COAL DUST ABATEMENT AT THE RICHARDS BAY COAL TERMINAL, SOUTH AFRICA

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SUMMARY

Richards Bay, South Africa was a village with a population of under 100 only 15 years ago. It was a fishing resort on a large, shallow coastal lagoon bordered by attractive coastal dunes and forestation. It now has a harbour which handles nearly 40 million tons per annum of cargo and several primary industries. A major coal export facility has been built in the harbour and the design brief included a comprehensive dust abatement system. After reviewing the methods of pollution control at various similar installations world wide, a series of tests were done on the site. The system selected is now in operation and is based largely on the use of water cannons to wet the piles and adjoining roadways.

This paper gives the background to the design selection, describes the tests undertaken and the way it operates.

1. INTRODUCTION

The Richards Bay Coal Terminal is currently the largest coal handling facility in the world with a throughput in excess of 30 million tons per annum. It has achieved this distinction in just over 8 years: the first coal was loaded through the terminal on 1 April 1976. This was also the occasion of the opening of the Richards Bay Harbour as no vessel had crossed the bar prior to that date. The decision to construct the coal terminal at Richards Bay was the main incentive in the development of this harbour and the transformation of a quiet coastal resort into a potential metropolis.

Richards Bay was a tidal lagoon of approximately 3 000 ha in extent, into which drained 3 small rivers. The average depth of water was 1 metre, and there were few places with a water depth as much as 2 metres. Fish and birdlife abounded in the lagoon. Selection of Richards Bay as a major port was made by the Central Government and development of the surrounding area was strictly controlled to ensure preservation of the environment as well as a well planned city-of-the-future. The lagoon was divided by an earth berm or causeway with one half being maintained as a nature reserve and the other being developed as the harbour. The Figure No 1 shows the lagoon before development of the harbour had started in 1973, and Figure No. 2 shows the same scene in 1983 when the third phase of the coal terminal was completed. The coal terminal was sited next to the coastal dunes, well separated from the "clean cargo" berths which handle container cargoes and other less pollution sensitive items. The winds prevail nearly parallel to the coast, however, and this meant that any dust from the coal terminal would blow either north into the residential areas or south into the coastal forestations and nature reserve.

RICHARDS BAY

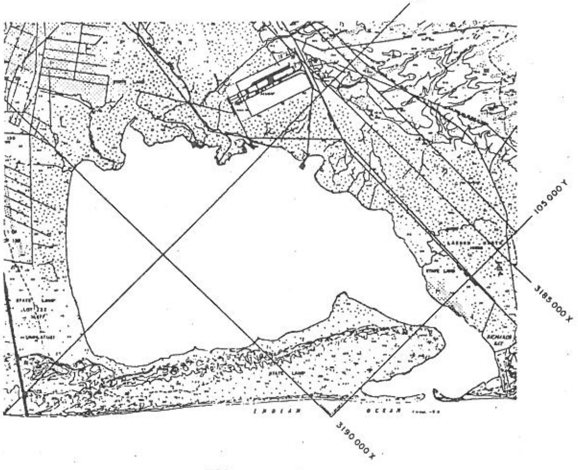


Figure 1

RICHARDS BAY HARBOUR

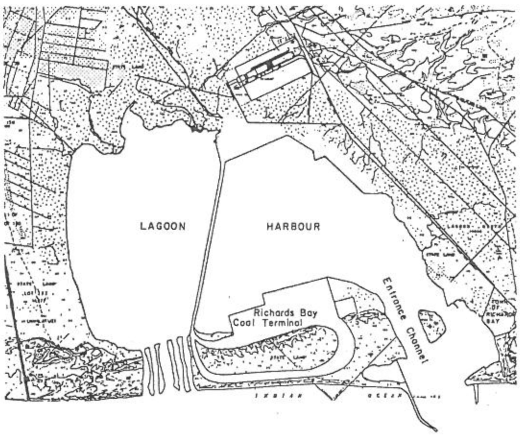


Figure 2

2. INITIAL DESIGNS

From the outset it was realized that the dust abatement would require particular attention.

The first phase development catered for a throughput of 12 million tons per annum (m.t.p.a.) with a 10% stockpile capacity in 4 stacks covering an area of 20 Ha. The rail marshalling yard covered a further 20 Ha. The rate of turnover of the coal is high and there is no problem of dust pollution from the coal in the rail wagons, so efforts were concentrated on the stockyard area and handling equipment. Dust sprays were installed at the rotary dumpers (ie tipplers), at the conveyor transfer points and at the ends of the booms of the stockpile machinery. Based more on manufacturers literature than on site testing, a series of water cannons were placed at 100 metre intervals along the base of the coal stockpiles with a control system that allowed individual cannons to be switched on in any selected sequence. The sprays at the tipplers were effective, the sprays at the conveyor transfers tended to cause blocking of the chutes and proved unnecessary, and a lot of difficulty was experienced in the supply of water to the yard machinery which move up and down a site gradient of 1 in 300. The water cannons were also not very effective in wetting down the coal stockpiles because of their limited coverage and the attention required from terminal personnel in selecting sequences and maintaining the controls.

There will always be conflict between the operator in a control tower and the operator in the field who gets drenched by the unheralded opening of a neighbouring water cannon. This tends to reduce the amount of water spraying undertaken.

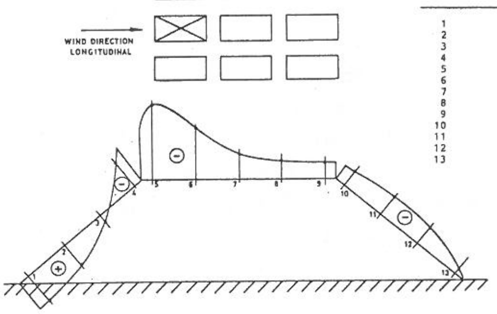
The second phase development of the Richards Bay Coal Terminal was completed in 1978. The stockpile capacity was doubled to 8 stacks covering an area of 40 Ha. Sprays were again installed at tipplers, but eliminated from conveyor transfer points and the booms of the yard machinery. Water cannons were again installed at 100 m intervals along the base of the coal stockpiles but now designed to operate in banks of 6. No attempt was made at automatic control and each line of water cannons was activated by manually opening the valves at either end. This system also had a limited effectiveness because of the limited coverage and the commitment required from the operator who frequently had other priorities.

The water cannons were usually only switched on when the wind was rising and it was frequently a case of too little too late. Modifications were made to the pumps to increase their capacity so that two lines of water cannons could be run simultaneously but the results were still not satisfactory.

3. INVESTIGATION FOR PRESENT DESIGN

When the decision was made to proceed with the third phase of the development of the Terminal (to a throughput capacity of 44 m.t.p.a. in 1984) the Client required an effective dust pollution control system of the 100 Ha stockpile area as an integral part of the proposal. The coal which is handled ranges in size from fines to cobbles in stockpiles up to 23 m high with base widths of 80 m. The use of surface bonding or sealing agents was considered but discarded because of the short time for which any stockpile stands before being rehandled to the ships. Water spraying was considered as the most likely solution and the best two methods of achieving this were considered to be by wetting the stockpiles through water cannons before the wind got up, or by throwing out a mist from a series of high mast installations for the wind to carry across the length or breadth of the stockyards.

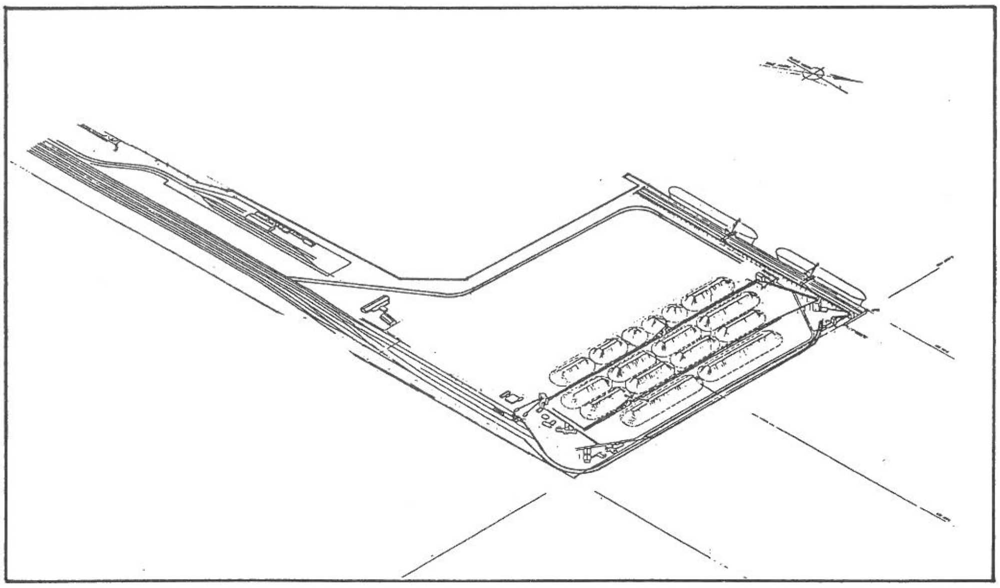
Various stockpile configurations were considered for the new development and a report was commissioned from the Council for Scientific & Industrial Research (1) on the Wind Effects on the Coal Stockpiles. This report considered both the strength of the gusts which could be expected and the problems associated with the curbing of dust pollution. The report concluded that it would be impractical to attempt spraying by mist dispersion from high masts over the long lengths envisaged for the stockpiles. Wind tunnel tests showed a marked suction effect on the upstream edges of flat stockpile tops as illustrated in Figure 3 and noted that a large percentage of decrease in dust pollution could be expected if these regions could be sprayed with water. Water cannons appeared to be the best solution.

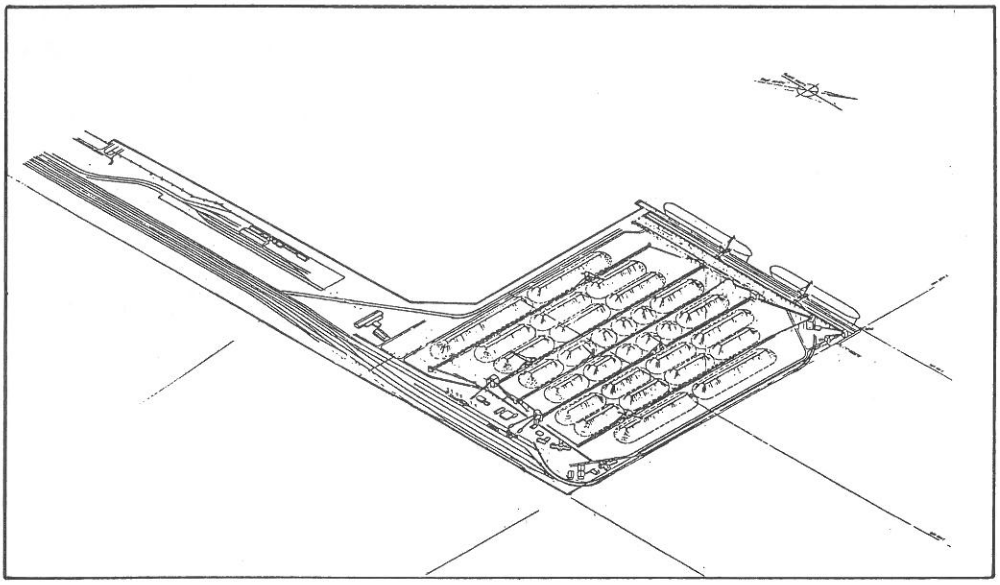


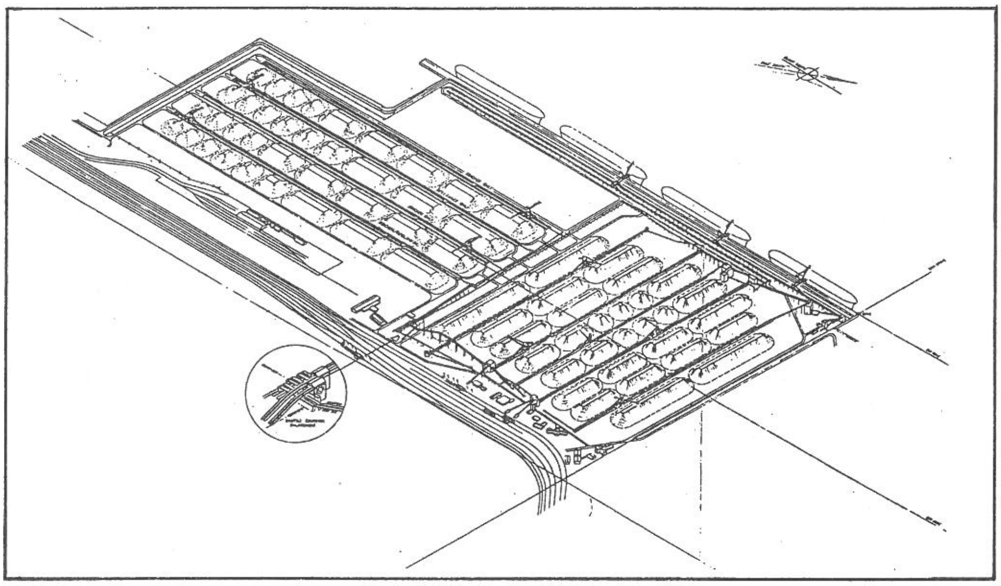
POSITION	STATIC PRESSURE COEFFICIENT Pc
1	0,493
2	0,384
3	0,138
4	-0,476
5	-1,135
6	-0,791
7	-0,338
8	-0,264
9	-0,258
10	-0,275
11	-0,338
12	-0,332
13	-0,103

STATIC PRESSURE COEFFICIENT DISTRIBUTION. Scale 1:600

Figure 3







Visits were then made to numerous similar coal handling facilities in Northern America and Europe with conclusions and observations being summarised in an internal report (2). It was noticeable in all installations visited where water cannons were installed, that they appeared to be working efficiently and were relatively effective in the control of dust in the environment from the stockpile. The remaining areas of the sites were usually treated by dumper sprays, car washing and wetting down of roads and other dusty areas by water carts.

It was therefore decided to proceed with a series of detailed tests at the Richards Bay Coal Terminal site as a basis for a dust pollution control system based on water cannons and spray carts.

4. FIELD TESTS

The tests which were conducted on site had the following objectives:—

a) To determine the evaporation from the coal stacks per day

b) To determine the spacing, spraying time and frequency of spraying to ensure an even deposition of moisture on the stacks from a selected water cannon

c) To assess the effectiveness of spraying water on layers of dust on the site as a means of dust abatement

Details of these test and the results were recorded in an internal report (3) which also put forward a proposal for monitoring weather conditions to relate the likely evaporation to the conditions experienced.

Coal samples were taken on selected faces of coal stacks at hourly intervals and the percentage moisture was calculated for each sample. These samples were limited to the 80 mm closest to the surface as it was found that most of the evaporation occurred in that layer. A series of rain gauges were placed at 10 metre intervals within a 50 metre radius of the water cannon and the quantity of water caught in each gage was recorded after each test and plotted to given an assessment of the total coverage area per mm.

5. ANALYSIS OF TEST RESULTS

5.1 Evaporation

A typical plot of the evaporation measured is given as Figure 4. Average hourly evaporation varied between 0,08 and 0,91 mm/hour over a 13,5 hour day, i.e. between 1,08 and 12,3 mm/day. The rate of evaporation usually increased during the day, although as shown in Figure 5, increases in the relative humidity can cause the evaporation to drop even though the temperature is rising.

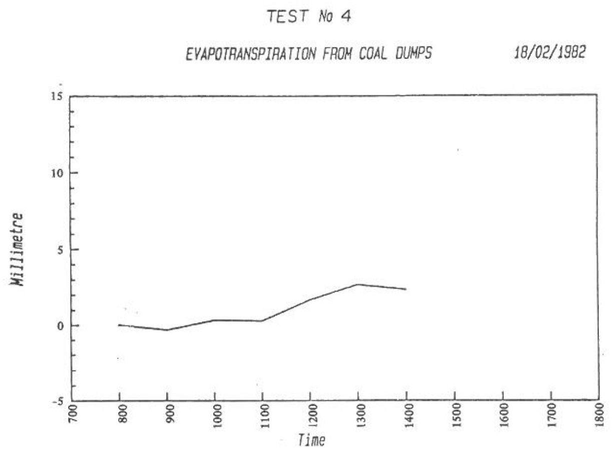


Figure 4

There were, however, many factors such as hours of sunshine and wind which affected the results and no conclusion could be drawn from the limited programme which had been authorised.

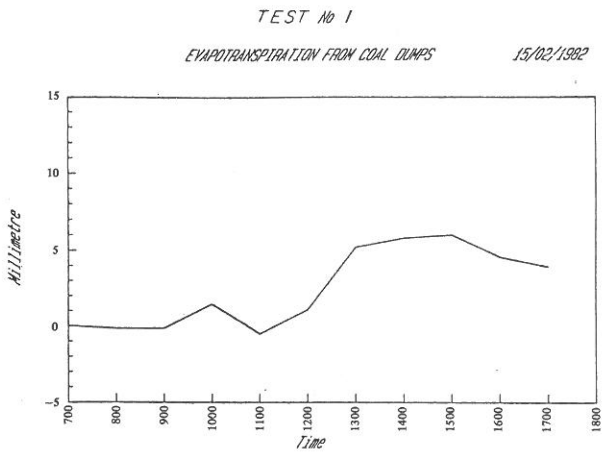


Figure 5

An analysis of the average meteorological data was attempted to see what correlation this had with the recorded results. The method proposed by Penman (4) was applied to the monthly average data for the area and the results are given in Table 1 below.

TABLE 1

Month	Ave. Daily Evapo. ration mm/day	Average Temp. °C	Average %Hum, %	Average Wind-speed m/s	Pos. % Sun-shine %
Jan	6,2	25,4	74	4,0	50
Feb	5,2	25,5	77	3,6	55
Mar	4,5	25,0	77	3,5	61
April	3,5	23,0	78	3,7	60
May	2,7	20,1	78	3,5	59
June	1,7	17,7	75	3,4	74
July	2,3	17,5	73	3,0	72
Aug	3,0	19,1	71	3,3	66
Sept	4,2	20,7	70	3,9	48
Oct	5,1	22,1	72	4,3	48
Nov	6,2	23,6	73	4,9	46
Dec	6,4	24,7	70	4,3	50

The formulae used in this analysis are given in Appendix 1 of this paper. According to these figures the monthly daily averages vary between 1,7 mm/day and 6,4 mm/day with a yearly average of 4,23 mm/day. However, rainfall is a stochastic process and evaporation must be related on a daily basis to determine the spray required to maintain the required moisture level.

It was, therefore, concluded that the rate of evaporation should be checked daily on site. The meteorological data for the site should also be monitored and checks done for one year on the relevance of the Penman method as a ready assessment.

5.2 Water Cannons

Tests were done, not only on different nozzle types, pressures, flows, times and weather conditions, but also on 5 types of water cannons which were available on the South African market at that time. The results of these tests were again subject of internal reports (3) and (5) and although the comparative tests between different suppliers cannot be reviewed in this paper, the following conclusions were made from the nozzle tests:

a) Nozzle sizes of 20,1 mm and less formed droplets so small that they were too sensitive to light winds and also required spray times in excess of 10 minutes to achieve the 2,4 mm precipitation required on the coal surface.

b) Nozzle sizes of 27,5 mm and greater form droplets which are too large and a slurry is formed on the slope of the coal dumps within a few minutes of starting to spray.

c) The 25,1 mm orifice nozzle (as opposed to the 25,1 mm straight bore nozzle) covered a large area at a pressure of 8,0 Bar, could spray 2 mm over an effective range of 25 m in about 5 minutes, had droplets which were not affected by windspeeds up to 5 m/sec, and had a relatively low flow rate of 12,5 litres/sec.

The isopeths of the results of typical water spreads are shown in Figures 6, 7, 8, 9 and 10.

5.3 Spraying of Level, Dusty Areas

Level areas of the site with dust depositions were sprayed with water carts. The water penetration was approximately 10 mm, but the effectiveness of the spraying was closely related to the ruling rate of evaporation and whether the area carried any traffic. It was concluded that spraying by water cart could be used effectively, even in roadways.

6. DESIGN OF COAL STACK SPRAYS

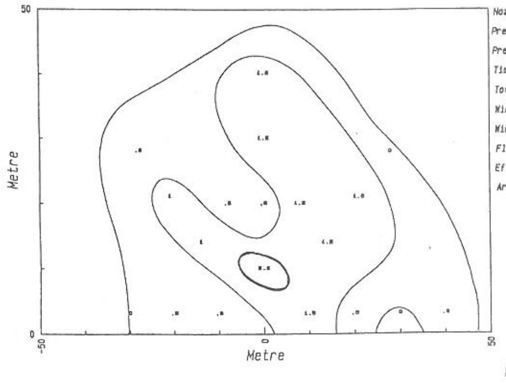
Results of observations by Ensink & Breedland as reported with regard to dust control at Estel Hoogovens Bv (6) indicated that ores and coals had one feature in common : if the moisture content of the surface layer exceeds 6% there is only a slight tendency to dust formation.

It was also noted at the Richards Bay Coal Terminal that the slopes of the coal stacks tend to slough off when the surface moisture content is above 9%. It was, therefore, concluded that the spray system should be designed to bring the moisture content of the surface from 6% to 9% , with repetious spraying whenever the moisture content dropped near 6%. The amount of water needed to effect this increase on the 80 mm closest to the surface would be 2,4 mm. This, coupled with the results of the tests performed, was the basis of the design.

Raingun type 105 CS water cannons were selected with 25,1 mm ring orifice nozzles to operate in successive banks of 13. The angle of the water cannon was to be 43° to clear the 37° angle of respose of the coal and the height of the water cannon nozzle was selected at 3 metres, or as close as could be obtained without interfering with clearances of the yard machinery. The water cannons would be placed at 50 m intervals on both sides of the yard machinery (ie. along both sides of each coal stack) and the working pressure would be not less than 7 Bar. The time required for each spraying cycle should be selectable by the operators, but would be of the order of 5 minutes to give a precipitation of about 2,5 mm.

TEST No 12

COVERAGE AREA OF RAINGUN (m²) 21/02/1982

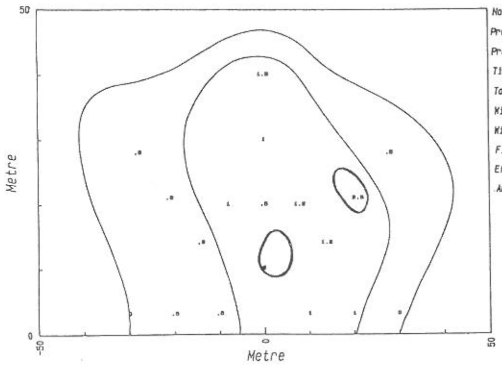


Nozzle Size (mm)	=	17.5
Pressure at Raingun (bar)	=	8.7
Pressure at Pump (bar)	=	9.7
Time of Spray (min)	=	5
Total Volume (l)	=	2930
Wind Direction	=	NE
Windspeed (m/s)	=	2
Flow (l/s)	=	9.77
Effective Spray Area (m²)		
1) Drops	=	3170
2) 1mm	=	1595
<u>3) 2mm</u>	=	75

Figure 6

TEST No 15

COVERAGE AREA OF RAINGUN (m²) 21/02/1982

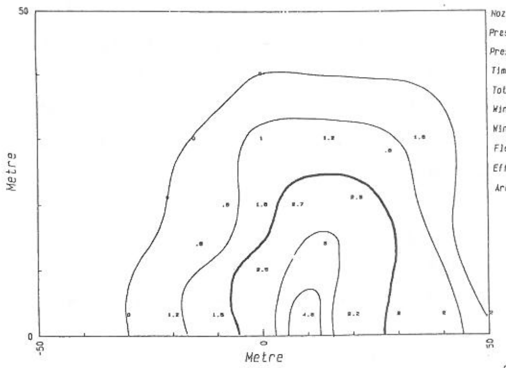


Nozzle Size (mm)	=	20.1
Pressure at Raingun (bar)	=	8.2
Pressure at Pump (bar)	=	9.7
Time of Spray (min)	=	5.0
Total Volume (l)	=	2780
Wind Direction	=	E
Windspeed (m/s)	=	2.0
Flow (l/s)	=	9.27
Effective Spray Area (m²)		
1) Drops	=	2121
2) 1mm	=	1098
<u>3) 2mm</u>	=	480
4) 3mm	=	60

Figure 7

TEST No 20

COVERAGE AREA OF RAINGUN (m²) 22/02/1982

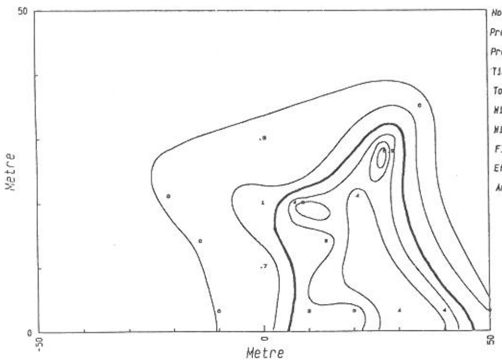


Nozzle Size (mm)	=	22.5
Pressure at Raingun (bar)	=	8
Pressure at Pump (bar)	=	9.7
Time of Spray (min)	=	5
Total Volume (l)	=	4750
Wind Direction	=	S
Windspeed (m/s)	=	1.9
Flow (l/s)	=	15.83
Effective Spray Area (m²)		
1) Drops	=	2660
2) 1mm	=	1538
<u>3) 2mm</u>	=	748
4) 3mm	=	178
5) 4mm	=	54

Figure 8

TEST No 33

COVERAGE AREA OF RAINGUN (m²) 20/02/1982

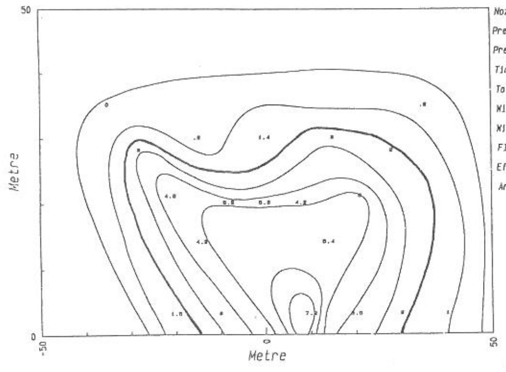


Nozzle Size (mm)	=	32.7
Pressure at Raingun (bar)	=	6.5
Pressure at Pump (bar)	=	9.7
Time of Spray (min)	=	2
Total Volume (l)	=	3695
Wind Direction	=	SW
Windspeed (m/s)	=	4.5
Flow (l/s)	=	30.8
Effective Spray Area (m²)		
1) Drops	=	1981
2) 1mm	=	1250
<u>3) 2mm</u>	=	1005
4) 3mm	=	763
5) 4mm	=	462

Figure 9

TEST No 37

COVERAGE AREA OF RAINGUN (m²) 24/02/1982



Nozzle Size (mm)	=	25.1
Pressure at Raingun (bar)	=	8.5
Pressure at Pump (bar)	=	9.7
Time of Spray (min)	=	10
Total Volume (l)	=	7500
Wind Direction	=	SSW
Windspeed (m/s)	=	3.8
Flow (l/s)	=	12.5
Effective Spray Area (m²)		
1) Drops	=	3216
2) 1mm	=	2408
<u>3) 2mm</u>	=	1973
4) 3mm	=	1544
5) 4mm	=	828

Figure 10

Reservoir capacity was required for an absolute maximum of 3 cycles of the system in any one day.

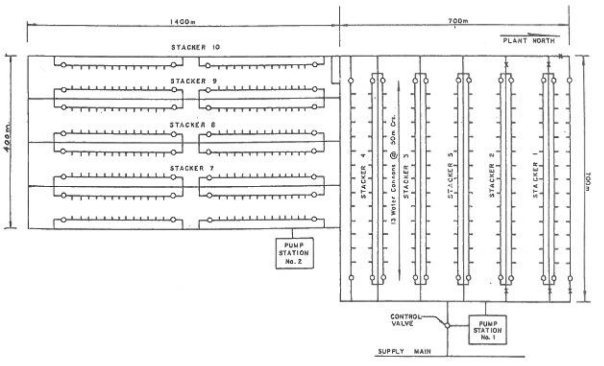
The system was modelled on a computer (7). There are 28 banks of 13 rainguns with each bank requiring a flow of 165 litres/sec. With due allowance for washdown, tippler sprays and other Terminal requirements the reticulation system in the Terminal was designed for a flow of 205 litres/sec. The existing facilities in the Terminal were utilized where possible but one new reservoir and a new pump station were required. The reticulation consisted of 25 kilometres of polyproplene and asbestos cement piping, with most of the polyproplene piping being above ground for easy maintenance.

7. OPERATION OF THE POLLUTION CONTROL SYSTEM

Experience on this site and similar installations throughout the world has shown that a system will only be effectively operated if it is easy to operate. It is also important that the operators have confidence in their ability to handle the system and in the effectiveness of the system.

The whole of the expanded Richards Bay Coal Terminal is now operated from a central elevated control tower. One train controller, two operators and one shift supervisor run the plant through a host computer which reacts to light pencil instruction on colorgraphic display to do all functions from conveyor route selection to monitoring of throughput. The pollution control is linked to the same system.

The spray system is controlled through a schematic display of the reticulation system as shown in Figure 11. The operator has three selections to make in each cycle:



DIAGRAMMATIC LAYOUT OF RETICULATION

Figure 11

a) *The sequence.* Although the sprays work most efficiently when there is no wind, they usually are run when there is some breeze (and sometimes when the wind is blowing quite strongly). Spraying into the wind is ineffective and programmes have, therefore, been put into the computer which automatically deselect lines of spray: if the operator selects (say) "North Wind", all spray lines on the south of coal stacks will automatically be de-activated. Five such options are available to the operator – North Wind, South Wind, East Wind and West Wind, as also No wind when all lines in the system will run in predetermined sequence. The operator also has the facility to activate one or more of the lines without running through a full "wind" sequence.

b) *The spray duration.* Three durations can be selected – short, medium and long. The timing of the durations cannot be altered by the operator, but can be altered by re-programming of the PLC (Programme Logic Control). The short cycle is currently set for a 2,5 minute spray duration, the medium for 4,5 minutes and the long for 6,5 minutes.

c) *The valves.* Each line of 13 water cannons is operated by activating a control valve at either end. If the operator so requires (eg if the yard machinery in that area is undergoing repair) he can disable a valve pair through the screen display so that those valves will not be part of an automatic "wind" cycle. The valve pairs can similarly be enabled by the operator at his computer screen.

The problems of strife between the operator in the control tower and his wet colleague in the field have already been touched on. A recommendation was therefore made with the design that the system be run once a day at 04h00 to complete its cycle in the calm of the early morning and before the day shift moves out into the site. Provision is made in the programming of the system to allow the operators to select up to 3 times a day when a selected sequence (eg No wind) will start up automatically and run the lines at a preselected duration. It is expected that one early morning cycle will usually be a sufficient supplementation of the moisture content to obviate the necessity of repeat cycles during the day.

If for any reason it is required that the spray control be divorced from the control tower, this can also be done. All valves on the lines of water cannons can to be opened and closed manually.

8. CONCLUSION

The water spray system has now been commissioned and performance tests have provided similar isopeths to those plotted after the initial tests. The display provided is also most impressive as the water cannons spray right over the crown of the 23 metre high stacks. The mist from the spray hangs well in the air and drifts onto the sides of the stacks as anticipated.

The control of dust on the level portions of the site is being adequately handled by water carts though, as with the water cannons, the frequency of spraying is being determined by operator experience rather than scientific analysis. Control of dust from the tipplers is still achieved by sprays around the perimeters of the tippler hoppers which are mechanically activated by each tippling cycle.

The system has cost about R2 000 000 to design and install and the Richards Bay Coal Terminal are rightly proud of their contribution towards maintaining the natural environment of this area. It is hoped that this method of design will provide the basis of a practical solution to the problems encountered by others responsible for the storage of granular bulk materials.

APPENDIX 1

CALCULATION OF EVAPOTRANSPIRATION

(PENMAN'S METHOD)

$$\boxed{E = \begin{array}{c} H + Ea \\ + \end{array}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where E = Evapotranspiration in mm/day.

= Slope of saturation vapour pressure vs temp. curve at ambient air temp. T, in mb per degree C^o.

H = Heat budget term.

= Psychrometric constant.

Ea = Drying ability of the air.

$$\boxed{\begin{array}{l} H = Ra(1-r)\ (0{,}18 + 0{,}55\ ({}^{n}/N) - Ta^{4} \\ \quad (0{,}56 - 0{,}092\ (ed)\tfrac{1}{2}\ )\ (0{,}10 + 0{,}9\ ({}^{n}/N)) \end{array}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where RA = Calculated maximum solar radiation reaching the earth.

r = Reflection coefficient of the surface.

${}^{n}/N$ = Ratio of actual to possible hours of sunshine.

TA^4 = Black-Body function of surface, Ta in degrees Kelvin, available from prepared tables.

$$\boxed{Ea = 0{,}35\ (1 + {}^{u}/100)\ (ea - ed)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where 8 = Windspeed at height 2 m (m/s)

ea = Saturation pressure at temp. T.

ed = Vapour pressure at Temp. T.