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ACARP REPORT

Australian Coal Research Limited

ELECTROSTATIC PRECIPITATION OF FLY ASH FROM AUSTRALIAN BITUMINOUS COALS

THE EFFICIENCY OF AN ELECTROSTATIC PRECIPITATOR IN COLLECTING FLY ASH DEPENDS ON A NUMBER OF FACTORS. SOME OF THESE RELATE TO THE NATURE OF THE ASH PARTICLES AND SOME TO THE DESIGN AND OPERATION OF THE PRECIPITATOR.

SUMMARY

The combustion of coal for power generation produces fly ash, which must be collected prior to discharge to the atmosphere. The most common method of collection is electrostatic precipitation but bag filters are also popular. The quantity of fly ash that needs to be collected depends largely on the ash content of the coal. The collection characteristics of the fly ash will depend on the coal and the combustion system.

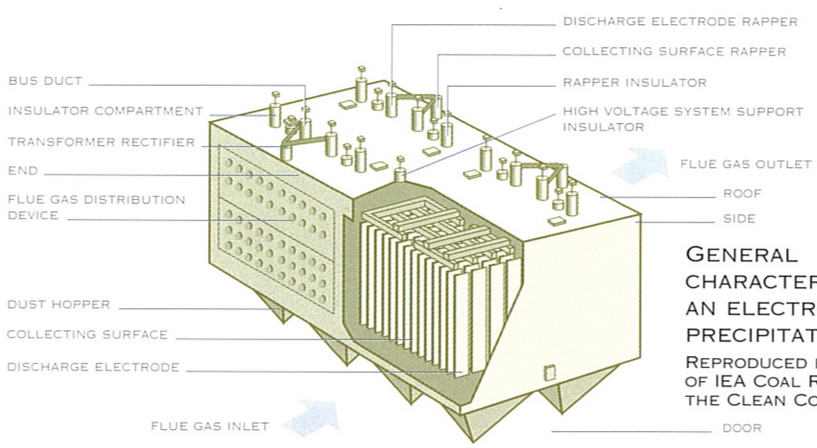
Many factors control the performance of an electrostatic precipitator collecting fly ash.

Those that are particle related include:

- Electrical characteristics
- Size distribution
- Shape
- Particle cohesivity
- Operating temperature
- Sulphur content
- Unburnt Carbon Content

Particle electrical characteristics largely relate to resistivity of the fly ash, which in effect is a particle surface conducting phenomenon.

Moisture can also have an effect and as well there are precipitator related problems. These will affect the overall performance and must be taken into consideration. Sodium has been found to have an effect on some North American coals but due their low sodium content is not applicable to Australian coals.



GENERAL CHARACTERISTICS OF AN ELECTROSTATIC PRECIPITATOR

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Precipitator related problems include:

- Mechanical problems
- Non-uniform gas distribution
- Re-entrainment
- Fouling of the plates

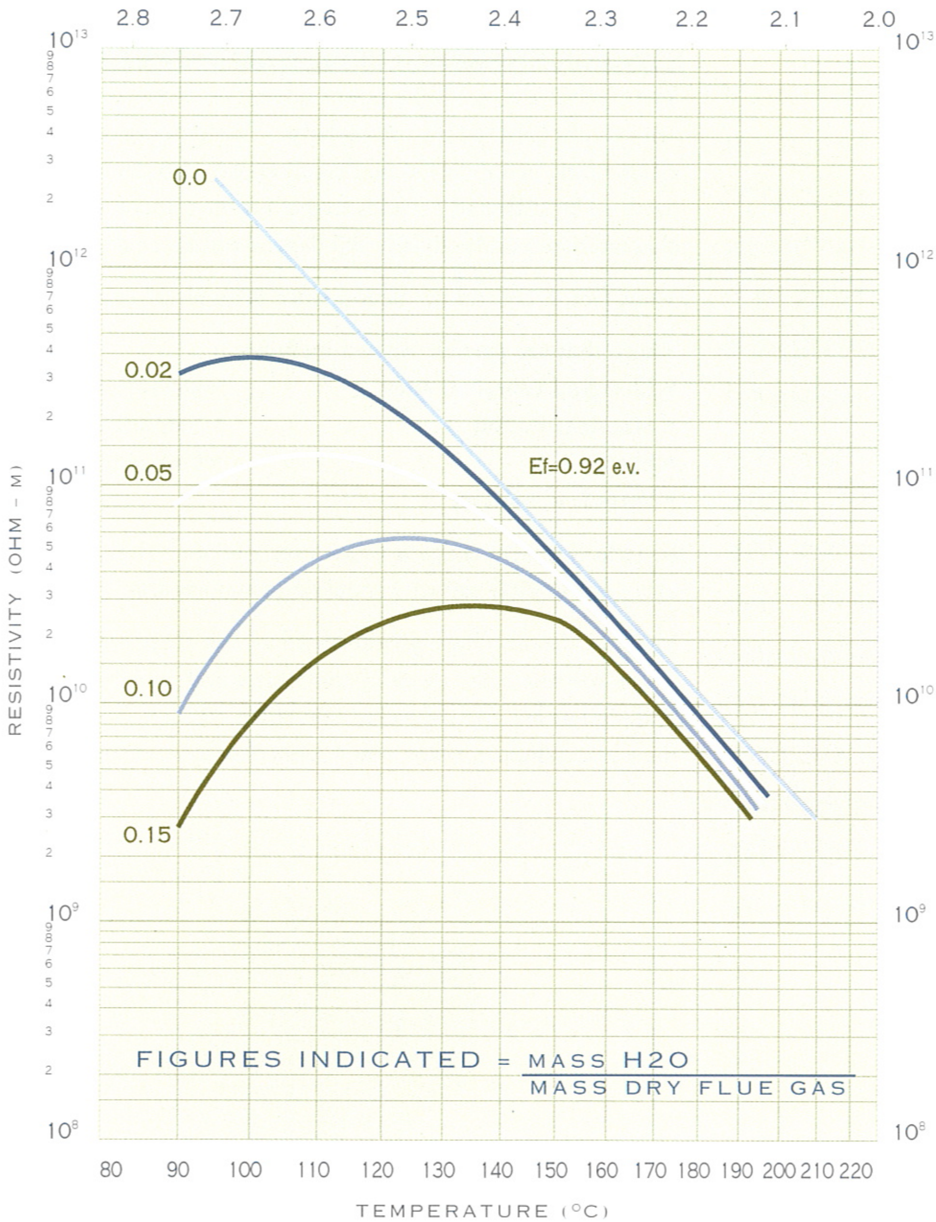
The performance of precipitators can usually be significantly enhanced by the use of flue gas additives such as sulphur trioxide or ammonia or by electrical enhancement such as intermittent or pulsed energisation.

Improved performance due to high coal sulphur content has been demonstrated for northern hemisphere coals with sulphur contents greater than about 1.5%. Conversely, reports of coals with the same sulphur content giving widely different precipitator performance have also been published.

RESISTIVITY

THE SULPHUR CONTENT OF AUSTRALIAN COALS HAS BEEN SHOWN NOT TO BE A RELIABLE INDICATOR OF THE LIKELY ELECTROSTATIC PRECIPITATION PERFORMANCE OF THE COAL. AUSTRALIAN BITUMINOUS COALS ARE PREFERRED FOR POWER GENERATION BECAUSE THEY EXHIBIT A WIDE RANGE OF FAVOURABLE CHARACTERISTICS, INCLUDING LOW ENVIRONMENTAL IMPACT, WHICH IS DUE IN PARTICULAR TO THEIR LOW SULPHUR CONTENT.

Resistivity is commonly used as a guide when evaluating the likely performance of coal's fly ash in an electrostatic precipitator. However, resistivity is only one of many factors which influence electrostatic precipitator performance and the actual resistivity of particles collected on the plate of an electrostatic precipitator at operating conditions can be significantly less than the resistivity measured by laboratory test apparatus.



RESISTIVITY - TEMPERATURE CURVES OVER A RANGE OF MOISTURE CONTENTS IN A FLUE GAS ENVIRONMENT DETERMINED AT AN ELECTRIC STRESS OF 400KV/M.

Electrical resistivity of the fly ash collected on the precipitator plates causes a voltage drop across the dust layer and if the resistivity is sufficiently high this will cause an electrical breakdown resulting in back corona or sparking at the surface of the dust layer causing particle re-entrainment. It is normal with higher resistivity fly ash to operate the precipitator at a voltage which initiates the onset of back corona and to control it at this variable condition by setting the precipitator at a specific sparking rate in order to maintain electrical stability. Therefore, the electrical resistivity of the collected layer is important to proper precipitation, thus leading to the dependence on fly ash resistivity as an indicator of electrostatic precipitability.

THE EFFECT OF SULPHUR IN COAL

When coal is subjected to pulverized fuel combustion, the sulphur it contains is converted to the oxides of sulphur in the gas phase[1]. Subsequently a portion of the sulphur may redeposit on the surface of the fly ash, forming particle sulphate bonds and a sulphate ion surface layer around each particle, resulting in an electrically conductive surface. However, the strength of this conductive surface will depend on the amount of SO_3 in the flue gas and the absorptive capability of the surface of the fly ash particles. As coal sulphur contents increase, so does the percentage of SO_3 in the flue gas.

Electrostatic precipitators collecting fly ash in power station boilers operate at temperatures in the region of 120-160°C and as close as practical to the acid dew point, but always safely above it in order to obtain a combination of best operating efficiency with lowest maintenance cost. Under these operating conditions within the precipitator it was first observed that fly ash surfaces carried soluble sulphate[2] as a result of natural conditioning by flue gas containing SO_3. This led to the belief that fly ash produced from coals with a low sulphur content was more difficult to collect in electrostatic precipitators.

Modifying the sulphur levels of several Australian coals has shown that the impact of sulphur is twofold. It acts as a mechanism for furnace bonding of particles and also tends to increase surface conductivity. The investigation also revealed however that increased sulphur in the coal may either increase or reduce resistivity, depending on the coal. This explains the lack of a direct correlation between sulphur content and collection efficiency in an electrostatic precipitator[6,7].

Clearly the SO_3 content of the flue gas, which can be related to the sulphur content of the coal, will affect the surface electrical characteristics of the fly ash. However, other factors also affect the precipitability of the dust and may be equally or more influential in the performance of the precipitator.

AN INVESTIGATION HAS BEEN MADE[8] OF AUSTRALIAN COALS RANGING IN SULPHUR CONTENTS FROM 0.2-5.8%, USING A PILOT SCALE COMBUSTION AND PRECIPITATION TEST RIG. THE OBSERVATIONS WERE MADE AT 120°C UNDER CONTROLLED AND COMPARABLE CONDITIONS AND INVESTIGATED THE VARIOUS FORMS OF SULPHUR IN THE COALS AND A RANGE OF OPERATING PARAMETERS. NO ASSOCIATION COULD BE ESTABLISHED BETWEEN COAL SULPHUR CONTENT AND PRECIPITATOR PERFORMANCE.

OTHER FACTORS AFFECTING ELECTROSTATIC PRECIPITABILITY

A number of factors affect the performance of electrostatic precipitators and all must be taken into consideration before the constraints on precipitator performance can be determined. Some of these factors are described.

PARTICLE SIZE

The particles flowing to a precipitator vary in both size and shape but lie within a specific size distribution range. By and large the particles collect independently with each size fraction collecting at a different rate, the larger ones more efficiently than the smaller ones[9]. It is usual to use the mass median diameter (MMD) to represent the size distribution of any fly ash. The MMD is the diameter above and below which 50% of the weight of the particles lie. Studies of the effect of changing MMD on the efficiency of a precipitator[10] show that at constant operating conditions if a dust with an MMD of 5 microns (micrometres) exhibits a collecting efficiency of 96%, then with the same dust at an MMD of 10 microns the efficiency is increased to 98.5% and at 15 microns it is 99.4%.

The precipitator alters the particle size distribution of the dust so that as the material passes through the precipitator the dust becomes finer. Therefore the latter stages of a precipitator collect material at a much lower efficiency than the earlier stages.

PARTICLE SHAPE

The shape of the collected particles can have an impact on the performance of the precipitator. It is thought that angular particles tend to interlock in the collected layer on the electrostatic precipitator plates and are rapped off in a more coherent agglomerate, giving less re-entrainment than for more spherical particles.

LOW SULPHUR COALS CAN POTENTIALLY OPERATE AT HIGHER COLLECTION EFFICIENCIES THAN HIGHER SULPHUR COALS.

PARTICLE COHESIVITY

Particle cohesivity (the ability to adhere to one another) on the plate of an electrostatic precipitator is an important determinant in minimising re-entrainment. The more cohesive the ash particles, the less likely they are to re-entrain with the gas stream.

TEMPERATURE

The temperature at which electrostatic precipitation occurs will have a significant effect on the collection efficiency and affects a number of other properties related to precipitability[12,13,14] e.g., the viscosity of the flue gas rises slowly as the temperature increases, giving greater drag forces on the particles and hence reduces the velocity of the particles as they migrate to the collecting plate. This means that low sulphur coals which, due to practical considerations can operate at lower temperatures than high sulphur coals, can potentially operate at higher collection efficiencies than the higher sulphur coal, if no other factors affect the precipitator performance.

The electrical characteristics of fly ash particles are affected by temperature. Electrostatic precipitators for practical reasons must operate above the acid dew point of the flue gas, but at the lowest safe level above this point for greatest plant operating efficiency. Within this region of operation, as temperature increases, resistivity of the fly ash that is collected on the plates will reduce. However, the precipitator operating temperature is determined by plant design and the sulphur content of the coal being used.

MECHANICAL DIFFICULTIES

The flash over voltage within the precipitator is reduced by decreasing the wire to plate distance. Hence any distortions or misalignment of wires and plates within the precipitator can cause a loss of voltage in a precipitator stage. Moreover, persistent flash over at any one spot on a wire can weaken it to breaking point.

Rapping is the term used for the mechanical agitation of the collector plates to dislodge accumulated deposits. Accumulation of irregular and fixed deposits on wires and plates can also lead to serious operating problems if

ACCUMULATION OF IRREGULAR AND FIXED DEPOSITS ON WIRES AND PLATES CAN LEAD TO SERIOUS OPERATING PROBLEMS.

IF RE-ENTRAINMENT HAPPENS BECAUSE THE GAS VELOCITY IS TOO HIGH OR BECAUSE THE DUST DEPOSIT IS WEAK AND FLUFFY, THEN THE EFFECT IS CONTINUOUS AND THE EFFICIENCY OF THE PRECIPITATOR WOULD BE SIGNIFICANTLY REDUCED.

they cannot be removed by rapping. Corona is impeded by such deposits becoming discontinuous and corrosion may occur under them.

RE-ENTRAINMENT

Re-entrainment of dust from the collecting plates may be followed by successful recollection or by emission. Re-entrainment may be caused by maladjusted rapping, which is either premature or too violent, then the re-entrainment may be detected as a "puff" emitted from the precipitator on rapping. On the other hand if the re-entrainment happens because the gas velocity is too high or because the dust deposit is weak and fluffy, then the effect is continuous and the efficiency of the precipitator would be significantly reduced.

MAINTENANCE

All collected fly ash is not removed from the plates of an electrostatic precipitator on rapping. A layer of increasing thickness and resistivity builds up over time and must be physically removed at intervals to enable the precipitator to operate efficiently.

Electrostatic precipitator plates and wires may become distorted or misaligned. Periodically they need to be checked and restored to ensure satisfactory precipitator performance.

PRECIPITATOR PERFORMANCE ENHANCEMENT

If an existing precipitator is not controlling fly ash emissions to the degree required in spite of the electrical and mechanical components of the precipitator being found to be satisfactory, then it is usually possible to use flue gas additives and/or electrical enhancement to significantly improve the overall efficiency of the electrostatic precipitator.

FLUE GAS ADDITIVES

Conditioning the flue gas prior to the electrostatic precipitator with certain components has long been recognised as a means of enhancing the precipitator's performance. Many ingredients have been evaluated, but the most successful have been sulphur trioxide and ammonia.

The use of sulphur trioxide is generally well accepted for enhancing the performance of fly ash in an electrostatic precipitator[15,16,17]. Addition of sulphur trioxide to the flue gas will generally improve the surface conductivity of the dust and in addition may enhance its agglomeration propensity. However there have been instances where the addition of SO_3 has not improved the precipitator performance.

Ammonia has been used as an additive to flue gas and although not apparently affecting the resistivity of the particles[18], has increased their cohesiveness leading to an increased agglomeration and greater effective particle size.

For example, for a specific coal the addition of ammonia has reduced the required precipitator size by 22% whilst the addition of SO_3 reduced the required precipitator size by 30%, demonstrating how effective flue gas additives can be in reducing the precipitation areas required to carry out a specific task.

ELECTRICAL ENHANCEMENT

Electrical modifications can be carried out on an existing precipitator to significantly enhance its performance with a specific coal [19,20,21]. The simplest means of enhancing the precipitator performance is to install a control system that can be used to effect intermittent energisation of the stages. Intermittent energisation has been shown to greatly increase the collection efficiency with some fly ash, whilst at the same time reducing by up to 90% the power consumed by the precipitator.

Alternatively in some plants it may be necessary to install additional equipment on the electrostatic precipitator to generate electrical pulses. This has proved an effective means of improving the collection efficiency of a precipitator.

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FLY ASH COLLECTION

Electrostatic precipitation and fabric filtration are the two main methods used to collect the fine particles of fly ash that are generated from coal combustion in power station boilers. However, although the use of fabric filters is increasing, the principal means of collection is by the use of electrostatic precipitators.

Electrostatic precipitators for the collection of fly ash in power station boilers comprise an enclosed casing containing several parallel gas paths, with each path containing several stages in series. Flue gas containing fly ash enters the precipitator and is distributed into the several gas paths. Each gas stream then moves progressively through a number of electrified stages. Each stage comprises a series of vertical electrically earthed plates between which wires or electrodes are suspended, to which a high voltage is applied for the purpose of electrically charging the fly ash particles as they move through each stage. Once charged, the particles are attracted to the earthed plate and under given conditions will adhere to the plate to be subsequently removed by applying a mechanical force, called rapping, at selected intervals, in order to remove the collected particles by gravity into hoppers beneath each stage.

The size of electrostatic precipitators will vary depending upon the design requirements. This is governed by the coal ash content, the fly ash collection characteristics and the emission control requirement. Provided that the precipitator design suits the coal characteristics, then the precipitator collection efficiency can be expected to exceed 99.5%.

In practice precipitator size and design characteristics vary considerably and in order for the precipitator to operate effectively it is important that the design incorporates uniform gas/fly ash distribution into the several parallel paths and that the gas velocity and temperature through the paths be within the design specification. That means that the specific collecting area (total collecting plate area / total gas volume) must be adequate for the conditions prevailing within the precipitator and that re-entrainment of fly ash is minimal. Also for efficient collection it is important that the precipitator be maintained to a satisfactory degree.

Electrostatic precipitators have been the preferred means of fly ash collection in the majority of the worldís power stations, due largely to their lower capital cost compared to other collection devices, combined with the low energy consumption required to collect fly ash, which is mainly related to power consumed for energisation, since pressure drop through the precipitator is comparatively low.

PROVIDED THAT THE PRECIPITATOR DESIGN SUITS THE COAL CHARACTERISTICS, THEN THE PRECIPITATOR COLLECTION EFFICIENCY CAN BE EXPECTED TO EXCEED 99.5%.

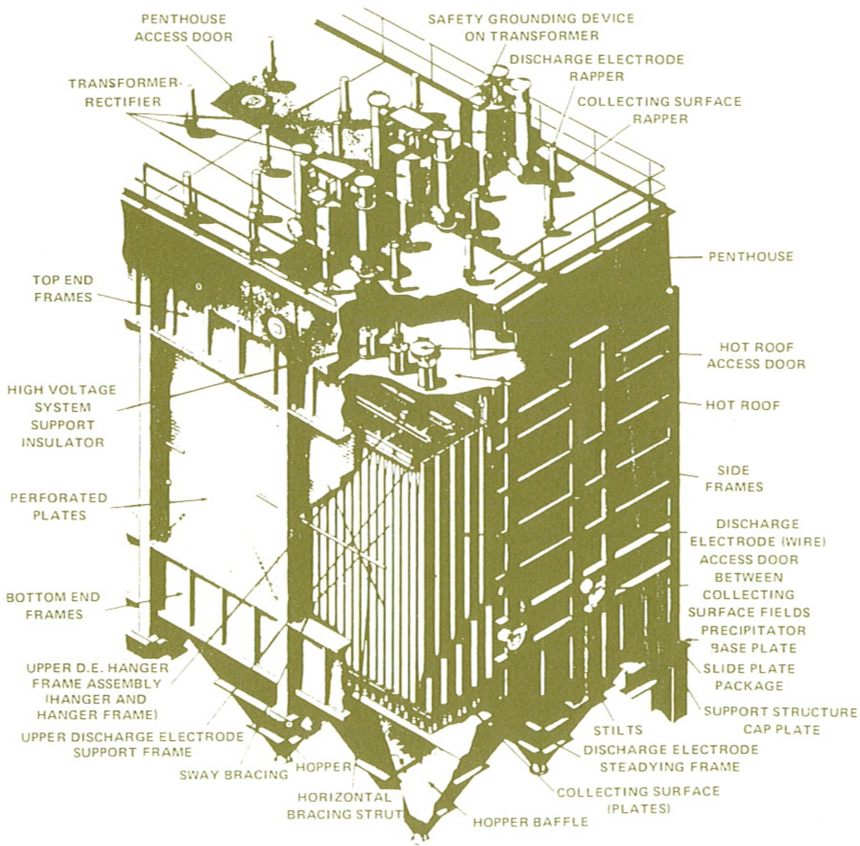
One of the difficulties confronting many of the worldís power stations, is that they were designed with electrostatic precipitators at a time when emission limits were set at a level above those that are currently acceptable. Also the characteristics of coals that are presently being used may well be different to those of the coals for which the plant was originally designed. Means of overcoming these difficulties in order to comply with reduced emission limits have been addressed in a number of ways, including the use of a flue gas additive to modify the characteristics of the fly ash and thus make it easier to collect. Alternatively, relatively simple, low cost modifications to the electrical charging system of the precipitator have been adopted as a means of significantly improving the collection efficiency.

Early experience with electrostatic precipitation of Australian coals, fired in pulverised fuel fired boilers resulted in poor collection efficiencies. This was largely due to inexperience with Australian coals, the precipitator designs being based on experience with northern hemisphere coals having vastly different properties. Subsequent precipitators commissioned in Australia during the 1960s and early 1970s were designed for a then existing more liberal emission limit and for boilers using largely raw coal with ash contents exceeding 30%. These precipitators by and large complied with emission requirements, but gave the international impression that fly ash produced by Australian coals was difficult to collect in electrostatic precipitators, compared to many northern hemisphere plants using high sulphur coal.

Australian export thermal coals are beneficiated to a controlled ash level of the order of one-third or less than coals used in many Australian power stations. In consequence they have completely different ash characteristics and cannot readily be compared to coals used in the power industry within Australia. Nevertheless, Australian coals have developed a reputation for being difficult to collect in electrostatic precipitators. This was often thought to be due to the low sulphur content of Australian coals, which in itself was considered to be a considerable virtue for all other aspects of utilisation. However, experience with Australian coals has shown that in most cases satisfactory electrostatic precipitation performance can be achieved.

CONCLUSIONS

1. Electrostatic precipitators continue to be the main means of collecting fly ash from the worldís coal fired power stations.
2. Many factors influence the performance and behaviour of an electrostatic precipitator, such as the coal being used, the design of the plant, the conditions of operation and the emission limit applied to the plant by control authorities.
3. Although sulphur content can be a useful indicator of precipitator performance for many high sulphur content coals originating from other areas of the world, this is not necessarily the case for Australian bituminous coals .
4. The collection efficiency can be affected by a number of other factors related to the fly ash characteristics, the precipitator design and the operating conditions.
5. The use of a suitable additive to the flue gas and/or the installation of enhanced electrical energisation onto the precipitator can improve performance significantly.
6. Many of Australia's environmentally preferred, low sulphur export thermal coals have been found to perform satisfactorily in electrostatic precipitators.



TYPICAL WIRE AND PLATE PRECIPITATOR COURTESY OF RESEARCH-COTTRELL INC

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