THE CONTROL AND COST OF AIR POLLUTION

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SYNOPSIS

The industrial growth rate in South Africa has been on a steadily rising curve and the consequent rise in emissions of gases and particulates has necessitated an increase in the efficiency of air cleaning equipment to hold the level of atmospheric pollution concentration to an acceptable level.

The paper describes some of the techniques used to improve air cleaning efficiency and indicates the financial costs of this improvement.

OPSOMMING

Die industrieële groei tempo in Suid Afrika is aan die toeneem en die gevolglike toename in die uitlaat van gasse en stofdeeltjies noodsaak 'n verhoogde doeltreffendheid van lug suiwerings toerusting om die konsentrasie atmosferiese besoedeling op 'n aanvaarbare vlak te hou.

Die artikel beskryf sommige tegnieke wat gebruik word om die doeltreffendheid van lugsuiwering te verbeter en dui op die finansiële koste van hierdie verbetering.

1. *INTRODUCTION*

At the turn of the century South Africa's industrial sector consisted mainly of mining activities, some manufacture of explosives and cement and some isolated steam generation facilities. From these humble beginnings the country has progressed into a recognised force in the fields of mining and metallurgy. The chemical industry got a major injection with the establishment and further development of SASOL and this together with the emphasis on local manufacture and self-sufficiency has resulted in a well developed industry.

This progress was inevitably accompanied by the emission to atmosphere of larger and larger amounts of particulate and gaseous air pollutants. Until 1965 air pollution control measures were mainly taken to recover product and to protect the industry's own people, plant and property. There were also those industries who looked further ahead and tried their level best to get cost effective solutions. Since the implementation of the Atmospheric Pollution Prevention Act in mid 1965, much progress has been made towards co-ordinating efforts and expenditure on air pollution control measures in the chemical and metallurgical industry.

Before 1960 the supply of the soft and hard-ware for air pollution control in South Africa was fragmented and based almost exclusively on overseas experience. As the market for control equipment expanded and became more sophisticated and better defined, the supply industry also became more streamlined and specialised in order to meet future challenges.

The theme of the 1981 symposium "Air Pollution – The Unseen Hazard" is very significant in our time. Even visible air pollution still does not concern a large sector of our general public and therefore remains "unseen". Although solutions for most sources of visible air pollution are available, many challenges still remain. As far as the invisible pollutants are concerned, techno-economical considerations have caused South Africa to hold back somewhat on controlling some of these emissions.

2. *CONTROL MEASURES AND MEANS*

Apart from dilution by dispersion, air pollution control measures are generally directed at the removal of undesirable substances from gas streams by separating the substance from the gas stream or by converting the substance to a less offensive substance, i.e. by process modification or incineration.

This paper deals with some of the technical aspects of air pollution control equipment currently supplied by members of the Gas Cleaning Equipment Suppliers' Association of South Africa.

2.1 *Mechanical Collectors.* Apart from grit arrestors and drop-out boxes designed and supplied as and when needed, this category includes proprietary cyclone and multicyclone collectors. Cyclones operate by the principle of imparting centrifugal force to the particle to be separated from the gas stream. Collection efficiency depends on various factors such as:

a) inlet velocity into the cyclone,
b) density and size of the particles,
c) ratio of cyclone body diameter to cyclone outlet diameter
d) cyclone body length and
e) viscosity and density of the carrier gas.

Generally an increase in factors a - d will result in an increased collection efficiency whereas an increase in gas viscosity or density will decrease collection efficiency.

Cyclonic separators can be designed to handle a very wide range of chemical and physical conditions. Construction is relatively simple and any conditions can be met provided a suitable material of construction is available and the desired collection efficiency is within the range of the cyclone. At the pressure drops which cyclones are usually used (50 to 150 mm w.g.) their efficiencies are adequate for use as pre-collectors in order to protect fans or other equipment downstream from the cyclone. However, the potential of the cyclone is not yet fully exploited. Recent data would indicate that efficiencies in excess of 85% can be obtained with metallurgical fume if the pressure drop factor (a) above is increased to about 400 mm w.g.[1]

2.2 *Wet Scrubbers.* According to their principles of operation, wet scribbers can be divided into absorbers and particulate scrubbers.

2.2.1 *Absorbers.* Absorption for purposes of air pollution control is a relatively new concept which really took hold when the world's attention concentrated on invisible gaseous air pollutants. Prior to this, absorption has had a long history of successful use in chemical processes such as hydrochloric-, sulphuric- and nitric acid plants. Unlike particulate scrubbers absorbers have mostly been designed and built by the end-user himself and/or a consultant.

Gas absorption occurs when a soluble component of a gas stream transfers to a liquid in contact with the gas. Gas absorption is a rate process, i.e. it does not take place immediately but at a rate dependant on several variables. Gas will migrate from a region of high pressure to one of low pressure and this is the driving force that causes gas to be absorbed in liquid. The larger the contact surface area the higher will be the rate of transfer or absorption.

Where the gas-phase controls transfer, a rate equation can be written as follows:

$N = K_G A (P_G - P_L)$ where:

N = Number of moles of gas transferred per unit time.

K_G = Coefficient (gas phase controlling)

A = Interfacial area between gas and liquid.

P_G = Partial pressure of pollutant in gas phase.

P_L = Vapor pressure of pollutant over liquid phase.

The removal of SO_2 from boiler flue gases is done overseas by several variations of the above absorption process. In the wet processes, an alkaline solution is used to chemically bind the SO_2 in a soluble or insoluble sulphate form. The so-called "wet-dry" processes use alkalis such as limestone or lime slurries which are injected into the flue gases at such a rate that all the water is evaporated leaving a dry sulphate dust to be collected. Dry absorbents such as nahcolite have also been tested extensively. A tremendous amount of technical and economical resources are being directed at flue gas desulphurisation in developed countries overseas. Except for the financial aspect, various technical problems have thus far limited work on flue gas desulphurisation in South Africa to the chemical and pyrometallurgical fields.[2]

2.2.2 *Particulate Scrubbers.* Efficient particulate scrubbing is dependant on two factors viz:

a) Efficient wetting of the particles by contact with liquid droplets.
b) Efficient removal of the wetted particles from the gas stream e.g. by impingement on collecting surfaces from which they are flushed by the liquid.

Various scrubbing mechanisms can be used in scrubber technology to ensure that the above requirements are met, such as impaction, interception, diffusion, gravitational collection by falling drops, electroststic properties, condensation and evaporation, magnetic forces, ultrasonic vibration and chemical reaction.

In general, all conventional scrubbers use energy to impart velocity to particles and to obtain certain droplet sizes. Semrau[3] has quantified this in his contacting power theory. He defines contacting power as that portion of energy usefully expended in producing contact of the particulate matter with the scrubbing liquid as well as in producing turbulence and mixing in the scrubber.

Similar or equivalent contacting power would then result in equivalent removal efficiencies even if the use of the contacting power is somewhat different.

The recent emphasis on the collection of submicron particles has led to the use of higher and higher energy scrubbers. Many research programmes are now being directed at the greater use of scrubber mechanisms such as condensation, ultra-sonic vibration, electrostatics and especially diffusion where advantage is taken of the increased Brownian movement of submicron particles.

2.3 *Electrostatic Precipitators.* Electrostatic precipitation is defined as the use of an electrostatic field for precipitating or removing solid or liquid particles from a gas stream. It is based on the force that results from the interaction of an electrically charged particle and an electric field. Coulomb, in the late 1700's, demonstrated that the force of attraction or repulsion between two static charges is proportional to the product of the charges and inversely proportional to the square of the distance between them, i.e.

$$F = \frac{q_1 \; q_2}{DS_2}$$ where:

F = force of attraction or repulsion between two particles.

q_1 and
q_2 = charge on particles

D = dielectric constant of the medium between the particles

S = distance between the particles

As practised in air pollution control, the process of electrostatic precipitation consists of the following mechanisms:

a) The formation of gas ions by means of high voltage corona discharge.
b) Charging of the solid/liquid particles by gaseous ions or electrons.
c) Migration of the charged particles to an opposite polarity collecting electrode under influence of the electrostatic field.
d) Neutralization of the charge on the particle by the collecting electrode.
e) Efficient transfer of the collected particles from the collecting electrode to storage or disposal facility.

The first commercial electrostatic precipitator was installed in 1907 on sulphuric acid mist from a contact acid plant at Pinole in California. Many researchers worked at developing empirical equations for precipitator design, most results being derivatives of the Deutsch equation:

$$\eta = (1 - e^{wf})$$ where:

η = weight fraction of dust collected

e = base for Naperian logarithms = 2,71828

w = migration velocity (i.e. drift velocity of a particle toward collecting electrode)

f = ratio of the area of collecting electrodes to the volumetric flowrate of the gas

The migration velocity is dependant on many factors, the most significant in well designed electrostatic precipitators being the resistivity of the particles. A large amount of work has been done to influence resistivities of dusts, e.g. by conditioning of the gas with various chemicals such as H_2O, SO_2, H_2SO_4, NH_3 and T.E.A.[4]

To date, the market has preferred to use gas conditioning only when the efficiency of an existing installation had to be improved. Thus, emphasis for new installations has been on designing large enough precipitators (factor F. in the Deutsch equation).

2.4 *Fabric Filters.* The use of fabric filtration techniques dates back to biblical times where surviving records indicate the use of woven cloths tied over head and neck to prevent the inhalation of dusts in the mining and refining of lead oxides. The problems experienced in lead and zinc smelters were largely responsible for the early stages of the development of bag filters.

The mechanisms by which fabric filtration take place (on a clean fabric) are interception (due to v/d Waals forces), impingement (due to the inertia of the particles), diffusion)due to Brownian motion in the smaller than 0,2 micron particle size range) and electrostatics. When a filter cake has been formed, this also acts as a sieve giving very high efficiencies even on submicron particles.

Many types of filter fabric are commercially available ranging from cotton and wool (natural fibres) to acrylic, polyester and polypropylene (synthetic fibres) for low temperature applications. For high temperature fabric filtration, fibres such as nomex, teflon and glass have been used extensively. For filtration at temperatures over 500°C some interesting metals and ceramics are coming onto the market.

Fabric filters can be classified according to the method of cleaning the bags viz; shaker, reverse flow, pulse jet, reverse jet and vibration cleaning types. Generally, the reverse pulse and reverse jet filters use needlefelted fabrics whereas the other types use woven fabrics.

In sizing a bagfilter for a specific application careful consideration is given to the filter velocity (or air to cloth ratio - metres/second). Factors which have a bearing on the selection of a filter velocity are:

a) The type of particulates – chemically and physically stable materials like grain can be filtered at higher velocities than unstable materials like activated carbon and metallurgical fumes.
b) Temperature – experience has shown that higher gas temperatures necessitate lower filter velocities and vice versa.
c) Particle size distribution – the finer the particles, the lower the filter velocity.
d) Dust load – the higher the dust load, the lower the filter velocity.

3. *SELECTION AND COSTS OF CONTROL EQUIPMENT*

3.1 *Selection.* Factors which influence the selection of a specific type of equipment are numerous, eg.

a) High humidities in the gas stream and very hygroscopic particles would favour wet scrubbing.
b) Mists which form free running liquids can be collected in electrostatic precipitators.
c) Very high gas volumes would favour electrostatic precipitators — if the particle characteristics are suitable — due to the low pressure losses.
d) Emissions which are fire or explosion hazards favour wet scrubbing.
e) The increasing collection efficiency requirements of our times give fabric filters an edge, expecially when significant quantities of sub-micron particles are involved.

3.2 *Costs.*

3.2.1 *Equipment Costs.* What follows is an attempt to give some indication of the current flange-to-flange costs of the various devices in South Africa. These figures must be qualified as follows:

a) High efficiency cyclones:	R 20 to R 30/m^3/min
b) Wet Scrubbers:	R 70 to R100/m^3/min
c) Electrostatic Precipitators (m^2 of collecting plate area):	R 60 to R120/m^2
d) Fabric Filters:	R100 to R150/m^3/min

These costs exclude costs for fans, ducting, effluent removal/treatment, transport, erection, civils and ancillary equipment.

There is rarely one unique method of air pollution control and the final selection mostly depends on the overall cost. For a fair comparison, overall cost should not only include capital expenditure, but also operating and maintenance costs over the expected life of the system.

3.2.2 *Expenditure in South Africa.* Since 1978, the Gas Equipment Suppliers' Association has been collating statistics on the orders booked by all it's member companies. In 1979, the 1978 figures were given at the International Conference on Air Pollution[5].

Annual statistics on flange-to-flange equipment are as follows:

Equipment	1978		1979		1980	
	Amount (R x 1 000)	%	Amount (R x 1 000)	%	Amount (R x 1 000)	%
Cyclones	182	0,9	195	0,7	1 035	6,0
Wet Scrubbers	658	3,1	876	3,0	1 682	9,8
Fabric Filters	2 872	13,6	5 980	20,1	4 169	24,2
Electrostatic Precipitators	17 352	82,4	22 640	76,2	10 341	60,0
Total	21 064	100	29 691	100	17 227	100

Not enough statistics are available to indicate trends in the sales of the different types of equipment, but electrostatic precipitators still constitute by far the largest portion. Judging by the rate at which new power stations have been announced, electrostatic precipitators could maintain this lead for at least the next decade.

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