GAS CLEANING BY GAS-TO-PARTICLE CONVERSION TECHNOLOGY

R Strydom* and R G von Gogh+

Atomic Energy Corporation of SA Ltd
P O Box 582, Pretoria, 0001

1. INTRODUCTION

Atmospheric pollutants consist of two basic forms: particulate and gaseous. In general, particulate contamination is relatively easy to remove with filtration elements of various types. The gaseous contaminants, however, penetrate through conventional filters. Alternative techniques such as charcoal absorbers therefore have to be used for removal of most gases. Coal burning power stations frequently make use of flue gas desulphurisation (FGD) processes principally using limestone slurries in wet scrubbers for removal of sulphur dioxide from flue gas. The technique is expensive and produces large amounts of difficult-to-handle solid waste by-products. A viable alternative to FGD is dry scrubbing by the gas-to-particle conversion process.

2. GAS-TO-PARTICLE CONVERSION PROCESSES

In this process, contaminant vapours are transformed into ultrafine aerosol particles which can be removed by conventional particulate filtration. The conversion can be realised in two ways:

a) In one method the gas containing the vapours is irradiated with ionizing or ultraviolet radiation. Through the process of radiolysis various reactive chemical species are formed which oxidize the vapours under consideration into low vapour pressure compounds. These compounds can then nucleate to form ultrafine aerosol particles. Nucleation can occur homogeneously, where the molecules of low vapour pressure compounds combine spontaneously to from droplets (usually including water vapour) or heterogeneously around ions present due to the ionizing irradiation. These processes are schematically illustrated in Figure 1. For nucleation to occur, particular threshold concentrations of the condensable vapours have to exist, this threshold being lower for heterogeneous nucleation around ions. Once formed, the nucleation embryos, as they are called, can grow to large sizes via condensation of the vapour onto the embryos and by coagulation with each other, depending on the number and density of the particles.

b) The vapours to be removed may already have a vapour pressure low enough for nucleation to take place, so that particle formation occurs directly. The formation of reactive chemical species is then not an important step in the process. Some vapours, such as those of nitric acid, do not have low enough vapour pressures for spontaneous nucleation to take place. It is possible, however, that these vapours can condense onto pre-existing particle surfaces.

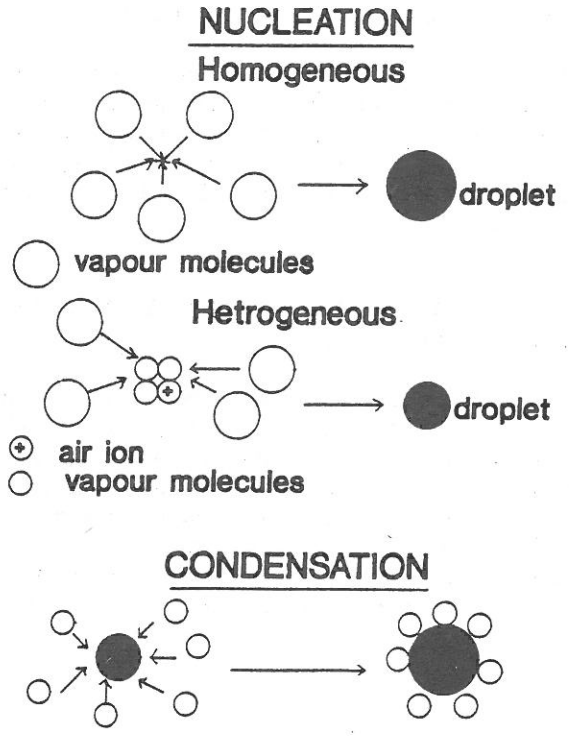


Figure 1: Schematic representation of nucleation and condensation processes in EBDS.

3. ELECTRON BEAM DRY SCRUBBING (EBDS) OF FLUE GAS

The EBDS process for removal of SO_2 and NO_x from, for example, power station flue gases will be discussed briefly as a special application of the conversion phenomenon.

As schematically shown in Figure 2, flue gas, preconditioned - to a temperature of 70° - 110°C, humidified via spray-cooler and typically with 400-500 ppm of SO_2 and 300-400 ppm of NO_x, passes through a reaction vessel where the gas is irradiated using an accelerated electron beam. Gaseous ions are formed which lead to formation of various reactive chemical radicals via a complex reaction scheme. Of these, OH, HO_2 and O are the most important. These radicals oxidize the SO_2 and NO_x vapours to sulphuric and nitric-acid respectively. In the presence of water vapour, sulphuric acid then nucleates both homogeneously and around air ions to form fine aerosol droplets. Nitric acid condenses onto

* Radiation Physics Division
\+ Corporate Marketing Division

these droplets as well as any other aerosol surfaces (such as fine fly ash particles).

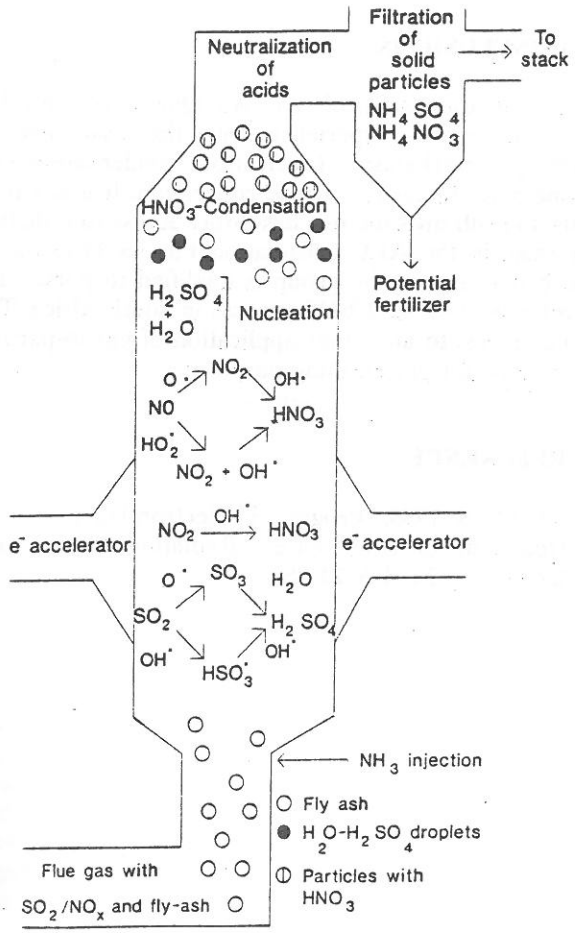


Figure 2: Schematic depicting the EBDS process in emissions resulting from coal burning (e.g. power stations)

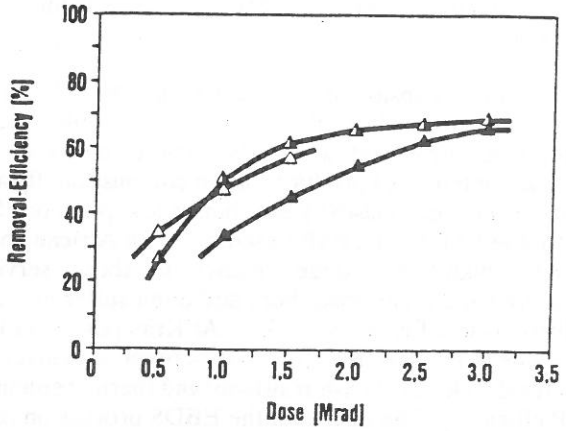
Ammonia is added to the gas mixture to neutralize the acid aerosols which are finally collected by conventional filter system as ammonium nitrate and ammonium sulphate particles. The collected material can be recovered and marketed as fertilizer in the form of ammonium sulphate and ammonium nitrate salts.

It is interesting to note that the particle formation process that takes place in the EBDS process is therefore analogous to that responsible for smog formation by ultraviolet radiation of the sun. It should be noted that while the EBDS system described here is applicable for SO_2/NO_x removal, the gas-to-particle conversion technique can be considered for removal of any vapour, with a vapour pressure low enough for nucleation to take place.

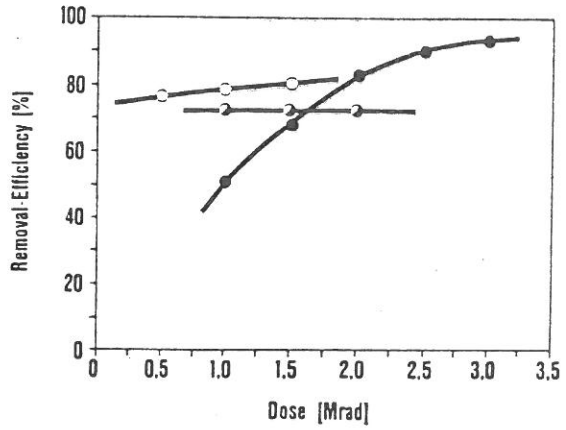
4. EXISTING EBDS INSTALLATIONS

At present, a number of pilot scale EBDS plants are in operation around the world, notably in Japan the United States and Germany. These systems yield excellent results, with removal efficiencies of up to 90% for SO_2 and 80% for NO_x (Figure 3 and accompanying tables).

The removal efficiency depends on many parameters but most important, as may be seen in Figure 3, is the radiation dose administered.



		AGATE	RDK 7	EBARA
NO_x		△	▲	▲
NO_x-Rawgas conc.	[vpm]	325	400	300
SO_2-Rawgas conc.	[vpm]	540	400	300
Temp. after Rad.	[°C]	75	68	88
H_2O	[Vol-%]	16	7	
NH_3-Stoich.		0.64	1.0	0.85



		AGATE	RDK 7	EBARA
SO_2		○	◑	●
SO_2-Rawgas conc.	[vpm]	540	250	1000
NO_x-Rawgas conc.	[vpm]	325	400	300
Temp. after Rad.	[°C]	75	64	88
H_2O	[Vol-%]	16	8	
NH_3-Stoich.		0.64	1.0	0.85

Figure 3: Results of EBDS removal efficiencies for NO_x (top) and SO_2 (bottom) achieved in three pilot plant gas streams at different dose levels. (After Jordan, 1988)

AGATE AND
RDK 7: Two different plants in Karlsruhe, FRG

EBARA: Pilot plant in Indianapolis, VSA

5. SUMMARY

EBDS represents a viable, simple and relatively inexpensive means to remove gaseous pollutants from plant emissions.

It is likely that considerable secondary benefit will accrue to fly ash removal via ESP in South Africa should EBDS systems be implemented. This is because the local low sulphur content coal produces, upon combustion, fly ash with a very high resistivity and hence low potential for capture in ESP filters. ESP's used by South African coal-burning plants are large relative to those serving similarly sized plants elsewhere and often suffer marked reductions in efficiency with time. At Kriel power station SO_3 injection into the flue gas stream is currently practiced to lower fly ash resistivity and thereby enhance ESP efficiency. The effects of the EBDS process on coal burning emissions would be similar to that of flue gas conditioning. Using EBDS it is possible therefore not only to remove substantial amounts of the gases responsible for producing adverse environmental effects such as acidification of rain, soils and surface water, but also to improve the efficiency with which particulate matter is prevented from entering the atmosphere.

6. CONCLUSIONS

The subdivision Aerosols and Air Quality of the AEC has considerable experience with the basic aerosol formation mechanisms (nucleation, condensation etc) taking place in gas-to-particle conversion. It is felt that, since the sub-division also has direct access to radiation expertise in the AEC's Radiation Physics Division, of which it is a part, the group is qualified to pursue the development of the EBDS process in South Africa. The same applies to any other application of gas-to-particle conversion for gas cleaning purposes.

7. REFERENCE

JORDAN, S. 1988: Progress in electron beam treatment of stack gases. Radiation Physics and Chemistry, 31, 1-3, 21-28.