ELECTROSTATIC PRECIPITATORS FOR RESOURCE RECOVERY PLANTS

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ABSTRACT

Incineration of municipal waste has been practised for about 30 years and is increasingly becoming the preferred method for the elimination of solid waste. The majority of incinerators utilize electrostatic precipitation for control of particulate emissions. Precipitators have here proven that they can reliably meet the strictest emission standards when sized and designed for the characteristics of the incineration process. Parameters of importance for the sizing and design of precipitators for incinerators for burning of municipal waste are reviewed. The occurrence of considerable temporal variations in precipitator emission with little or no correlation to registered plant data is illustrated. Further, the occurrence of corrosion at law gas temperatures and high gas temperatures is discussed. Problems in connection with the extraction of dust from precipitators are also dealt with.

INTRODUCTION

In densely populated countries, incineration is increasingly becoming the preferred method for hygienic and economic elimination of solid waste, with reduction of its volume by more than 90 percent to an inert, solid residue or slag.

In Europe, mass burning of municipal waste in a refractory or water wall furnace with a heat recovery boiler has been practised successfully for about 30 years. In West Germany alone, there are today about 45 resource recovery plants which burn the municipal waste produced by approximately 30 percent of its 62 million population [1].

In the United States, scarcity of land for sanitary landfill and concern with water pollution from the leachate as well as increased energy costs have led to installation of resource recovery plants at a rate which has accelerated markedly in the last few years.

Particulate emission standards — more or less strict — must be met, and some countries further require control of gaseous emissions. In West Germany, for instance, regulations (TALuft 1974) for incinerators burning more than 750 kg of refuse per hour (1650 lb/hr) require particulate emissions of max. 100 mg per normal cubic meter of wet gas, referred to 11 percent O₂. This corresponds to approximately 0.055 grains per cubic foot of dry gas at 12 percent CO₂. West German incinerator installations built after 1974 are further required to control gaseous emissions of HCl and HF to respectively 100 mg (measured as Cl⁻) and 5 mg (measured as F⁻) per normal cubic meter of wet gas referred to 11 percent O₂. In most cases this is accomplished by absorption, utilizing a wet scrubber downstream of the precipitator. Recently, dry scrubbing methods have also been introduced.

PARTICULATE CONTROL METHODS

The large majority of the European municipal refuse incinerators utilize electrostatic precipitators for control of particulate emission. At the previously mentioned 45 West German waste burning plants, precipitators are used for 95 percent of the incinerators.

A considerable amount of experience in the application of precipitators to incinerators for municipal waste has been accumulated through the years. Today, electrostatic precipitation for this special application is a well-proven method, which with certainty continuously, and
with high reliability, can meet the strictest emission standards when the precipitator is properly sized and designed for the characteristics of the process.

Fabric filters have been used directly after the incinerators in only a very few cases due to the high temperature and the corrosive nature of the gases, as well as the risk of damage to the filter medium from the occasionally occurring unburnt, incandescent particles.

Venturi scrubbers have been used for particulate control in a few cases. They have the advantage of being able to simultaneously remove a major part of the gaseous emissions (HCl, HF, SO₂) where this is required. However, they require large pressure drops with correspondingly high power consumption to meet present day particulate emission standards.

**ELECTROSTATIC PRECIPITATION**

Economic and successful application of electrostatic precipitators to municipal refuse incinerators, with emission standards being met continuously without unscheduled outages, requires that the singular characteristics of the process are taken properly into account when sizing and designing the precipitator. One of the key factors here is the variability of the process parameters.

The composition of the refuse burnt, the design of the incinerator, and the way in which it is operated all have a pronounced effect on the emission from the incinerator to the precipitator.

The refuse is often a mixture of municipal and industrial waste, and large variations, of seasonal as well as of other nature, in quantity, composition, moisture content, and heating value of the refuse occur.

Table 1 shows typical values for some of the parameters of importance for the sizing and design of a precipitator for an incinerator burning municipal waste.

Two other parameters of particular importance for precipitator design are particle size distribution and electrical resistivity of the fly ash.

Figure 1 shows particle size distribution curves for fly ash from four different plants A, B, C, and D, while the photo Fig. 2 shows fly ash in enlargement from plant D. As seen from Fig. 1, large variations in mass median particle diameter from plant to plant occur.

Though the fly ash measured by median particle size is generally rather coarse, it is also well dispersed, containing significant amounts of very fine as well as very coarse particles. A high content of fine particles increases the necessary treatment time of the gas in the precipitator due to the lower migration velocities of fine particles than of coarse particles under the influence of the electric fields in the electrode systems.

A high content of very coarse particles, often consisting mainly of silica, increases the risk of excessive abrasion and, therefore, requires limitation of the gas velocity in the precipitator.

The electrical resistivity of the fly ash is determined by the physical and chemical properties of the ash and the gas surrounding it. The resistivity ideally should be in the
FIG. 2 FLY ASH FROM PLANT D

range $10^6$ to $10^{10}$ ohm·cm. Too low a resistivity may cause dust already deposited on the collecting electrodes of a precipitator to be reentrained into the gas stream. If the resistivity becomes too high, i.e., above approximately $10^{11}$ ohm·cm, the electrical conditions in the precipitator are upset and precipitator performance deteriorates.

Figure 3 shows resistivity curves for fly ash from plants A, B, C, and D. The curves exhibit a maximum around 250 - 300°F, and have a rather steep back. As seen there may be considerable variation in the resistivity level of fly ash from different plants.

In the temperature range 400°F to 575°F, which usually applies to precipitators for incinerators for municipal waste, the resistivity of the fly ash does not as a rule present any difficulties for electrostatic precipitation.

In spite of the efforts by the incinerator designer to ensure complete combustion, the fly ash always contains smaller or larger quantities of unburnt combustible particles. Such particles with a high carbon content have a low electrical resistivity and, therefore, after precipitation onto the collecting plate until rapping, and the combustible particles are, therefore, exposed to reentrainment into the gas stream, necessitating the use of moderate gas velocities in the precipitator. Typically, gas velocities in the range 2-3 ft/sec are chosen.

Figure 4 shows in the form of a curve the results of 32 particulate emission measurements made around the clock over a period of 5 days (120 hours) after the precipitator at plant B [2] with the incinerator burning a mixture of two parts municipal waste and one part industrial waste at a rate of 19,000 lbs per hour.

Each of the emission measurements covers a period of approximately two hours with a net sampling time of 90 minutes at 12 measuring points evenly distributed over the cross-section of the duct after the precipitator. The dust measuring apparatus utilizes an “in stack” filter corresponding to EPA test method No. 17.

The full line curve shows particulate emission in grains per standard cubic foot of dry gas at 12 percent CO₂, while the broken, dot and dash, and dotted line curves show gas flow, gas temperature, and CO₂ content of gas, respectively, as measured in the tests.

The particulate emission exhibits extremely large variations, and these have little or no correlation with the measured gas data, or with other recorded plant data for that matter.

The occurrence of such large temporal variations in the emission, not related to any registered variations in fuel composition and plant operation, must be taken duly into account in the sizing of precipitators for municipal refuse incinerators in order to achieve satisfactory precipitator performance year in and year out over the lifetime of the installation. In this connection, of course, it is important whether the prescribed particulate emission limits are defined as a two-hour average as in some countries, or as monthly average, as in others.

LOW TEMPERATURE CORROSION

The gases leaving incinerators are characterized by having a high moisture content, typically 10-15 percent H₂O by volume, and in addition containing significant
amounts of hydrogen chloride as well as other corrosive and harmful gases, particularly sulfur dioxide and hydrogen fluoride. Typical ranges for some of these constituents of the gas are given in Table 2.

Further, the fly ash from incinerators often contains considerable amounts of water soluble alkalies and chlorides (refer to Table III) showing chemical analysis of fly ash captured in the precipitators at Plants A, B, C, D, E, and F.

The high moisture content of the gas, its content of corrosive agents, particularly hydrogen chloride, and the water soluble salts in the dust combine to create an environment in the precipitator with considerable potential for corrosion.

In connection with incinerator startup and shutdown, the gas temperature in the precipitator can be below the acidic dew points, and hydrochloric acid, and to a minor degree also sulfuric acid, are then precipitated from the gas and start to attack the precipitator internals.

Further, moisture from the gas at low gas temperatures can be absorbed by the hygroscopic salts in the dust, also at gas temperatures above the water dew point, thereby causing corrosion, for instance at “cold spots” in the precipitator caused by locally insufficient heat insulation.

To minimize low temperature corrosion, the precipitator must be properly heat insulated and furnished with bottom hopper heating. The periods of low gas temperature at plant startup and shutdown should be made as brief as possible. Further, the gas temperature in the precipitator at normal operation should not be below 400°F, and preferably it should be above 450°F.

It would not be practical, nor economical, to manufacture all the parts of the precipitator from corrosion-resistant steel. For the discharge electrodes, however, with their long-term corona emitting properties being totally dependent upon maintaining the geometry of sharp or small curvature elements, the use of stainless acid-resistant steel is justified. Also, the use of collecting electrodes made from gauge 16, or still better gauge 14, plate is good practice.

**HIGH TEMPERATURE CORROSION**

It is not only during startup and shutdown that the precipitator is exposed to corrosion. At a number of precipitator installations, which have been operated at high gas temperatures for prolonged periods, i.e., at gas temperatures above 575°F, a special form of corrosion occurring during operation has been experienced.

This so-called high temperature corrosion attacks the precipitator internals, particularly the collecting plates, and has in some cases necessitated complete replacement of all the collecting plates after a few years of operation.

Investigations made in Germany [3, 4] have shown that this type of corrosion is caused by alkali and zinc chlorides which, in reaction with other compounds in the dust, form a highly corrosive melt at the elevated gas temperature. When the precipitator is cold, the solidified melt can be observed as a hard coating on the collecting plates.

The corrosion may first appear in the outlet field, where the alkalies and chlorides, which are associated with the finer particles, occur in higher concentrations than in the inlet field, due to the particle size selectivity of electrostatic precipitation. Table 4 with chemical analysis of dust scraped from the collecting plates at the inlet end and the outlet end, respectively, of the precipitator at plant C illustrates this effect.

Increased refuse throughput, high heating value of the refuse, and fouled boiler tubes may raise the gas temperature sufficiently to cause high temperature corrosion. Also, temperature stratification of the gases entering the precipitator, for instance originating from the design of the heat recovery system, may cause this type of corrosion.

In order to minimize the risk of high temperature corrosion, the inlet gas temperature to the precipitator should preferably be maintained below 535°F during normal operation and should not be allowed to exceed 575°F for any appreciable length of time.
Plant B
Test Series 1

Emission Standard: max $10.4 \times 10^{-2}$ gr/scf
dry at 12% CO$_2$ monthly average

FIG. 4 PARTICULATE EMISSION AND GAS DATA AFTER PRECIPITATOR OVER A PERIOD OF
5 DAYS AT PLANT B
FIG. 5 TROUGH TYPE BOTTOM HOPPER WITH SCREW CONVEYOR AND AIR SLUICE

TABLE 1 TYPICAL DESIGN PARAMETERS FOR PRECIPITATORS FOR INCINERATORS FOR MASS BURNING OF MUNICIPAL WASTE.

<table>
<thead>
<tr>
<th>Waste</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>30 - 40%</td>
</tr>
<tr>
<td>Non-combustibles</td>
<td>25 - 35%</td>
</tr>
<tr>
<td>Combustibles</td>
<td>30 - 40%</td>
</tr>
<tr>
<td>Heating value</td>
<td>2000 - 4500 BTU/lb</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solid residue</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Slag</td>
<td>500 - 600 lbs per ton of refuse</td>
</tr>
<tr>
<td>Fly ash</td>
<td>25 - 75 lbs per ton of refuse</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gas</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gas flow:</td>
<td>75 - 105 scf per lb of refuse</td>
</tr>
<tr>
<td>Moisture content :</td>
<td>10 - 15% by volume</td>
</tr>
<tr>
<td>Grain loading</td>
<td>1 - 3 gr/scf</td>
</tr>
</tbody>
</table>
TABLE 2 RANGES FOR CONTENTS OF HCl, HF, AND SO₂ IN GAS FROM CINERATORS

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>HCl, ppm</td>
<td>400 - 1600</td>
<td></td>
</tr>
<tr>
<td>HF, ppm</td>
<td>10 - 20</td>
<td></td>
</tr>
<tr>
<td>SO₂, ppm</td>
<td>100 - 700</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 3 WATER SOLUBLE SALTS IN FLY ASH FROM PLANTS A, B, C, D, E, AND F

<table>
<thead>
<tr>
<th>Water soluble</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na₂O %:</td>
<td>3.9</td>
<td>2.12</td>
<td>3.22</td>
<td>3.80</td>
<td>5.44</td>
<td>3.13</td>
</tr>
<tr>
<td>K₂O %:</td>
<td>11.6</td>
<td>3.22</td>
<td>4.73</td>
<td>7.68</td>
<td>6.86</td>
<td>4.90</td>
</tr>
<tr>
<td>Cl⁻ %:</td>
<td>12.7</td>
<td>5.15</td>
<td>8.00</td>
<td>9.83</td>
<td>8.65</td>
<td>7.70</td>
</tr>
</tbody>
</table>

TABLE 4 CHEMICAL ANALYSIS OF DUST SCRAPED FROM COLLECTING PLATES AT PLANT C

<table>
<thead>
<tr>
<th>Water soluble</th>
<th>Inlet</th>
<th>Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na₂O %</td>
<td>2.06</td>
<td>5.60</td>
</tr>
<tr>
<td>K₂O %</td>
<td>1.85</td>
<td>6.70</td>
</tr>
<tr>
<td>Cl⁻ %</td>
<td>5.12</td>
<td>13.00</td>
</tr>
</tbody>
</table>

DUST EXTRACTION

Also the dust extraction and transport systems for the precipitator installation must be carefully designed if the desired high degree of reliability is to be achieved.

Problems with dust removal have been encountered at many installations. Such problems are often due to selection of undersized or less suitable dust extraction and dust transporting equipment, and may stem from adherence to traditions inherited from other industries or from too much concern for initial costs at the expense of operation and maintenance costs.

By using trough type bottom hoppers furnished with heating elements, and having continuous extraction of the dust by means of a screw conveyor with a proper air sluice arrangement, e.g., as shown in Fig. 5, instead of for instance using unheated pyramidal hoppers with discontinuous pneumatic dust extraction, hopper plugging problems can be effectively eliminated.

Also, the subsequent dust conveying system must be properly sized and designed with due regard to the special nature of the dust, the occurring load variations, surges, startup and shutdown conditions, etc.

Further, proper operation of the dust removal system is important. When, for instance, the incinerator is shut down for a period, the dust removal system should be operated long enough to empty it, in order to prevent packing or solidification of dust in the equipment during the standstill.
CONCLUSION

Precipitators are used for the large majority of incinerators for municipal waste. They are here capable of meeting the strictest emission requirements when properly sized and designed for the characteristics of the incinera-
tion process. The variability of the process parameters in particular must be taken into account. The resistivity of the fly ash as a rule does not present problems in the temperature range 400°F to 575°F usually applying to precip-
itators for incinerators. Effective precipitation of unburnt combustible particles in the fly ash necessitates the use of moderate precipitator gas velocity. Ideally, the precipitator should be operated in the temperature range 450°F to 535°F to minimize the risk of low or high temperature corrosion.

REFERENCES