AIR POLLUTION CONTROL FOR BAGASSE FIRED BOILERS

A PROGRESS REVIEW BY S.A. SUGAR MILLERS SMOKE STUDY GROUP*

Abstract

In order to implement the Atmospheric Pollution Act 1965 the South African Sugar Millers Association formed a Smoke Study Group consisting of representatives from the Sugar Milling Research Institute and factory engineers. Emission levels, dust gradings and fall-out rates (within 500 m radius from the mill stacks) have been measured and a survey of existing boiler and smut collection plant is included in this progress report.

1. INTRODUCTION

No. 45, 1965.

ACT

To provide for the prevention of the pollution of the atmosphere, for the establishment of a National Air Pollution Advisory Committee, and for matters incidental thereto.

(Afrikaans text signed by the State President.)
(Assented to 17th April, 1965.)

BE IT ENACTED by the State President, the Senate and the House of Assembly of the Republic fo South Africa, as follows:—
1. (1) In this Act, unless the context otherwise indicates—
(i) "best practicable means", when used with reference to the prevention of the escape of noxious or offensive gases or the dispersal or suspension of dust in the atmosphere or the emission of fumes by vehicles, includes the provision and maintenance of the necessary appliances to that end, the effective care and operation of such appliances and the adoption of any other methods which, having regard to local conditions and circumstances, the prevailing extent of technical knowledge and the cost likely to be invoved, may be reasonably practicable and necessary for the protection of any section of the public against the emission of poisonous or noxious gases, dust or any such fumes; (iv)

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Early in 1970 a meeting of representatives of the Department of Health (Air Pollution Control) and the S.A. Sugar Millers Association took place to discuss aspects of stack emission from sugar factories and implementation of the Atmospheric Pollution Prevention Act, 1965.[1] The outcome of the meeting was the formation of a Smoke Study Group consisting of the representatives of the Sugar Milling Research Institute and of engineers representing a wide cross-section of the industry. The terms of reference of this committee were:

(i) Short term action to be taken by more serious offenders, i.e. factories close to towns from which complaints had been received.

(ii) Long term action with regard to new installations, installation of suitable collectors, bagasse storage, etc.

(iii) Code of practice for bagasse-fired boilers, etc.

In October, 1970, in terms of the 1965 legislation, "Bagasse Incineration Works - processes involving the combustion of bagasse" were included in the second schedule of the Act.[5] The practical implication of this scheduling places our factories directly under the control of the Chief Air Pollution Control Officer in Pretoria and not under local authorities. Any complaints concerning atmospheric pollution by the sugar industry should therefore be forwarded direct to Pretoria. In order that a measure of evidence may be available to the Chief Officer, the Committee has requested mills to measure deposition (or fall-out) rates around their mills. With suitable dust collection equipment installed at the factories deposition rates before and after this installation will afford evidence that effective steps have been taken to reduce emission levels.

Of great assistance to us in our work on pollution control has been a comprehensive report by the Australian Sugar Research Institute[3] in which tests on pilot plants and a full scale smut collector installation have been fully documented.

The committee has encouraged the installation of pilot plants and presently two are in operation, one at Mount Edgecombe and one at Jaagbaan. It is felt that if there is more than one proven method of collection available to the industry, then the individual requirements of each mill can be more closely met.

TABLE I

Mill	Installed Capacity at MCR kg/h x 1 000	No. of Units	No. of Stacks	Furnace Type			Collectors			Boilers not covered by collectors	Smut handling System
				Dutch oven	Spreader Stoker	Thomson Eisner	No.	Type	Seal wet/dry		
ML	3 x 45	3	1 x MS	—	3	—	3	Davidson Multicell	W	Nil	Wet- settling tank and rotating screen
PG	2 x 23 4 x 11	6	2 x MS 1 x BR	—	6	—		Nil		6	Nil
UF	1 x 57 2 x 25 5 x 14 2 x 18	10 (5 on stand by)	1 x MS 5 x MSg	4	6	—	5 1	Howdens Multi-Vortex Howdens up-flow collector*	W	Nil	Wet — DSM Screens
EM	1 x 45 1 x 32 1 x 23 4 x 14	7	1 x RC 1 x MSg	5	2	—	1 1	Howdens Multi-Vortex Owner-built spray chamber*	W	Nil	Wet — DSM Screens
FX	2 x 45 1 x 16 1 x 23	4	1 x RC	2	2	—	1 1 1	Owner-built spray chamber Howdens Multi-Vortex B&W Cyclone Separator	W	Nil	Wet — settling tank
EN	3 x 7 1 x 23	4	2 x MS	3	1			Nil	—	4	Nil
AK	4 x 36	4	2 x RC	—	4	—	4	Howdens Multi-Vortex	W	Nil	Wet — DSM Screens Settling tank
DK	1 x 21 1 x 11 3 x 7 1 x 5	6	2 x MS 1 x BR	5	—	1 (mod)		Nil	—	6	Nil
GD	1 x 14 2 x 7	3	2 x MS	2	1	—		Nil	—	3	Nil
DL	1 x 45 2 x 32 2 x 23	5	1 x RC 3 x MS	3	2	—	1	Howdens Multi-Vortex	D	4	Grit refiring system
GH	2 x 45 2 x 34 2 x 18	6	4 x MS	3	3	—	2 1	Howdens Multi-Cyclone B&W Cyclone Separator	W	3	Wet — DSM Screens
MV	1 x 23 1 x 14 1 x 7 2 x 4 2 x 2	7	2 x BR 1 x MS	5	2	—		Nil	—	7	Nil
JB	3 x 45	3	1 x RC	—	—	3		Nil	—	3	Wet Ash system
UC	1 x 23 1 x 14	2	3 x MS	1	1	—	1	Davison Multi-Cell	W	1	Wet — DSM Screen
TS	1 x 36 2 x 32 1 x 23 1 x 27 3 x 9 5 x 7	13	2 x BR 3 x MS (1g)	10	2	1	2 2 1	Davidson-Sirocco Cellular* Owner-built spray Chambers* Peabody wet impingement collector	W	2	Wet — Vibrating Screens

TABLE 1 (contd)

Mill	Installed Capacity at MCR kg/h x 1 000	No. of Units	No. of Stacks	Furnace Type			Collectors		Boilers not covered by collectors	Smut handling System
				Dutch oven	Spreader Stoker	Thomson Eisner	No. Type	Seal wet/dry		
ME	1 x 27 4 x 25	5	3 x MS 1 x BR	4	1	—	— Nil	—	5	Nil
IL	1 x 25 5 x 9 2 x 11	8	2 x BR 2 x MS	7	1	—	1 Howden Multi-Vortex	W	7	Wet
RN	1 x 23 3 x 11	4	1 x MS 1 x BR	3	1	—	1 Owner-built spray Chamber* 1 Howdens up-flow*	W	Nil	Wet — Rotating Screen and sand filter
SZ	2 x 54 6 x 16	8	3 x BR	—	8	—	1 Howdens Centricell 2 Howdens Multi-Vortex	D	3	Wet — settling tank
UK	1 x 41 1 x 18 2 x 16 1 x 14	5	1 x RC 1 x MS	4	1		Nil		5	Nil
TOTALS		113		61	47	5	34		59	

* These eight units are not expected to reach 1 000 mg/m³ and will require replacing with new installations.

MS Mild steel: BR Brick: RC Reinforced concrete: g gunite.

2. SURVEY OF INSTALLED BOILER EQUIPMENT

A survey of existing boiler and smut collection plant has been carried out and has been tabulated. It can be seen that there are 113 boilers installed in the industry together with 34 collector units, many of these handling more than one boiler. Fifty nine boiler do not have collectors.

Considering the fact that in the past there has been no effective legislation compelling the sugar industry to act in reducing air pollution, the installation of 32 dust collector plants covering 50 boilers is an indication of the awareness of the industry to its obligations to the general public.

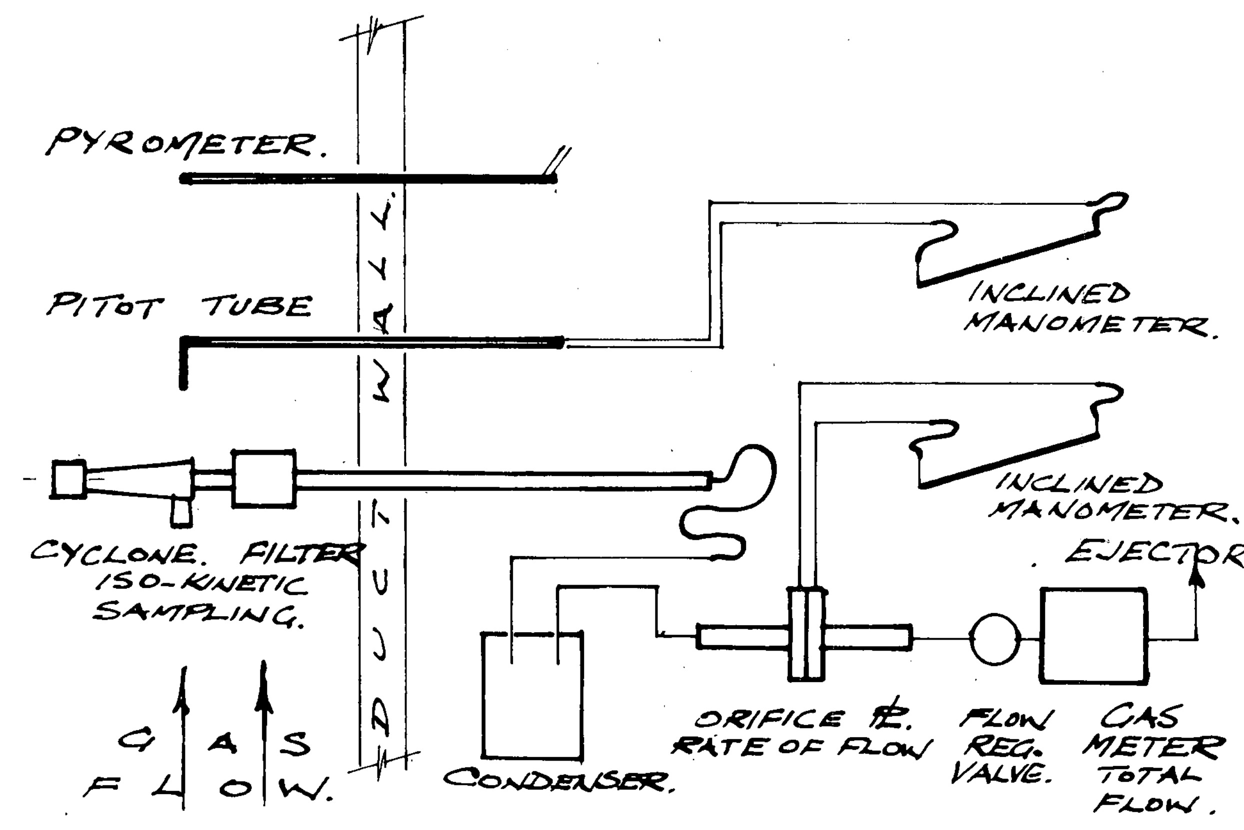
Most of the existing collector installations are of the multi-cyclone type, i.e. with cells of about 300 mm diameter, with or withour secondary separation. In perfect working order, i.e. with discharge seals intact and no internal leaks, efficiencies of 70% (higher with secondary separation) can be expected. With input burdens of about 3 000 mg/m³ an emission of slightly under 1 000 mg/m³ can be expected.

The basic problem of fly ash collection is the low weight to high surface area ratio of burnt bagasse particles. The conventional large diameter multi-cyclone collectors installed in the industry have had moderate success but a new technique is required to ensure close to 100% collection efficiency. We feel that we have the answer with wet type, and improved type dry, collectors and papers will be presented by Study Group members on the results of two full scale plants installed this season at Tongaat and Sezela.

With the successful operation of the wet type collector at Tongaat, a water rate of 11 200 kg/h has been needed at a boiler rating of 36 000 kg/h. This water can be obtained from evaporator condensate and factories are advised to measure the quantity of condensate available for possible use in wet type collectors. I.D. fan characteristics should be obtained and compared at current performance rates, with existing pressure drops and power demand.

Collection and disposal of sand and flyash has been handled by a variety of means, and possibly the most successful wet system uses a settling tank with a slow scraper and a recycle pump to return solids-free water to the collector. DSM screens, a rotary screen, and vibrating screens have all been used but involve extra maintenance.

From the data acquired, a cost estimate has been made for the sugar industry. Allowing for some combination of boiler units to a common collector, some existing units failing to reach specified limits, etc., it appears that 44 new collectors for boilers or groups of boilers between 23 000 to 45 000 kg/h will be required. The estimated cost of this equipment is of the order of R1,5 million. Very roughly, R170 000 will be required for repairs and modification to the existing 24 units which are expected to be capable of reaching a level of 1 000 mg/m³.



SCHEMATIC ARRGT. SAMPLING EQUIPMENT.

3. MEASUREMENTS

3.1 Emission levels

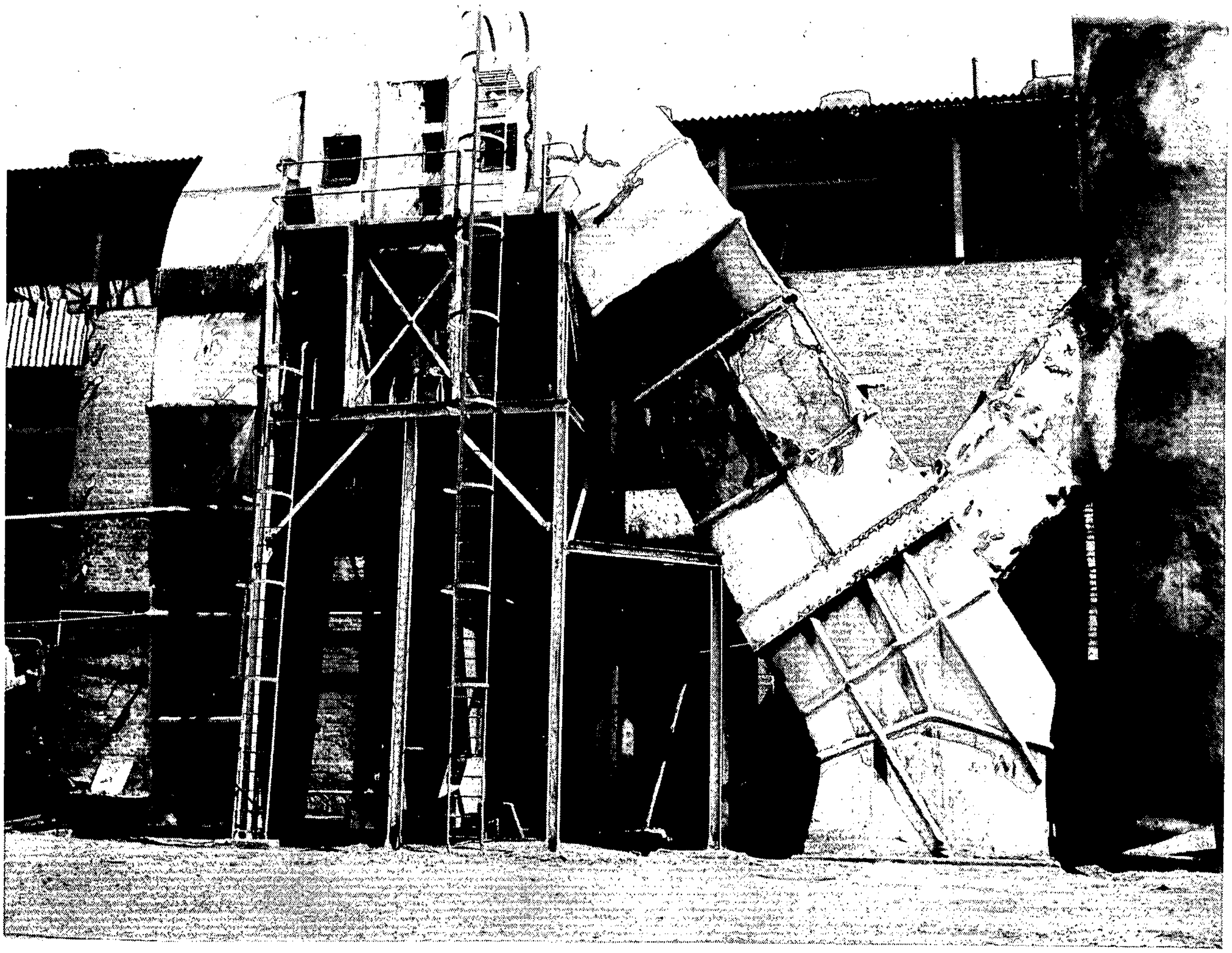
The measurement of emission levels is carried out by a duct or stack probing technique. A reasonably straight length of ducting is required to establish even flow velocities or, failing this, the stack itself must be probed well above the fan inlet duct. Detailed specifications are available in BS 3405:1961[2]. Once a suitable position is located doors must be fitted to enable sampling probes to be passed across the flue or stack. A sketch of the basic apparatus required is shown in Fig. 1. Iso-kinetic sampling is required to achieve the necessary accuracy and a pitot tube probe is first carried out to establish the gas velocity across the duct. Beforehand, the duct is divided into a number of equal areas, and the velocity at the centre of each area is established. The probe (cyclone and filter) is then inserted into the duct and held in the centre of each area for, say, 10 minutes and in this way a complete probe can last for four hours in a large duct. During this period it is desirable that the boiler load should remain sensibly constant. Temperatures, CO_2 level and gas flows are noted. The dry smuts are quickly weighed and the results calculated including a correction for conditions of dry gas and 12% CO_2. The committee commissioned Messrs James Howden to measure emission levels at various mills during November/December, 1971. The results are shown in Table 2 and some comment is appropriate on them. Three different types of furnaces were selected but several different effects cancel out an accurate comparison of furnace types.

JB: No CO_2 reading was taken so a correction could not be applied. However at a boiler load of 65% MCR the emission level is high.

DL : At roughly half load this boiler had the lowest level of the three completed tests. As load increases it is obvious that this emission will increase still further.

UF : Test 1 and 2. Upon receipt of these values an inspection of the collector was carried out and it was discovered that the cover plates on the water seals had been wedged open by an operator to facilitate an occasional clearing of the smuts discharge opening.

UF : Test 3, 4 and 5. The smaller boiler No. 4 is connected in parallel with two other boilers onto a common collector and I.D. fan. It is obvious from the CO_2 readings that leakage from the various duct isolating dampers is taking place. The cyclones in the collector were also found to be eroded causing short-circuiting of gases, thereby re-entraining the smuts.



MULTI-VORTEX DUST COLLECTOR
This outdoor unit cleans flue gases from 3 boilers (total output 45 000 kg/h) via an underground duct, through a common ID fan to a gunited stack. This installation has been in operation for over 15 years.

TABLE II

SUMMARY OF STACK EMISSION RATES

NOVEMBER — DECEMBER 1971

FACTORY	JAAGBAAN		DARNALL		UMFOLOZI		UMFOLOZI			EMPANGENI	
DATE	18.11	19.11	1.12	7.12	14.12	15.12	16.12	17.12	18.12	21.12	22.12
Test No.	1	2	1	2	1	2	3	4	5	1	2
Boiler No.	1	1	4	4	10	10	4	4	4	1	1
Boiler MCR (kg/h x 1 000)	45	45	32	32	57	57	20	20	20	45	45
Load during test (kg/h x 1 000)	25	29	18	18	46	49	13	8	12	45	42
Furnace Type	Thomson-Eisner		Dutch-oven		Spreader-Stoker		Spreader-Stoker			Spreader-Stoker	
Dust collector type	Nil	Nil	Nil	Nil	Multi-Vortex		Multi-Vortex			Multi-Vortex	
Sample before collector	—	—	—	—	—	—	—	x	x	—	—
Sample after collector	—	—	—	—	x	x	x	—	—	x	x
% CO_2	—	—	8,5	8,5	9,4	10,0	4,25	5,87	5,12	9,5	8,4
Flue gas temp °F	367	371	429	473	477	474	342	323	313	359	375
DUST CONCENTRATION AT NTP											
mg/m³ wet	2 745	4 173	1 063	1 266	2 323	3 098	608	1 911	1 792	5 765	4 761
mg/m³ dry at 12% CO_2	—	—	1 558	1 915	3 038	3 877	*	*	*	7 435	7 294

* CO_2 values too low for approx. linear correction.

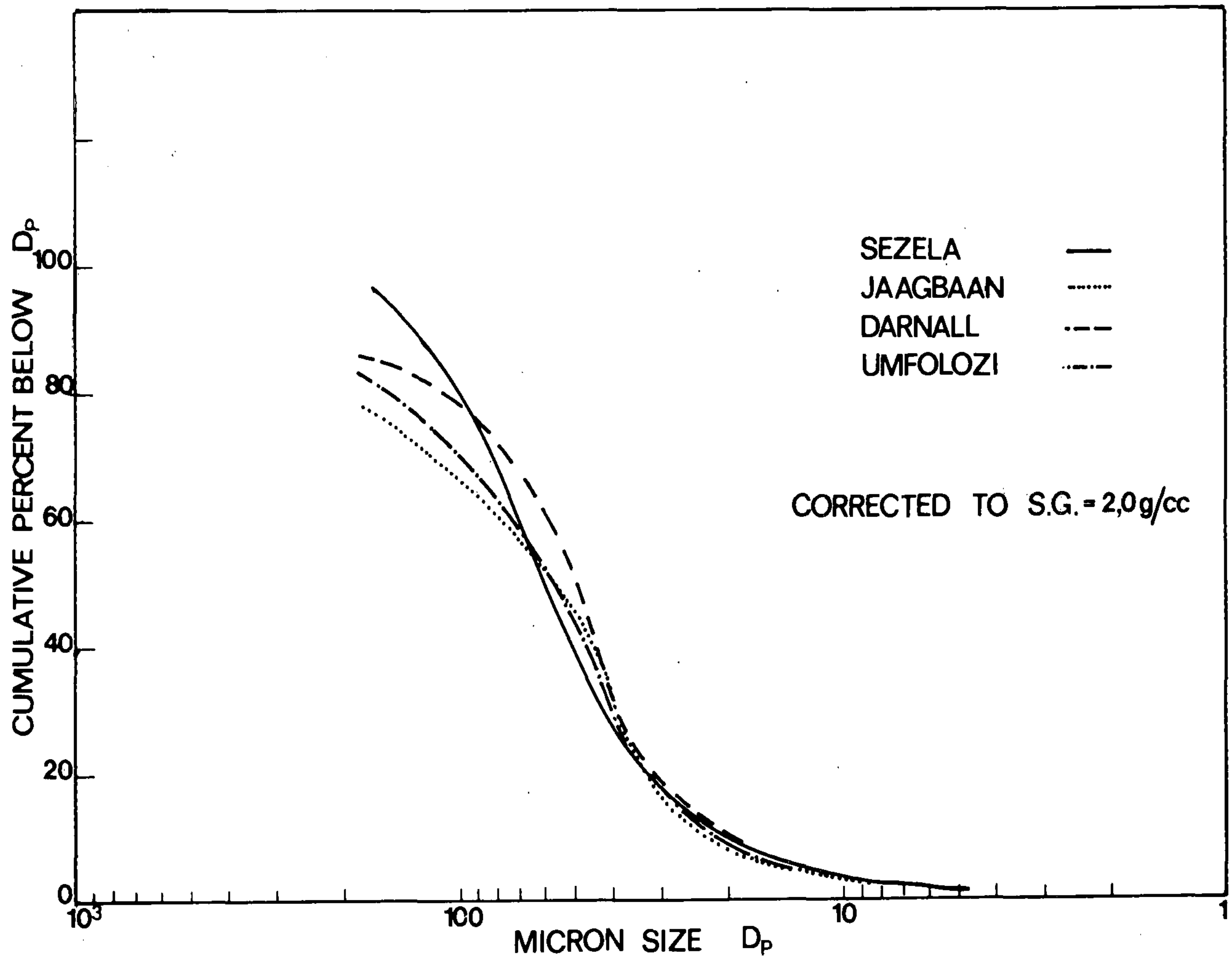


Fig 2.

EM : Empangeni has been embarrassed by a surplus of bagasse and together with 100/92% MCR loading this boiler has produced a very high stack emission. The collector cyclones were subsequently found to be eroded.

It is obvious that any defect in the cyclones, breaking down the pressure drop across them, results in an immediate loss of performance. Grit removal seals form an important part in maintaining this pressure drop. Despite the high (corrected) emission levels, none of these boilers tested had obvious "black stacks" due to the dilution of the solids by large quantities of excess air. Particle size plays an important part in smoke visibility, and big particles which would cause a high emission level may not be as visible as much smaller particles. For this reason optical tests on smoke emission are, at best, rough guides to emission levels.

Low CO_2 and high backend temperatures indicate that very little attention is being paid to combustion efficiency.

3.2 Dust gradings:

Size gradings were conducted on the material obtained during the above tests and are presented in Fig. 2. It should be noted that these gradings have been corrected to a specific gravity of 2.

Two samples were obtained from Sezela and Illovo mills and subjected to a dry sieve analysis at the Sugar Milling Research Institute. These results are plotted on probality co ordinates in Fig. 3, and are uncorrected for density differences between particles. The importance of this type of plot is that a normal or Gaussian size distribution will appear as a straight line defined completely by two parameters: the average particle diameter and the variance of the distribution.

The curvature obtained is due to the higher specific gravity of the smaller particles, a feature which is evident from a consideration of Table 3, where the percentage sulphated ash may be taken as representative of the percentage of sand present in each size fraction. This rather distinct distribution of "sand" results in two normal distributions - one for pure bagasse ash (ash < +20%) and one for sand (ash > +80%).

The important practical aspect of these results is that the design of any bagasse-smut handling and disposal system must take into account the amount of sand present, otherwise serious blockage problems could arise. The increase in the amount of mechanical handling of cane and the possible introduction of mechanical harvesting will increase the sand burden on any disposal system.

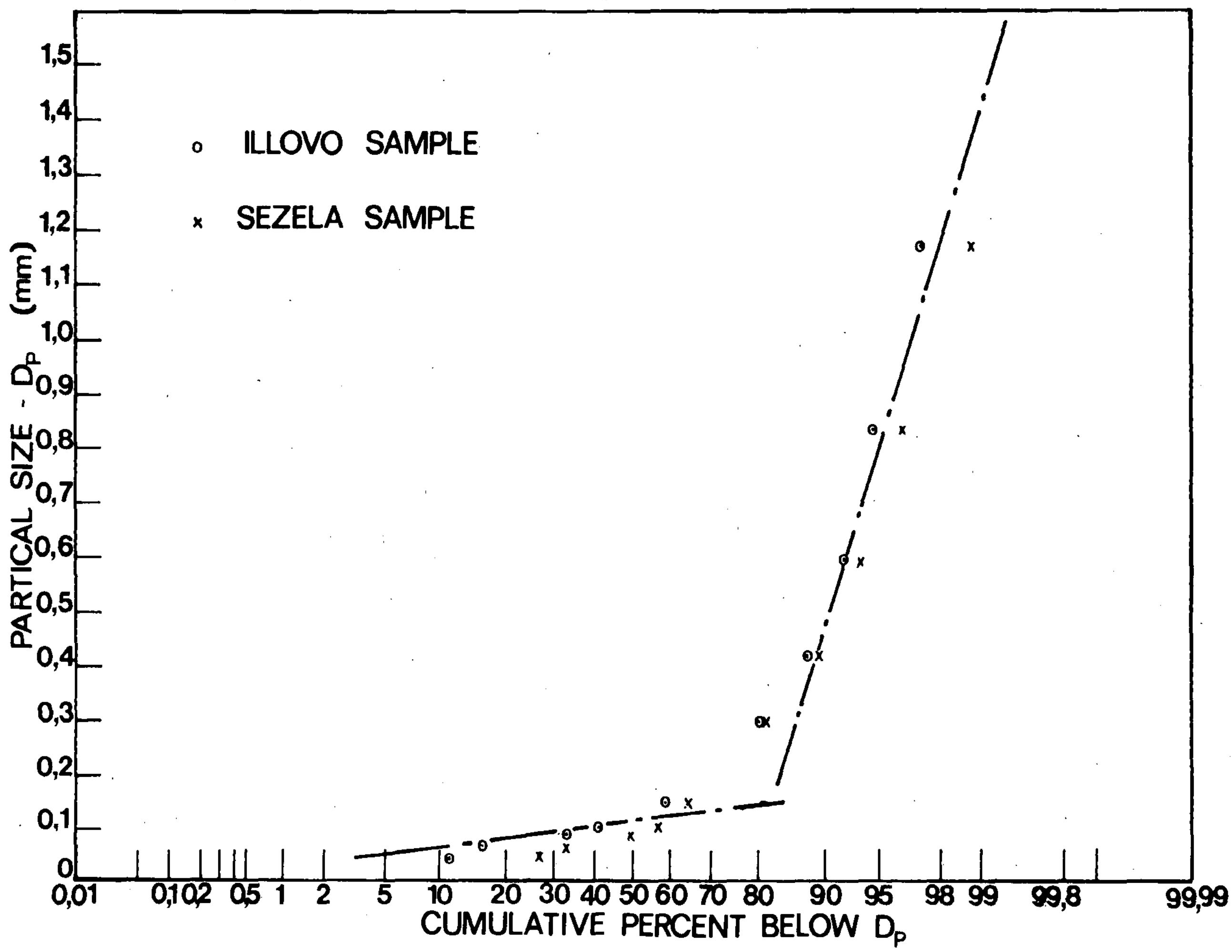


Fig 3.

TABLE III

Tyler Mesh No.	Ave. Particle Size (mm)	ILLOVO Weight Fraction	ILLOVO % Sulphated Ash	SEZELA Weight Fraction	SEZELA % Sulphated Ash
10	1,981	0,003	28,9	0,003	24,5
14	1,409	0,024	52,5	0,008	20,1
20	1,000	0,028	21,0	0,024	28,3
28	0,711	0,024	14,5	0,028	17,8
35	0,503	0,043	14,4	0,042	18,1
48	0,356	0,077	16,3	0,082	26,1
100	0,221	0,217	26,9	0,166	46,5
150	0,125	0,174	66,5	0,070	70,3
170	0,096	0,080	76,1	0,088	82,8
250	0,074	0,171	87,8	0,165	91,6
270	0,057	0,049	89,6	0,058	94,9
> 270	0,026	0,110	91,3	0,265	88,4

3.3 Deposition rates:

A programme of deposition rate measurements was initiated by the Committee mid-way through the 1970/71 crushing season.

The primary objective of this programme is to develop a continuous yet simple and cheap means of recording the magnitude of the emission of particulate matter at individual mills. Further, it is expected that once a mill starts to implement its proposed "clean-up" policy, there will be a steady reduction in the fall-out readings, eventally reaching the levels recorded in areas unaffected by mill emissions or the levels recorded during off-crops.

At present 11 mills are engaged in recording these measurements while three have erected the deposition gauges but have not submitted any figures to-date (March 1972). Table 4 is a summary of the results obtained during the 1971/72 crushing season. A limited number of mills submitted values for the previous season and during the off-crop but these have not been included.

As the deposition of emitted particulate matter at any mill is effected by the micro-climatic and topographic features of the particular region, it is extremely doubtful whether comparisons between mills are valid. Provided a standard procedure is adopted at a mill i.e. only obvious extraneous matter such as stones and dead birds are discarded, comparisons should be restricted to within each individual mill's results

TABLE IV

Mill	Installed Capacity MCR kg/h x 1 000	Distance from Centre of Stack(s) Deposition Rate (Tons/km²/30 Days)								
		±200m.			±500m.			±900m.		
		AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN
ML	135	NO INFORMATION								
PG	90	51,61	86,64	35,34	28,84	42,65	18,46	25,90	—	—
UF	213	GAUGES ERECTED — NO DATA SUBMITTED								
EM	156	107,80	274,49	22,32	43,79	158,59	5,87	—	—	—
FX	129	20,85	52,68	5,67	2,27	4,87	0,83	5,66	—	—
EN	44	NO INFORMATION								
AK	144	43,35	63,94	13,17	19,66	31,11	10,35	—	—	—
DK	58	NO INFORMATION								
GD	28	NO INFORMATION								
DL	155	61,55	150,59	30,17	34,89	48,24	26,35	48,83	54,92	40,43
GH	194	40,05	60,77	27,31	22,45	28,85	18,23	—	—	—
MV	56	NO INFORMATION								
JB	135	55,53	140,33	13,15	37,00	55,44	17,23	—	—	—
UC	37	60,00	—	—	5,54	6,86	4,14	—	—	—
TS	212	GAUGES ERECTED — NO DATA SUBMITTED								
ME	123	14,50	32,01	6,42	13,55	23,62	4,40	—	—	—
IL	92	GAUGES ERECTED — NO DATA SUBMITTED								
RN	56	21,43	28,73	10,48	7,89	15,57	1,44	1,75	1,92	1,66
SZ	204	NO INFORMATION								
UK	105	12,27	17,78	7,42	15,58	24,78	5,66			

AVE = average of all gauges situated at approximate distance quoted
MAX, MIN = maximum and minimum average values recorded at any gauge at distance quoted.

only. It is of interest to note that using the same recording method at the Sugar Milling Research Institute, and average value of 17,17 ton/km²/30 days was initially measured. This fell on completion of the building extension to 9,77 ton/km²/30 days.

Figures 4 and 5 are graphical representations of the results recorded at two particular mills, Pongola and Darnall. From these figures is seen to what extent the recorded values may be effected by external factors, e.g. marshalling yards, dusty roads, etc. The prevailing wind directions are evident as well.

Figure 6 is a graphic representation of Jaagbaan's results for the 1970/71 crushing season. During the latter period covered by the diagram, the I.D. fan of No. 2 boiler was out of commission. Modifications to the ducting enabled the I.D. fan from No. 1 boiler to extract the flue gas from No. 2 boiler which was kept in operation. While not detracting from the credit due to the engineering staff at Jaagbaan for this temporary repair, it does show to what extent air pollution can be reduced by the implementation of good boiler-house operation.

4. OVERSEAS LEGISLATION

Queensland, Australia[4]

In Australia the urban emission level has been set at 450 mg/m³. Brieflv. the findings of a series of Sugar Research Institute tests are as follows

Dry collectors Efficiency 90-92%
Wet collectors Efficiency ±98%

With boiler emissions ranging from 4 500 mg/m³ to 9 000 mg/m³ a collector system would have a maximum emission of 900 mg/m³ for dry types and 180 mg/m³ for wet types.

Florida, U.S.A.[6]

Discussing bagasse emissions from the Florida mills, Dr. E.R. Hendrickson observed that existing cyclone installations had removal efficiencies of from 21 to 63%. A wet type pilot plant achieved efficiencies of from 94-98% depending on its action as a cyclonic or venturi scrubber. The Florida Department of Pollution Control has a table of emission rate (lbs/hr) against a process weight (lbs/hr) of material burnt. 80 000 lbs/hr of process weight is permitted an emission rate of 31,19lbs/hr. This is roughly equivalent to 110mg/m³. The author's further comment is that it is generally acknowledged that the present code cannot reasonably be applied to bagasse-burning power boilers and will likely be replaced by a more realistic code on particulate emissions.

An ambient air survey was carried out across 3 counties by means of dustfall buckets and highvolume samplers, which latter collected samples during a 24-hour period. Geometric mean values for all settleable particulate matter (+ 10μm) from 34 stations measured were from 1,92 ton/km²/month to a high of 8,5 ton/km²/month. The average was less than 3,85 ton/km²/month. Suspended particulate matter, (0,1 to 100 μm) checked on geometric mean concentration measured 41 μg/m³. The acceptable Florida level is 50μg/m³.

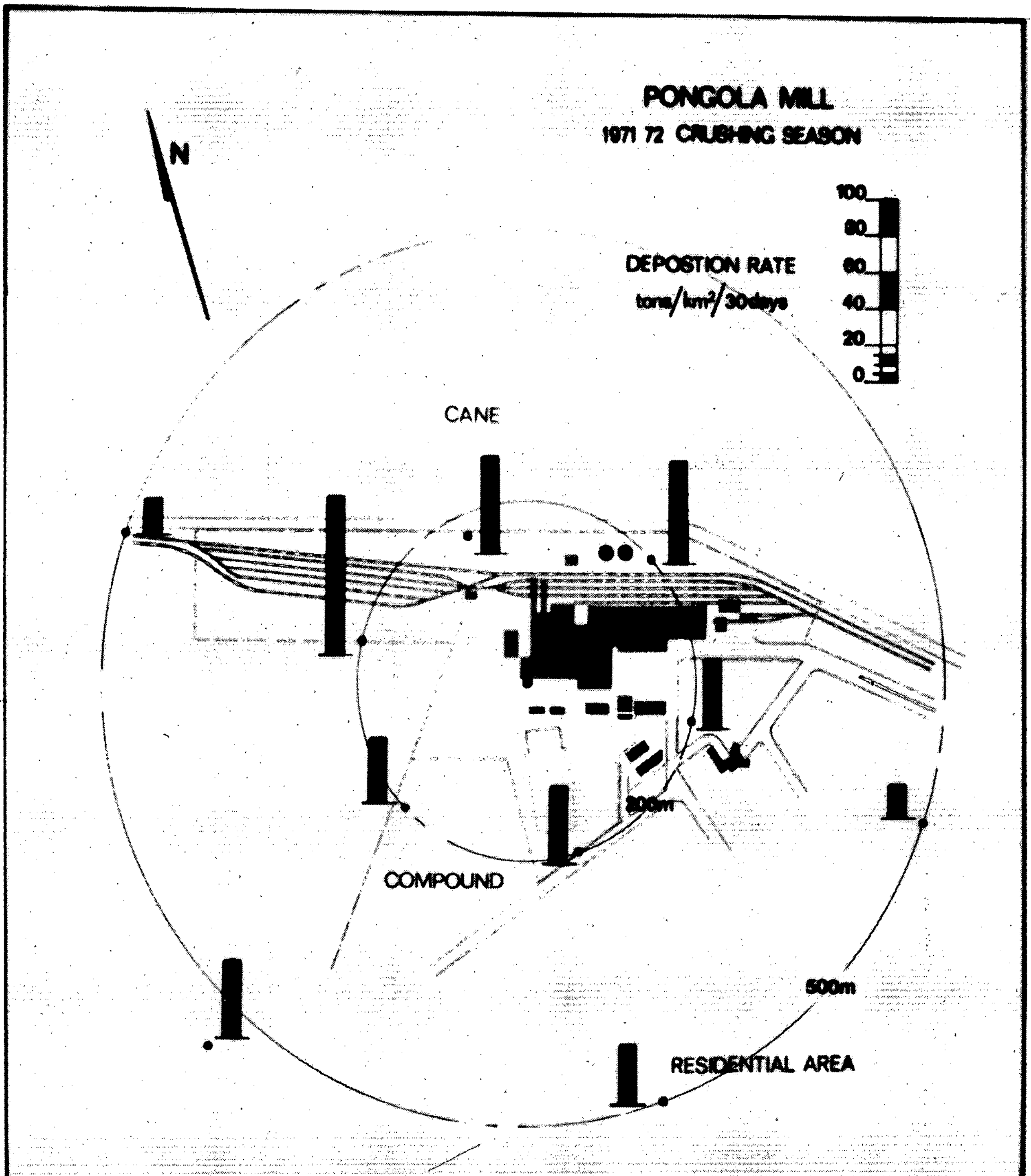


Fig 4.

Deposition rates Pongola mill 1971-72 season

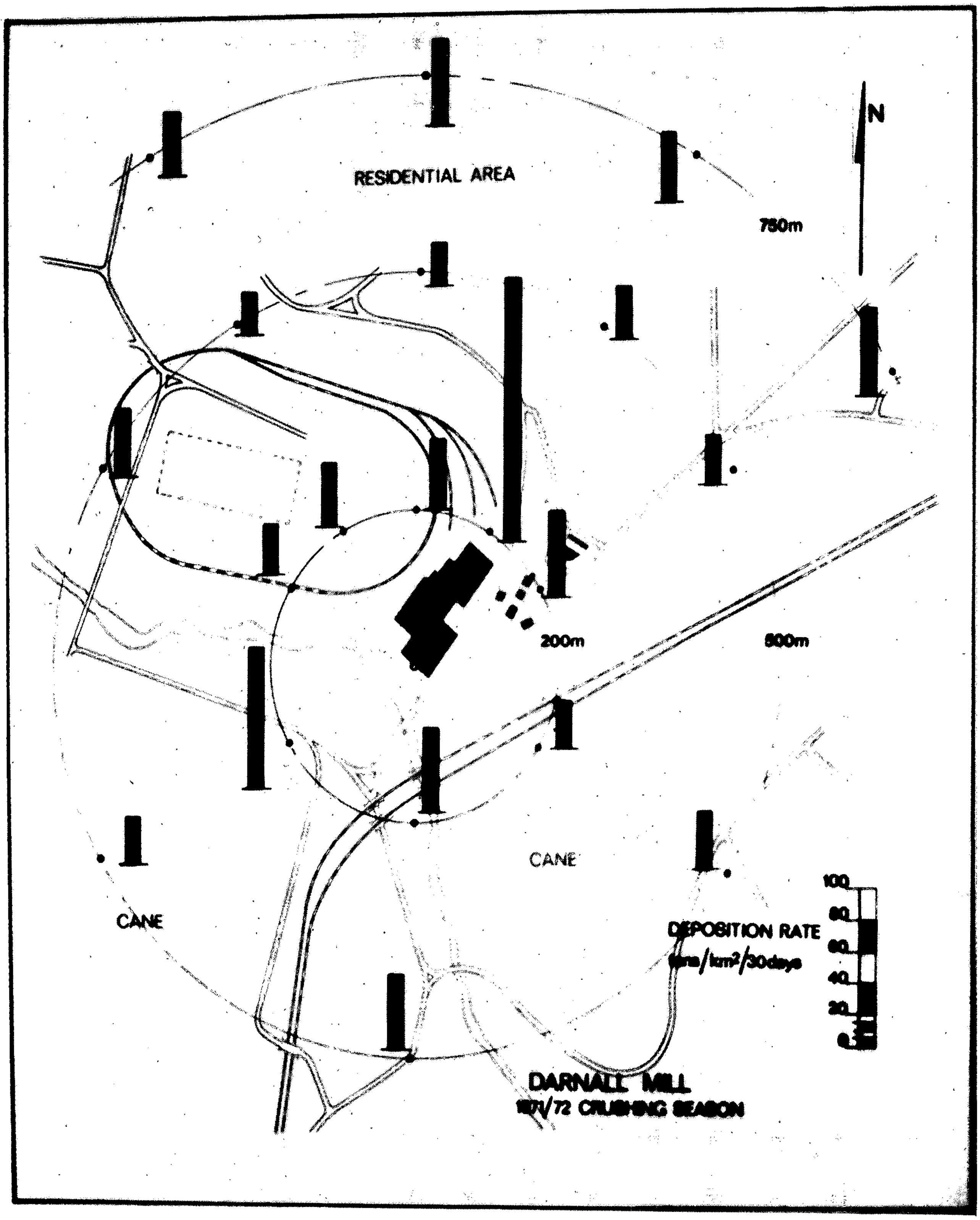


Fig 5.

Deposition rates at Darnall mill 1971-72 season

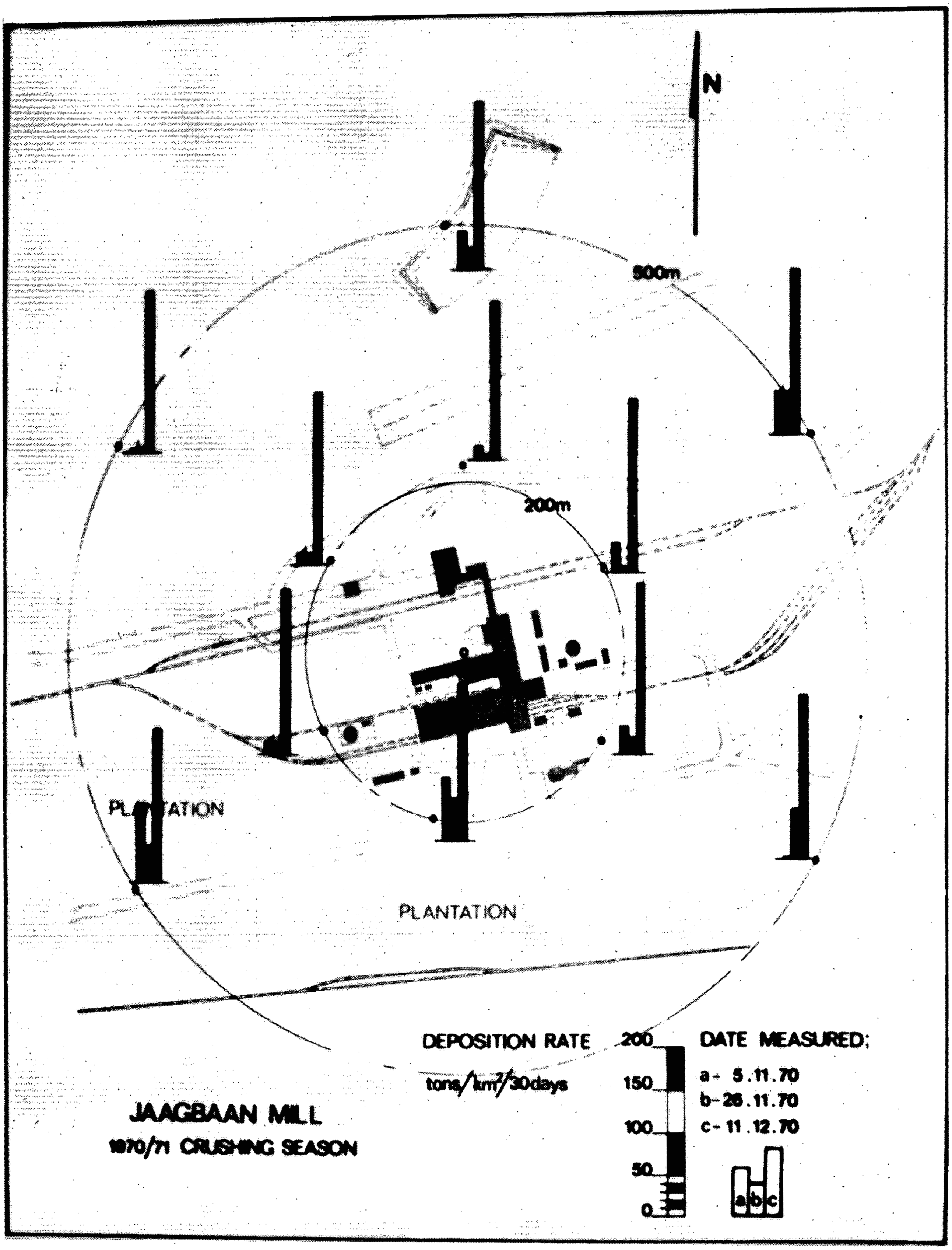
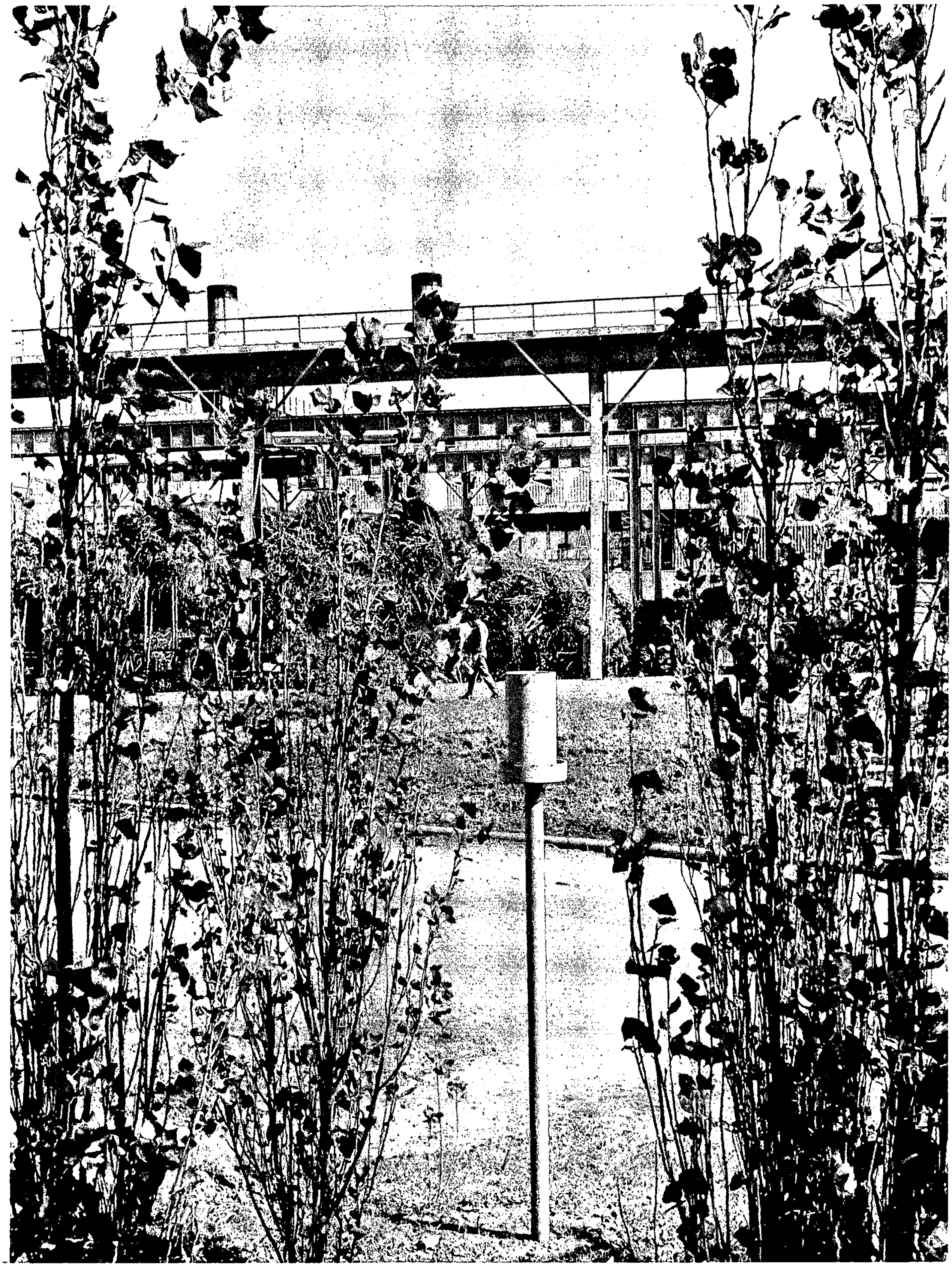


Fig 6.

Deposition rates at Jaagbaan mill 1970-71 season



DEPOSITION RATE GAUGE
Sample collection is easily effected with a plastic bag liner.

Hawaii *U.S.A.*

The Public Health Regulations[7], Chapter 31 on air pollution state that:

"No person shall cause etc. to be emitted into the atmosphere etc. dust in gases to exceed 0,85 lbs per 1 000 lbs of gases, adjusted to 50% excess air (1 000 mg/m^3). There are excepting conditions that a dust collection efficiency of NOT MORE than 85% shall be required for special dust-separating equipment constructed after the effective date of the regulations and not more than 75% shall be required for plant installed before the effective date of the regulations.

Ringelman Chart numbers 2 and 3 are specified as maximum opacity of smoke for short specified periods.

The maximum ground level concentrations given are 150 µg/m^3 (suspended particles) and a fall-out of 3 tons/km^2 for 14 days (for settleable particles). Jars 8" Ø x 12" deep are specified for collecting samples.

U.K.[8]

Responsibility for Pollution Control rests with the Department of the Environment consolidating a previous spread of responsibility through three ministries. Smoke levels are regulated by "dark" (Ringlemann Chart No. 2) and "black" smoke (Ringlemann Chart No. 4). New plant is required to be capable of operating as far as practicable without emitting smoke. Chimney heights are considered with reference to SO_2 emissions. Grit and dust emissions are rated by table according to Maximum Continuous Rating of boiler plant. For a 100 000 lb/hr unit the maximum permitted quantity of grit and dust is 66 lbs/hr. This is equivalent to an emission level of 350 mg/m^3. Measurements are to be made in accordance with BS 3405:1961 which describes five different types of instruments which may be used. The standard of control in The Alkali Act dealing with emissions from specific industrial and chemical processes is that the "best practical means" should be employed for dealing with emissions. This is interpreted as the provision, efficient maintenance and proper use of appliances to prevent the escape of gases, smoke, grit and dust and the proper supervision of operations causing such emissions. It also takes into account the effect of such measures on the operation of the process and their cost, since a balance has to be preserved between the amount of money to be spent and the degree of harm or nuisance involved.

CONCLUSION

Since the formation of the Smoke Study Group, the committee has:

1. Made a survey of the installed combustion plant in the industry;
2. Studied reports of overseas developments in the field.
3. Encouraged mills to set up deposition measuring routines.
4. Assessed progress with new collection plants and carried out site inspections of these installations.
5. Assisted with arrangements for pilot plant installations.
6. Organized an emission measurement programme at four selected factories.
7. Maintained liaison with the Chief Air Pollution Control Officer.

Now that the initial measuring and assessing of "best practical means" is drawing to a close, the South African Sugar Industry is faced with the implementation stage. This committee will remain in existence:

1. to assist the industry where required with all phases of implementation from planning to acceptance, and
2. to maintain the close liaison already established with the Air Pollution Control Department in Pretoria.

REFERENCES

1. Atmospheric Pollution Prevention Act. 1965. Government Gazette Extraordinary No. 1089 21 April 1965.
2. British Standard 3405 : 1961. Simplified Methods for Measurement of Grit and Dust from Chimneys.
3. **Cullen R.N. and Ivin P.C.** 1970. Further Fly Ash Emission and Collection Investigations. Technical Report No. 107. Sugar Research Institute. Queensland.
4. **Cullen R.N. and Ivin. P.C.** 1971. The Control of Boiler Fly Ash Emission in Queensland Sugar Mills. Proc. I.S.S.C.T. XIV Congress p. 1.
5. Government Notice No. R 1864. Government Gazette No. 2910 30 October 1970. Item 56.
6. **Hendrickson E.R. and Grillot F.A.** 1971 Raw Sugar Factory Wastes and their Control. Proc. I.S.S.C.T. XIV Congress p.2. p.5.
7. Public Health Regulations, Board of Health, Territory of Hawaii. p.3.
8. **Reynolds F.** 1972 Current Clean Air Legislation and its Application to Industrial Emissions. Journal of Inst. Public Health Engineers. p.30. p.44. p.52.