CONDITIONING REFRACTORY FURNACE GASES FOR ELECTROSTATIC PRECIPITATOR APPLICATION

R. L. BUMP
The Wheelabrator Corporation
Mishawaka, Indiana

INTRODUCTION

The impact of the solid waste problem, coupled with increasingly stringent air pollution codes, has posed a dual challenge for municipal planners and designers in recent years. In those communities where incineration is indicated as the solution not only must consideration be given to larger, better designed, more sophisticated plants, but air pollution control equipment must be provided to meet standards of emission which did not exist just two years ago. Here then is the dual challenge — more sophisticated incineration plants and air pollution control equipment, specifically electrostatic precipitators, on an application where there is no domestic experience.

You are aware, from published information as well as reports from numerous visitors abroad, that the European technology in the field of incineration has progressed at a considerably faster pace than ours due, primarily, to sheer necessity as a result of population density and unavailability of landfill area. Moreover, we have utilized the refractory furnace as our principal incineration device rather than the water-wall furnace — boiler approach more prevalent in other parts of the world. Needless to say comparative economies enter into this basic difference. The large plants in Eastern Europe — and there are quite a number in Japan — are not experimental prototypes. Moreover, they are equipped with electrostatic precipitators which are dependable, proven in performance, and operate in most cases at collection efficiencies in excess of 99 percent. This is well above the present requirements in the United States. It is also worthwhile to mention that experience has dictated the need for a number of design considerations in the application of precipitators to incinerator gases which set it apart from other applications. It is not the intent of this paper to discuss this aspect.

Although larger municipalities will undoubtedly be installing the water-wall-furnace-boiler type of plant, it is certain we will be seeing many refractory furnaces in the years ahead. The use of an electrostatic precipitator with a refractory furnace poses an entirely different set of circumstances than in the case of a boiler system. By cooling the gases, the boiler is designed to yield the conditions required for the proper application of an electrostatic unit — not so in the case of a refractory furnace. The result, then, in the case of a refractory furnace is a need for a dependable and proven system to handle the gases as they emanate from the final stage of combustion and prior to entering the precipitator. The importance of this function has been somewhat minimized to date, and since performance of the electrostatic precipitator can be no better than the job done on the gas before it enters the precipitator, we wish to describe how best this can be done.

Basically there are three systems which can be used to precondition the high temperature gases.

Figure 1. An evaporation cooling tower which is a separate piece of equipment may be used. In this case the furnace design terminates with the last combustion chamber and the tower is installed as a separate piece of equipment. The cooling is done entirely by water.

Figure 2. The furnace design may be such as to accommodate a combination water-air system. In this scheme
the hot gases are cooled partially by water and partially by air infiltration.

Figure 3. The final system is one in which the furnace design is such that the cooling is done entirely with water but in the back end of the furnace rather than in a separate evaporation cooling tower.

In order to familiarize you with these systems we will describe a typical installation of each which is in service:

**SYSTEM No. 1. EVAPORATION COOLING TOWER**

This arrangement can be seen typified at the Castle Bromwich Refuse Disposal Works at Birmingham, England (Fig. 4). The gas cleaning installation, which is the first of its kind to be associated with refuse disposal plant in the United Kingdom, consists of a Howden/Lurgi electrostatic precipitator preceded by a Peabody conditioning tower and followed by induced draft fans.
This plant was designed in conjunction with Heenan & Froude Ltd., Worcester, to clean the flue gases from the incineration process to meet the requirements of the Birmingham Corporation.

The high temperature waste gases from the incinerators, which may rise to a peak temperature of 2050°F, are humidified and cooled in the conditioning tower by the injection of water through a series of high pressure atomizing nozzles. The quantity of water injected into the system is regulated by automatic controllers actuated by temperature signals from thermocouples suitably located in the gas stream.

*Normal temperature and pressure.

The conditioned gases then pass through distribution plates into the precipitator, in which the dust is extracted dry.

The guaranteed dust collecting efficiency of the plant is 98.3 percent when handling a gas volume of 112,700 cfm at 482°F which gives an outlet dust concentration of less than 0.06 grains/cu ft at N.T.P.* with an inlet concentration of 3.5 grains/cu ft N.T.P.

The dry dust falls from the precipitator’s hoppers into rotary air locks, which provide a gas seal and control the dust feed into the flushing funnels where the dust is wetted and discharged into a culvert en route to the settling tank. The water which is clarified in the settling tank is recovered and pumped back to the funnels by a “Megator” pump, with one stand-by.

The gas cleaning system is shown diagrammatically in Fig. 5.
FIG. 3 WATER COOLING SYSTEM

FIG. 4 PRECIPITATOR AND DUCTING TO CHIMNEY
FIG. 5 SCHEMATIC LAYOUT OF FUME CLEANING PLANT
EVAPORATION COOLING TOWER: DESIGN DATA

Purpose: To cool and humidify the incinerator gases down to 482 F prior to cleaning in the electrostatic precipitator.

Peak Gas Flow at inlet to tower: 234,500 cfm at 2050 F
Gas Flow at outlet from tower: 112,700 cfm at 482 F (1300 F at Tower inlet).

Water Spray Guns: 44 Type A Peabody wide range atomizing assemblies.

Water quantity for conditioning: Quantity required approximately 90 gpm. Pump designed to handle 115 gpm at 950 ft head.
Water quantity for flushing sprays: 90 gpm at 80 ft head.

Temperature control equipment: Honeywell Electronic Temperature Controller with circular chart and pneumatic proportional control.

Pumps: High pressure pumps . . . Harland
       Low pressure pumps . . . Sigmund

The purpose of the tower is to cool and partially saturate the gases prior to entering the precipitator. Since the gases from the incinerator will vary in temperature and quantity, depending on the burning rate, the water spray control equipment has been designed to operate over a wide range of inlet temperatures, up to a maximum of 2050 F.

To ensure optimum precipitator performance the gas temperatures should remain reasonably constant within the range 470 to 520 F. and to facilitate this, the correct quantity of water to cool the gases entering the tower with temperatures up to 2050 F. must be injected into the tower. This is achieved by the use of Peabody wide range atomizing gun conditioning tower equipment.

The tower is 18 ft 0 in. diameter of mild steel construction, refractory lined to protect against corrosion, with gases entering the tower at the base and discharging at the top into the connecting duct to the precipitator.

Immediately after the gases enter the conditioning tower they pass upwards during which time the atomized water will be evaporated and cool the gases down to the required temperature.

The method of supplying varying quantities of water to the tower is explained as follows:

There are two (2) high pressure centrifugal pumps, one stand-by of Harland Engineering Co. manufacture, drawing water at a rate of 115 gpm and delivering this to the supply line at a head of 950 ft. Initially the high pressure water passes through a fine strainer which removes all particles in the water stream greater than 0.001 in. The water then passes through a Honeywell control valve, and a differential control valve, referred to as valve V.7 and V.6 respectively on Flow Diagram, Fig. 6.

The water is then carried to the conditioning tower by means of high pressure galvanized piping and the required quantity is discharged into the tower by means of the atomizing nozzles.

The quality of atomization remains constant with variations in the actual amount of water sprayed, since regulation of this quantity is obtained by controlling the amount of water returned from the atomizing nozzles. The water, when sprayed into the tower, is atomized so that the particle size of the free water will be in the region of 50 microns.

Water at a pressure of 300 to 350 psi is fed to the atomizing assembly from the multi-stage centrifugal pump, driven by a 60 h.p. motor running at 2950 r.p.m. The atomizing guns are supplied from the ring mains located around the outside of the tower, and connected to the spray headers by means of flexible hoses.

Water flows into the actual tip of the atomizing assembly through tangentially disposed slots. These tangential slots feed the water into the whirling chamber from where the atomized water is discharged through the orifice. If, however, the control valve (Valve V.8.) in the return line on the spray assemblies is closed, the whole quantity of water fed to the atomizer is discharged, but on this return valve being opened, some of the water is bled away from the atomizer, thus reducing the actual quantity sprayed.

This reduction in spray water quantity is effected without reducing the quantity fed to the whirling chamber which means that considerable load variations can be achieved without affecting the quality of the spray. Automatic control is obtained by means of the Honeywell Control Ltd. instrumentation fitted in association with the conditioning tower.

It will be seen, therefore, that the amount of water sprayed into the tower is effected by opening or closing the automatic valve V.8. This valve is a diaphragm operated, pneumatically controlled valve, and it receives the pneumatic signals from an indicating, recording and controlling potentiometer.

Thermocouples are installed at the inlet and outlet to the conditioning tower, and it is the thermocouple on the
outlet of the conditioning tower which carries out the main controlling, with a set point of 482 F.

If, therefore, the potentiometer senses a rising temperature above the pre-set point, signals will be transmitted to the return line valve, V.8, to open or close the valve and vary the quantity of water sprayed into the conditioning tower.

While the gases are entering the conditioning tower at a temperature in excess of 482 F, water will be required for cooling purposes. However, if the temperature drops below 482 F, no water will be required. Therefore, the inlet potentiometer will note this temperature, and will shut the valve V.7 and open the valve V.4. Water will then be discharged back into the re-circulation tank, by-passing the conditioning tower. The reverse, of course, will happen if the temperature to the conditioning tower rises above 482 F.

A valve is also incorporated in the system to maintain a constant difference between the supply line pressure and the return line pressure; by opening or closing to increase or decrease the water supply pressure proportionately in response to increase or decrease in the water return pressure imposed on the valve diaphragm.

Two (2) rows of flush down spray nozzles are also provided in the tower. They are supplied with 90 gpm of water at a nominal pressure at the spray nozzles of 15 to 20 lbs psi and are intended to be used daily, when the temperature of the tower is at its minimum. By flushing down the sides of the conditioning tower, the water will remove dust, paper, etc., so that a continuous build-up does not occur.

FIG. 6 FLOW DIAGRAM
It is not intended that these sprays be in continuous operation, or operated while high pressure water is being injected into the tower for means of cooling. The water from the flush down nozzles would drain out by means of four drain holes in the gulley of the tower, and then into culverts by means of four rubber lined pipes, and nonreturn valves. Each spray header is fitted with a stainless steel flood jet nozzles manufactured by Delavan Watson Ltd. The top of the tower showing the inlet to the precipitator is shown on Fig. 7.

**SYSTEM No. 2: WATER EVAPORATION–AIR INFILTRATION**

Another means of preconditioning the gas from a refractory incinerator prior to treatment in an electrostatic precipitator is shown in Fig. 8. This plant is located at Tourcoing, France. The refractory furnace has a capacity of 100 tons of municipal refuse per day and was designed by Stein and Roubaix. The intent in this case was the elimination of the separate evaporation cooling tower and, due to a limitation on availability of a water supply of adequate purity, a combination air-water cooling system was devised.

This method is a two-step cooling process where water sprays are used to cool the exhaust gas from approximately 1300 F to 900 F and where ambient air is added to cool
FIG. 9 AIR-WATER SYSTEM CONTROL
from 900 F to approximately 560 F before entering the precipitator. Selection of the intermediate temperature (900 F in this example) affects the amount of spray water, the volume of cooling air, and the resulting total gas volume. Enough water must be evaporated to raise the water dew point of the gas to between 115 F and 125 F.

Back-flow nozzles are used for the water spray system with controls shown diagrammatically in Fig. 9. The spray nozzles are installed in the back end of the incinerator and the refractory-lined settling chamber following the burning zone becomes the evaporation cooler.

Further downstream in the system the cooling air is blown into the exhaust gas through a manifold which directs the cooling air up-stream against the main gas flow.

Both water and air quantities are governed by the same temperature signal from the duct just ahead of the precipitator. As a result temperature changes in the gas stream are counteracted by changes in spray water and cooling air at the same time.

**SYSTEM No. 3: EVAPORATION CHAMBER IN INCINERATOR**

In the case of a new refractory furnace it will often be more practical to give consideration to doing the job which the separate dry evaporation cooling tower does in the incinerator itself. Economics, layout and common sense point in this direction. It must be emphasized however, that the same design consideration which go into the tower design must be followed by the incinerator designer if the system is to function properly. Three basic points must be given proper attention: 1) Adequate residence time for the gas-water mixture. 2) A high pressure water spray system to insure total evaporation of the water. 3) A good control system sensitive to changes in burning zone exit temperature.

**COMPARISON OF CONDITIONING SYSTEMS**

To give an example of how the conditioning systems described influence the system design and size of precipitator required for each we refer to Table I.

With identical incinerator exhaust conditions from a typical 250-ton furnace it can be seen that the "Water and Air Cooling" system results in a 57 percent larger gas volume to treat. Examination of Table I indicates that the "Water Cooling" system results in a higher water dew point which is favorable to the precipitator and results in a less conservative sizing factor for that system. The end result is that the "Water and Air Cooling" system requires a precipitator of 77 percent larger collecting surface area to do the same collection job as the "Water Cooling" system precipitator. A further point on the "Water and Air Cooling" system is that the outlet or residual dust load leaving the precipitator (point 4.3) must be lower than that for the "Water Cooling" system based on the same efficiency required by incinerator conditions. In other words, the more dilution of the gas stream that occurs, the lower the discharge residual from the precipitator to meet a process weight guarantee.

The "Water and Air Cooling" system has two (2) strong advantages. The expensive refractory and acid brick lined evaporation cooler is eliminated, and the visible vapor plume at the stack discharge is reduced because of the lower dew point of this system.

The control and mechanical system of the "Water and Air Cooling" arrangement is more complex than that for

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>COMPARISON OF CONDITIONING SYSTEMS</th>
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<tbody>
<tr>
<td></td>
<td>Water only</td>
</tr>
<tr>
<td>1.0 Incinerator exhaust</td>
<td>169,500 cfm at 1310 F</td>
</tr>
<tr>
<td>1.1 Gas volume</td>
<td>169,500 cfm at 1310 F</td>
</tr>
<tr>
<td>(250 ton fce.)</td>
<td>104 F</td>
</tr>
<tr>
<td>1.2 H2O Dewpoint</td>
<td>104 F</td>
</tr>
<tr>
<td>1.3 Dust load</td>
<td>0.241 grains/acf</td>
</tr>
<tr>
<td>1.4 Precipitator Size</td>
<td>X</td>
</tr>
<tr>
<td>1.5 Precipitator Outlet</td>
<td>120 F</td>
</tr>
<tr>
<td>2.0 Conditioning System</td>
<td>205,200 cfm at 572 F</td>
</tr>
<tr>
<td>2.1 Spray water</td>
<td>40 gpm</td>
</tr>
<tr>
<td>2.2 Ambient air</td>
<td>45,400 cfm at 68 F</td>
</tr>
<tr>
<td>3.0 Precipitator Inlet</td>
<td>205,200 cfm at 572 F</td>
</tr>
<tr>
<td>3.1 Gas volume</td>
<td>130,150 cfm at 560 F</td>
</tr>
<tr>
<td>3.2 H2O Dewpoint</td>
<td>150 F</td>
</tr>
<tr>
<td>3.3 Dust load</td>
<td>0.20 grains/acf</td>
</tr>
<tr>
<td>3.4 Precipitator Size</td>
<td>X</td>
</tr>
<tr>
<td>3.5 Precipitator Outlet</td>
<td>120 F</td>
</tr>
<tr>
<td>4.0 Power required -</td>
<td>350 KVA</td>
</tr>
<tr>
<td>4.1 Gas volume</td>
<td>130,150 cfm at 560 F</td>
</tr>
<tr>
<td>4.2 H2O Dewpoint</td>
<td>150 F</td>
</tr>
<tr>
<td>4.3 Dust load</td>
<td>0.010 grains/acf</td>
</tr>
<tr>
<td>(Residual dust)</td>
<td>0.010 grains/acf</td>
</tr>
<tr>
<td>5.0 Power required -</td>
<td>640 KVA</td>
</tr>
<tr>
<td>5.1 Precip., fans, pumps</td>
<td></td>
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</tbody>
</table>
the “Water Cooling” arrangement since the injection of two cooling media must be regulated.

The comparison cannot end here, since the complete economics of the systems must be thoroughly evaluated before arriving at a decision as to which is best. For the example shown on Table 1, the “Water and Air Cooling” system had a somewhat lower initial installation cost, but a higher operating cost due to the power consumption.

In conclusion we would like to summarize as follows:

1) Proper conditioning of high temperature gas from a refractory furnace is essential to the trouble free operation of an electrostatic precipitator. The resultant gas must not have any free moisture if a dry precipitator is to be used.

2) There are several tried and proven methods of accomplishing the required gas conditioning. These have been described in this paper.

3) Traditional methods of cooling and scrubbing gases from refractory furnaces involving low pressure water sprays, little, if any, control of the spray system and inadequate residence time are not satisfactory for use with an electrostatic precipitator.

Refractory incinerator designers, manufacturers and purchasers are urged to take heed if misapplication and troublesome operation of electrostatic precipitators on refractory furnaces is to be avoided.

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