THE CONTROL OF AIR POLLUTION AT SOUTH AFRICAN COAL-FIRED POWER STATIONS

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SUMMARY

South Africa, whilst lacking indigenous oil and gas resources, has large coal reserves, unfortunately of a rather poor quality. Coal is therefore used extensively both as a feedstock for chemical manufacturing as well as for electricity generation. In fact, 60% of all electricity used on the continent of Africa and nearly 90% of all electrical power consumed in South Africa, is generated in our pulverised coal-fired power station network with a total generating capacity of nearly 24 000 MWe.

The Republic could however be facing a serious deterioration in its air quality as more and more of the huge 3 600 MWe stations are built. In fact, at present stations are being constructed at a rate of one every third year in order to meet the growing demand for electricity. This development could have a disastrous impact on the local environment.

Figures on the current ambient pollutant levels, trends and predictions on future trends, are presented and steps taken to avert a potential threat of environmental damage due to power station emissions are discussed.

Compounding factors, aggravating the situation are highlighted and the results of extensive research, development and testing of methods and techniques to combat air pollution successfully with specific reference to fly-ash, sulphur oxide and nitrogen oxide emissions, are presented.

INTRODUCTION

Due to the fact that a major proportion of its industrial activities are centred around mining, mineral beneficiation and pyro-metallurgical processes for the production of steel and ferro-alloys as well as the extraction of inter alia copper, aluminium, lead, chromium, platinum and titanium oxide, South Africa has a relatively high electricity demand in relation to its overall industrial size.

Lacking natural oil and gas resources and with a limited hydro-electric potential, the country relies heavily on coal fired power stations to provide for its electricity requirements. Our large coal reserves concentrated mainly in the Eastern Transvaal (E. Tvl.) region, are being fully utilized for this purpose.[1]

Economic considerations dictate that power stations should be located as close to collieries as possible and the concept of pit-head stations, using run-of-mine coal, has been adopted. Consequently, our power stations have been built right on top of the coal fields and at present at least 6 stations ranging in size from 2 000 to 3 600 MWe, with a total generation capacity of close on 20 000 MWe are in operation in the E Tvl in an area only 100 by 200 km in extent. Two more stations are under construction in this area.

From an air pollution point of view, the implications of concentrating so many large pollution sources in such a small geographical area, should be quite obvious. Further complicating factors such as adverse weather conditions, and poor atmospheric dispersion potential of the region, necessitate the implementation of a sound abatement strategy in order to avert a serious degradation in air quality and consequential damage to the environment of the E Tvl and the adjacent regions.[2]

DEFINING THE PROBLEM AREA: EASTERN TRANSVAAL (E Tvl)

The E Tvl electricity generating region is situated approximately 150 km east of Johannesburg on a flat plateau at an altitude of 1 600 metres. The meteorology is characterised by high pressure systems dominating the dry, cold winter period. During these periods at night time, dispersion of air pollutants is severely impaired by strong radiation and subsidence inversion layers which form at 200 and 1 500 metres above ground level, respectively.

With a rainfall averaging 650 millimetre per annum maize cultivation is the most important agricultural activity in the region. The region is rather thinly populated by small farming communities and by coal miners, living in several small mining towns scattered across the area. There are no natural lakes or forests in the vicinity.

The reserve of recoverable coal in the region is estimated at 23 billion tons and occurs in 5 seams, up to a depth of 100 metres. Coal extracted by underground mining in the region is of a reasonable quality with a heat value between 20 to 25 MJ/kg and an ash content of 25%, while the open cast mining produces a poor quality coal with a heat value of between 17 and 22 MJ/kg and an ash content as high as 40%.[3]

DEFINING THE PROBLEM:

A) Fly-ash Emissions

The first of the new generation pulverized coal power stations to be erected in the E Tvl were commissioned over the period late sixties-early seventies. In terms of the air pollution legislation, which is based on the principle of "best practicable means", the technology available at that time was taken into account in laying down emission requirements.[4] Consequently, fly-ash collection efficiency of a rather low 96% was imposed. In order to obtain optimal dispersion of gaseous pollutants, stack heights of 200 metres were prescribed. Four stations fitted with electrofilters designed to meet these very lenient limits, were built.

The requirements were revised in 1976 and the minimum collection efficiency for fly-ash was raised to a still rather low 98%. Three more stations conforming to these requirements, were built.

Finally, in 1980 the basis of specifying efficiency of collection was changed to that of emission concentration and the current limit of 50 milligram of fly-ash per actual cubic metre was set, with the height of release at a minimum of 300 metres.

Soon after commissioning the first new stations in the E Tvl, optical monitors as well as visual observations showed the fly-ash emissions to be way above the design limits. Investigation has since diagnosed the following main causes of the poor electrofilter performance.[5]

1) With the very high ash content in our coal from open cast mining, a design efficiency well above 96% even 98% would be required to obtain an acceptable emission.

2) Due to boiler operational problems (slagging, poor ignition and excess air) the electrofilters were subjected to volume flows way above the design figures; with a resultant drop in efficiency.

3) With a sulphur content well below 1% our coal produces a fly-ash with a very high electrical resistivity (> 10 exp. 11 ohm. cm) causing severe back corona, thereby reducing filter efficiency.

4) Poor design of the rapper system resulted in excessive rapper failure.

5) Ash disposal problems were experienced because of under-designed conveying systems, with dust bridging in main hoppers, aggravating the situation.

6) Electrofilters were fitted with too few electrical fields (only 4 to 8 per boiler).

Of all these factors the high resistivity problem proved to be by far the most serious to be addressed.

A noticeable deterioration in the aesthetic quality of the E Tvl atmosphere was experienced in the period prior to 1980 as the number of stations with poorly designed electrofilters, escalated. The matter did however receive urgent attention and preventive measures were introduced by requiring all new stations to be fitted with electrofilters which:

a) have adequate reserve volume capacity
b) are fitted with at least 24 electrical fields, each having its own power supply
c) are provided with isolating dampers on each of the four casing to facilitate on-line maintenance and
d) are fitted with a reliable rapper and ash disposal system with ample capacity.[6]

These measures were implemented very successfully at two stations which have since been commissioned. Emission levels at these stations are well within the stipulated limits and are visually acceptable.

The question as to what remedial steps should be taken at the existing stations with the very poor emission records, will be discussed later.

B) Gaseous Pollutant Emission Problems

Prior to 1980 a tall stack policy was enforced, requiring stations to release flue gases above the radiation inversion height at 200 metres. Due to the low sulphur content coal being consumed (<1%), total sulphur dioxide emissions in the E Tvl at present amounts to a relatively small 800 000 t/a. Taking also into consideration the absence of other major sulphur dioxide sources on the subcontinent, the situation would appear not to be a cause of immediate concern. This has been confirmed by an ambient monitoring network comprising of 20 stations covering the area which indicates very good dispersion of pollutants. (Typical daily average SO2 levels are <0,05 ppm although sporadic short duration peaks exceeding 0,1 ppm do occur under fumigation conditions).[7]

These results confirm that, in spite of the poor ventilation potential of the region, by releasing flue gases well above the inversion layer, acceptable ambient levels can still be maintained.

However, aspects like acid deposition, long range transport into sensitive regions and the formation of "sulphate haze" conditions still require serious attention.

ADDRESSING THE POWER STATION AIR POLLUTION PROBLEMS:

A) **Fly-Ash Emission:**

The very high fly-ash emission levels (up to 2 000 mg/m^3) released at six of the older stations called for urgent remedial action. It was clear however that to enlarge the electrofilters, albeit the more obvious course to follow, would be prohibitively expensive, with no definite guarantee of success.

Since high resistivity was diagnosed as the primary cause of poor performance, several methods capable of counteracting this phenomenon, were assessed with the following showing the more encouraging results:

1) Sulphur trioxide conditioning: The effectiveness of SO_3 conditioning was demonstrated during a test run at the Hendrina station. Prior to conditioning, the dust resistivity was 10 exp. 12 ohm cm resulting in an efficiency of 98% and an emission of 500 mg/Am^3. Dosing with SO_3 at a rate of 30 ppm reduced the resistivity to 5 x 10 exp. 10 ohm cm and the emission concentration to 60 mg/Am^3! A commercially available system, burning liquid sulphur was used for the test. The units are unfortunately expensive to install, costing about R1m per boiler.[8]

2) Ammonia-conditioning: Ammonia injected at 50 to 200 ppm in the gas stream behind the air-heaters also proved to be effective in reducing emissions to within the limit of 175 mg/Nm^3, in a short test run, conducted recently. The system is relatively unexpensive to install.

3) Sulphuric acid-conditioning: In this system $H2SO_4$ is atomized in a special sonic pulse atomizer, subsequently vaporized in a hot air stream before being injected in the flue-gas stream. This system should give results very similar to SO_3-conditioning, but special precautions against acid corrosion of ducting, would be required. The system requires a minimum of capital expenditure.[9]

4) Pulse Energisation: This method, which has recently been further developed, depends upon an enhanced charging mechanism, whereby a high voltage pulse of up to 40 KV, with variable amplitude and frequency, is superimposed upon a base voltage of 25 KV. By applying the high voltage pulse, a much higher charging field can be maintained by avoiding spark-over and back corona formation. The method was tested at a number of stations with resistivity problems. Very good results were obtained: one particular electrofilter, collection efficiency was improved from 92% to well above 97%.[10] Retrofitting this system to stations would be fairly expensive, but a saving in electrofilter power consumption could partly offset the installation cost.

5) Multi-level rapping: Stations in South Africa are fitted with horizontal single impact swing hammer rapper systems and the rapping is done at one level on the collector plate. High resistivity fly-ash is characterised by the strong forces with which particles are adhering to collector plates. The unability of single level rapper systems to produce the intensive rapping, required to dislodge the dust layer was found to be a main cause for the poor performance of electrofilters. A multilevel rapping system retrofitted on one boiler in the Republic has substantially improved collection efficiency.[11] Retrofitting the system to non-compliant stations would however require major modifications to the electrofilter.

6) Micro-processor control: The micro-processors now available for controlling electrofilter operation, are ideally suited for optimising performance on high resistivity fly-ash. A micro-processor board, programmable to regulate vital parameters, such as to stop the firing angle at a point just before the onset of back corona, on the voltage/current curve, was recently tested. By avoiding back corona development, a significant improvement in performance was achieved. The system could be retrofitted to electrofilters at a minimum of cost, and could also be used to control and monitor rapper operation.

7) Baghouse filtration: Since the early 1980's the use of fabric filters has gained general acceptance with the overseas utility industry for controlling fly-ash emissions. Baghouses have also been proved more cost effective than electrofilters on high resistivity fly-ash. Further advantages of baghouses are:

   a) higher collection efficiencies, particularly particles in the respirable range.

   b) lower sensitivity to changes in excess air and fuel quality.

   c) better on-line maintainability and availability.

In South Africa, with its very high resistivity, fly-ash bag-filtration is a definite proposition. It was therefore in principle decided to install an experimental slip stream baghouse at one of the stations as soon as finance allows. Tests have further proved that up to 30% sulphur removal can be attained in the highly alkaline (available calcium) dust cake on the filter media! Bagfiltration could therefore also address our sulphur dioxide problem. (See next section).

An enhancement programme intended to improve electrofilter performance at the "noncompliant" stations, has been initiated. During 1986 at least one unit of each of the following systems will be installed at the Hendrina station: a sulphur trioxide, ammonia, and sulphuric acid conditioning as well as a pulse powering unit.

B) **Control of Sulphur dioxide and Nitrogen oxide Emissions:**

It became clear in 1978 that the escalation in the rate of release of SOx and NOx in the E Tvl must be curtailed. An official notice was therefore issued making it compulsory to recover at least 75% of the sulphur in coal at all new stations erected in the central part of the E Tvl.

The Electricity Corporation (Escom) has as yet not see its way clear to comply with these stipulations and has rather opted for building new stations on smaller coal fields outside the restricted area. This only serves as a temporary respite. The sulphur abatement problems have to be resolved very soon.

It is obvious that with it's very limited water resources the conventional alkali-scrubber based FGD technology cannot be applied in the E Tvl. Furthermore, lime supplies are not readily available in the region and will have to be imported over a long distance. In order to address the questions of pollution impact and suitable technology for combating gaseous emissions, a strategy, which incorporates the following facets was adopted:

1) An extensive monitoring and research programme was initiated to study aspects like chemical transformation, long distance transport, sources-receptor relationship and the impact on the environment.

2) Initiation of a programme for a systematic assessment of available sulphur removal technology with reference to viability under South African conditions. At present the spray dryer absorber technology would appear to be the most attractive alternative, for the following reasons:[12]

    a) Water consumption is low, compared with the "Wet" FGD systems.

    b) A semi-dry waste material is produced, thus obviating liquid effluent disposal problems.

    c) Spray dryer tests conducted with our fly-ash with its high content of available calcium, proved that by using this material as the sole absorbing agent, a sulphur removal of up to 40% can be achieved! Laboratory tests have shown that by regrinding the fly-ash prior to absorption, an even higher removal efficiency can be obtained.

3) Evaluation of the fluidised bed combustion (FBC) technology for SOx and NOx capture. FBC technology is developing at an astonishing rate and could soon emerge as the answer to many utility boiler problems. A test facility has been established and tests on in-bed SOx absorption and the release of NOx will commence in the near future.

C) **Nitrogen Oxide Control**

An assessment of the available NOx abatement technology identified the "low NOx" boiler design as the most viable alternative for South African conditions. The installation of "low NOx" boilers at all future stations has been made mandatory.

CONCLUSION

From the above it should be evident that suitable technology to successfully combat our particulate and sulphur dioxide pollution problems is now available.

The fly-ash abatement programme which has already been initiated will in fact use new technology like pulse-charging and micro-processor control to enhance the performance of noncompliant electrofilters.

The sulphur dioxide problem, on the other hand, is very complex and requires further research and investigation. Since no sign of damage to the E Tvl environment, which could be blamed on sulphur emission, has as yet been detected, the implementation of a sulphur abatement programme is not a matter of great urgency. However, should sulphur dioxide control become an unescapable necessity in future, the spray dryer absorber technology would appear to be the most appropriate option.

Finally, nitrogen oxide emissions will be curtailed by the installation of "low NOx" boilers at all future power stations.

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