus[7]) and mission levels of 738 and 719 mg m^{-3} at 0°C and 12% CO_2 dry gas were obtained. The particle size distribution was different from the original curve obtained during the 1972 tests and this new curve more closely followed the Australian pattern in that there was a higher fines fraction than had been previously shown. (Figure 5).

The higher percentage fines would indicate that the achievement of 400 mg m^{-3} by a multi-cyclone dry collector is probably impractical.

In an attempt to confirm this the Air Pollution Study Group approached the Gas Cleaning Equipment Suppliers Association of S.A. with the query as to what emission could be expected from a dry multi-cyclone collector assuming flue gas with an inlet burden of 5 000 mg m^{-3} using the particle size distribution derived from the NB test.

Only one reply was received, from Messrs. Protectaire and the relevant details are quoted :

"Taking curve (2) of CSIR at density 2,42 g ml^{-1}, and an inlet burden of 5 000 mg m^{-3}, we could expect the following emission figures :

(a) with the two-stage collector, at relatively low inlet velocity and low (50 mm WG) pressure drop, which I favour for friable dusts and for facilitation of refiring combustibles, would be approximately 630 mg m^{-3}
(b) with the highest efficiency mechanical collector of vertical-cell cyclonic type, with hopper purge to prevent interaction of cells, pressure drops 100 mm WG, theoretical 300 mg m^{-3}
(c) simple scrubber, self-induced spray de-duster type, at pressure drop 125 mm WG, emision 80 — 100 mg m^{-3}".

In practical terms, it would appear that the mutli-cyclone installations, although unlikely to comply exactly with the 400 mg m^{-3} specification, will still be within reasonable reach of this target if an emission level of say 700 mg m^{-3} is achieved. A target collection efficiency of 92% would thus be reduced to 86% which would still produce a relatively clean stack.

As a guide to the acceptability of the higher emission, the Australian maximum emission limits are 800 mg m^{-3} for existing boilers and 690 mg m^{-3} for new installations.

Furthermore the number of multi-cyclone installations is steadily dwindling and, as a general rule, only when water is at a premium where factories have restricted water sources, would this type of collector be required.

Materials of Construction

Materials used in the construction of the separating vessels have been mainly ASA grade 430 stainless steel, Incoloy 825 for highly corrosive (e.g. coal firing) areas, Gunite, fibre glass, acid resistant brick and fire-brick shell liners have worked successfully.

Bagasse firing alone does not produce serious corrosion problems but a build-up of chlorides takes place in the circulating water.

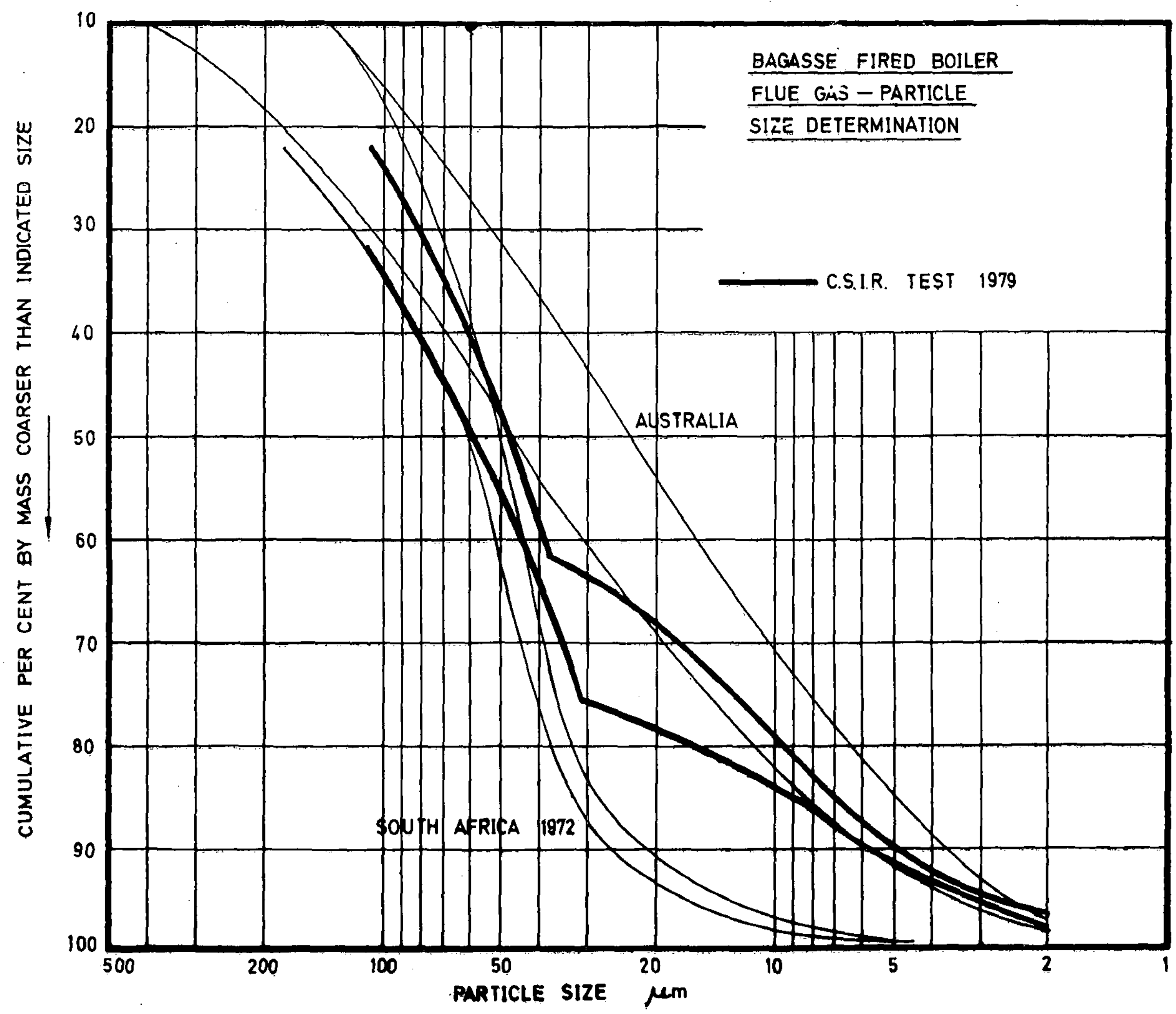

FIGURE 5 CSIR Flue Gas particle size determination.

Coal firing presents serious corrosion problems, however, and TS suffered the brunt of this learning process in 1973 when the ASA grade 430 stainless steel used on two scrubbers eroded within weeks. The scrubbers were rehabilitated by Gunite lining one shell and rebuilding the other with Incoloy 825, a highly expensive alloy contain 45% nickel[8].

Gunite lined shells have stood up well to occasional coal firing and appear to be a very cost effective solution. Incoloy 825 has been used for internal fittings on this type of scrubber.

The fibre glass scrubber body at ML has suffered some structural failures but after repair is still doing effective duty.

It is interesting to note that despite prognostications of gloom expressed by a consultant metallurgist in 1973, the ASA grade 430 scrubbers installed at that time are still working. The first perforated plate unit at TS has now completed 9 seasons and is still in good condition.

High density polypropylene piping, rubber lined or Nihard pumps have proved to be successful in handling the circulating water which is mildly corrosive but very abrasive.

Induced Draught Fans

Some difference of opinion has arisen about the use of induced draught fans positioned before or after the scrubber. The siting of the fan has led to the terms "hot" or "wet" fans being used in debates about the advantages and disadvantages of either practise. Currently more "wet" fans are being installed. The highly abrasive nature of the flue gases results in rapid wear of impeller blading but with the scrubber upstream a danger exists of a build-up of wet smuts on the curved blading used in some fans. However, an effective droplet eliminator should resolve the latter problem which caused severe "out of balance" conditions.

In a "wet" fan the gas volume is nearly halved after cooling down to 80°C so a smaller fan can be used. The density of the gas increases, however, and must be considered when calculating fan power.

Installed Plant Cost (1981)

Any review of progress in the air pollution control field should include the cost of the effort and to provide an order of magnitude some current cost estimates (March 1981) are given below :

For a boiler size of 150 th^{-1} (R 4m) the cost of perforated plate scrubber and ducting is about R400 000 and the ID fan and turbine drive about R100 000. For a 95 th^{-1} boiler (R 2m) a venturi type scrubber together with separator vessels and ducting will cost R240 000, the ID fan and turbine drive a further R85 000.

The smuts separation plant (clarifier/filter) being installed at IL this year to handle the ash and fly ash from the installed boiler plant of 145 th^{-1} will cost R280 000. The more common settling tank and scraper chain installation as installed at ME to handle the installed boiler plant of

110 th^{-1} would involve a cost of the order of R115 000. (The former plant produces cake of less than 50% moisture thereby reducing disposal costs).

These latter prices will vary according to piping length required, conveyor lengths for mud disposal etc., but they indicate an additional capital cost which was greatly underestimated in the early days of the campaign.

Conclusion

During the period under review, despite technical and financial crises, the industry has moved steadily ahead in its efforts to control air pollution. Even during periods of moratoria, new units being installed have usually resulted in several old, smaller, emission-prone units being rendered redundant, thereby continuing the on-going process of reducing air pollution.

The co-operation between the Department of Health through the Chief Air Pollution Control Officer and the Sugar Industry has been a workmanlike, practical relationship. Local authorities have had emission problems and through the Natal Area Senior Air Pollution Control Officer, the factory in question has made the effort required to improve conditions and when the Industry has had problems the Chief Air Pollution Control Officer has conceded time in the action plan to solve these problems. As a result of this co-operative basis and a heavy financial and technical commitment by the SA Sugar Millers, only a fraction of the task which faced the industry in 1970 remains to be completed.

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Appendix 1

Terms and specification for stack emission in South African sugar mills are as follows:

(*a*) All new boiler installations to have a maximum emission level of 400 mg m^{-3} — subject to review in five years time.

(*b*) All existing dust collection installations to conform to 1 000 mg m^{-3} within four years.

(*c*) All present boiler installations to conform to 450 mg m^{-3} within eight years, concentrations to be determined at standard flue gas conditions, namely, dry, 12% CO^2, 0°C and local barometric pressure.

(*d*) All air cleaning equipment installed under the agreement to be reconsidered fifteen years after installation, to assess if still "best practical means" at that stage.

(*e*) A factory unable to carry out requirements for technical reasons may apply to the Chief Air Pollution Control Officer for exemption through the Air Pollution Study Group, which will make recommendations.

(*f*) If exemption is sought for financial reasons, a factory is to apply direct to the Chief Air Pollution Control Officer.

(*g*) Each factory will, through the Air Pollution Study Group, present to the Chief Air Pollution Control Officer a plan of action for implementation of the agreement commencing the 1973 off-season.

(*h*) All proposed new boiler installations are to be submitted for approval to the Chief Air Pollution Control Officer through the Air Pollution Study Group. This group will continue to function as a Committee of the South African Sugar Millers Association Ltd.