ELECTROSTATIC PRECIPITATION

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BACKGROUND

The cleaning of gases emanating from various processes has exercised the minds of people for a long time and was prompted by two main factors:

The need to reduce and/or prevent air pollution, and

The recovery of materials from gases.

Practical application of electrostatic precipitation only occurred in the first decade of the 20th century. However, the attraction of small particles to rubbed amber has been known for over 2 000 years; quantitative measurement of electrostatic forces was started by Coulomb in 1785-1789 and he evolved the inverse square law. The first commercial application was at a lead smelting works in 1885 but this was not very successful due to the difficulties of precipitating lead and the primitive methods of producing the H.V. DC supply needed.

Schmidt's work in America during 1910/11 included investigations into collecting electrodes, methods of supplying HV energy, effects of sectionalising the precipitator and methods of controlling creepage and re-entrainment of dust - all these being problems which still interest researchers.

Conditioning of gases was found to be effective by Cottrell in his early work in the American metallurgical industry in 1912. This was on converter gases where the effect of SO_3-conditioning was first discovered. The improvement due to moisture conditioning, manifested in power station operation during soot blowing periods, was also discovered at this time.

PRINCIPLES

Electrical precipitation differs fundamentally from mechanical dust collection in that force is applied directly to the dust particles themselves and not to the complete gas stream. This gives rise to the following advantages:

(a) modest power requirements

(b) low resistance to gas flow

(c) performance is not materially affected by particle size

(d) the technique can treat large gas quantities - at fairly high temperatures if necessary

(e) it can cope with corrosive atmospheres

(f) it can cope with mist burdens.

Three fundamental operations are involved in the function of a precipitator:

1. The electrical charging of the particles.
2. The drift of the charged particles to the collector electrode under the influence of an electric field.
3. Removal of collected particles from the equipment.

The designers of electrostatic precipitators make use of the fact that electrically-charged particles in an electric field are attracted towards, and deposited on the electrodes which create the field.

Precipitators may be divided into two main classes, the so-called plate type, in which the collecting electrodes consist of parallel plates, and the tube type, in which the collecting electrodes consist of a nest of parallel tubes which may be round, square or some other shape. The discharge electrodes in each case are wires, strips or rods, either round, edged or barbed, which are placed midway between the collecting plates or in the centre of the collecting tubes.

In general precipitators are operated at the highest voltage practicable without excessive sparking since this increases both the particle's charge and the electrical field. For industrial applications this is best achieved with the discharge electrodes connected to the negative pole of the high voltage D.C. supply whereas the positive pole is connected to the earthed collecting electrodes. It is necessary to increase the high voltage D.C. applied to about 20 kV before corona discharge takes place.

The dirty gas after being evenly distributed across the precipitator, flows between the discharge and collecting electrodes. The corona discharge causes the particle-laden gas to become ionised, the charged particles being attracted to the earthed collecting electrodes where they are discharged.

In the first zone, which immediately surrounds the discharge-electrode there occurs the familiar corona glow, where ionisation of the gas takes place. The second zone, which occupies the greater part of the space between the discharge and collecting electrodes, contains a dense cloud of gaseous ions, of the same polarity as the corona wire, moving rapidly to the earthed electrodes under the influence of the electrical field.

It is this movement of the charges carried by these ions which constitutes the greater part of the precipitator current. The movement of the particles is called the "drift" or "migration" velocity and although it is a measure of precipitator performance it cannot for design purposes, be calculated from first principles. It is dependent on several factors, which are described later, and forms the basis of the Deutsch formula.

The means of providing this electrical field has been developed over the years - from the early Whimshurst machine, via the rotary rectifier to the static selenium and silicon rectifiers of today.

TECHNICAL ASPECTS

Design

The theoretically-derived Deutsch formula was developed in 1922 and has been used since as the basic design method for sizing precipitators. In its simplified form it can be represented by:

$$\text{Collecting Area} = \frac{\text{Gas volume x Efficiency factor}}{\text{Migration velocity}}$$

Where Efficiency factor = -ln x and x = (1 - Gas Cleaning Efficiency)

Thus, to determine a precipitator size for a given application it is first necessary to establish:

a) Gas Volume

this is usually advised by the Purchaser or the Manufacturer of the equipment which is to be dedusted.

b) Efficiency factor

the allowable emission level will be determined by the Purchaser in conjunction with the Air Pollution Authorities. The inlet gas burden will be determined from calculations or preferably measured where this is possible. The precipitator supplier will thus be able to derive the required efficiency and hence the factor.

c) Migration velocity

this figure is the most difficult to establish. It depends on many factors and the initial assessment of the figure to be used for a new plant can only be made as a result of:

1. Previous experience (know-how)
2. Laboratory tests to establish dust resistivity
3. The known effects of dust or mist composition and gas conditioning.

In many cases the design of the electrostatic precipitator is inseparably connected with design of the gas conditioning equipment preceeding the precipitator. An example of this is the design of a conditioning tower (evaporation cooler) and electrostatic precipitator to dedust exhaust gas from a modern heat-exchanger cement kiln.

Gas Distribution

A further aspect of design which has a marked effect on efficiency is the gas distribution. It can easily be appreciated that it is no use providing the correctly calculated collecting area if the gas distribution is poor; this has the effect of reducing the collecting area that is being utilised and thus the required efficiency is not reached.

Model tests at the design stage enable precipitator designers to determine the required inlet duct splitters and diffuser plates.

Pressure drop has to be provided by a fan and thus it is now usual to guarantee pressure drop across the precipitator and diffusers. Obviously it is of mutual benefit to reduce this pressure drop to the minimum, particularly as one of the advantages of the precipitator is its nominal drop of about 0,15 kPa.

Dust Resistivity

Certain dusts are easier to precipitate than others; the resistivity of a given dust acts as a measure of the ability to precipitate. It has also been found that the negative corona is superior to positive corona for most precipitation conditions.

It can be shown that for a dust of very high resistivity, precipitation can be seriously reduced and difficulties are experienced with resistivities higher than 10^{11} ohm-cm.

With a highly resistive dust the charged particles land on the surface layer of dust on the earthed plates, and the charge slowly leaks away through the underlying layer of high resistivity dust, and so the particles have the same polarity as the on-coming charged particle; this causes a repulsive force which opposes the action of the field.

It will be seen when inspecting precipitators with this type of dust that the dust is progressively more "sticky" from inlet to outlet and consequently more difficult to remove by rapping. Due to the slow leakage of charge to the collecting plate the highly resistive dust is strongly attracted to the plate and is thus more difficult to remove; as the dust layer gets progressively thicker due to the difficulty in rapping, a large potential difference is built up across the deposited dust layer; this reduces the effective electrical field and precipitation efficiency falls away. Attempts to increase the applied voltage to offset this deterioration are generally difficult due to the uneven nature of the dust layer, which would cause arcing with higher applied voltages.
With a highly resistive dust it is usual to experience relatively high voltages with low corona currents; however, the confusing problem of "back ionisation" occurs, manifested by a glow from both the collecting plates and discharge wires; in this case the applied voltage can be low and current high - the explanation being, that due to the high potential across the deposited dust layer, local breakdowns occur, and discharge glow (back corona) appears on the plates.

Rapping

Except where liquid dispersoids are being collected or, in the case of wet precipitators, where a liquid is circulated over the collecting electrode surface, thus continuously removing the precipitated material, the collected dust is dislodged from the electrodes either periodically or continuously by mechanical rapping. Rapping is carried out with either impact-type, vibrator-type or magnetic impulse rappers. Rapping with excessive force can lead to dust re-entrainment and possible mechanical failure of the plates, while insufficient rapping leads to excessive dust build-up with poor electrical operation and reduced collection efficiency.

EXAMPLES OF APPLICATIONS

Power Generation

Pulverised fuel boilers came into use about 1919 and thus led to production of a finer fly ash and more ash carry-over into flue gas than the stoker-fired boilers previously used. Precipitators were first used on boilers on a p.f. power station in America in 1923.

Rural stations could still manage with mechanical collectors but due to rapid industrialisation these have been superseded by electrostatic precipitators. In South Africa, the first precipitators were installed at Congella Power Station, Durban, but in rural districts mechanical collectors were still used on p.f. boilers at Wilge, Komati, Highveld and Taaibos; this situation has now changed and all new Escom stations are using Electrofilters with ever improving efficiencies; for instance, for the new Duvha power station an efficiency of 99,2% has been specified.

Cement Industry

Many years of successful operation have long since established the electro-precipitator as one of the standard types of gas cleaning equipment in the cement manufacturing industry.

The growth of kiln capacities coupled with the ability of electrostatic precipitators to effectively treat large gas volumes has led to precipitators becoming practically unchallenged in the field of cement kiln exhaust gas dedusting. Even the large scale introduction of heat exchanger kilns with their less favourable dust properties has proved to be no obstacle in this development. They have, however, underlined the importance of gas conditioning and have led to the acceptance of the evaporation cooler as an integral part of gas cleaning installations for this type of kiln.

With regard to clinker coolers and cement mills the picture is not as clear. Generally the dust from clinker coolers is unsuitable for electro-precipitation as it displays a high dust resistivity as the result of a low gas dew point and unfavourable gas temperature. The relatively low temperature of this gas makes conditioning by means of evaporation coolers unpractical.

In the case of cement mills electro-precipitators are widely employed. Their suitability does, however, depend on factors such as the type and size of mill whether direct water injection cooling is used or not.

Ferrous Industry

Electrostatic precipitators find wide application in the ferrous industry, e.g. dedusting of blast furnaces, open hearth furnaces, basic oxygen furnaces, arc-furnaces, sinter plants and direct reduction plants. The wet type of horizontal plate precipitator is often applied for the dedusting of blast furnaces.

Base Metals

The application in this field is very varied. A typical example is the dedusting of gases - containing SO_2 - which are produced by roasters for Pyrites and Zinc Blende as well as base metal converters and reverberatory furnaces etc. In this case the gases are often cleaned in a so-called hot-gas precipitator at temperatures up to 400°C.

Chemical Industry

The chemical industry of course, covers a very wide field and often involves corrosive media and liquid dispersoids. A typical example is the cleaning of SO_2 gases in sulphuric acid production. Here acid mists containing dust is precipitated. Vertical wet tube type precipitators are usually employed in this case, the material of construction being lead and lately plastic. A similar type of precipitator is often used for cleaning TiO_2-kiln gas.

Electrostatic precipitators, both tube and plate type, are often used for the removal of tar mists in gases from coke ovens, gas producers and electrode baking furnaces.

CONCLUSION

The intention of this short resumé has been to describe the fundamental principals involved and the practical application of electrostatic precipitation. The members of the Gas Cleaning Equipment Suppliers Association of South Africa will, however, gladly answer specific queries or supply additional information.