What Price Incineration Air Pollution Control?

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Abstract

This paper takes an objective but statistical approach to seventeen possible combinations of air pollution control equipment for municipal incinerators. Both refractory-lined and water-walled furnaces of identical capacities are followed by gas tempering systems, where required, and thence to mechanical cyclones, electrostatic precipitators, or bag filters. Additional alternates include the introduction of furnace gases directly to either a refractory-lined baffled spray chamber or to a wet scrubbing system. Thus, each furnace unit is equipped with a separate and independent air pollution control system.

Empirical latitude applies in certain design areas, but experience is combined to draw conclusions. Thus, assessment of capital and operating costs of incinerator air pollution control equipment indicates several entirely possible solutions to a universally acknowledged problem.

Introduction

Increasing attention is being directed to the design, purchase and operation of equipment which will promote the municipal incinerator as the best means of refuse disposal, one that is completely acceptable to the surrounding community.

A wide variety of power and water costs, labor charges, interest rates and equipment capital costs first prompts the selection of a hypothetical 500 ton per day incinerator plant comprised of two 250 ton per day refractory-lined furnaces. These furnaces are of the continuous-feed type, equipped with mechanical stokers. Figs. 1 through 5 depict this layout as well as five independent gas-cleaning systems.

Assuming a market for steam generated in a water-wall incinerator furnace, we show in Figs. 6 through 8 such an arrangement with three individual air pollution control systems. Reduced gas volumes resulting from direct cooling without water spray or air dilution make possible the practicality of high performance gas-cleaning equipment at significantly lower costs [1].

Equipment Selection

Selection of air pollution control equipment as presented herein is based on total amounts of gases to be cleaned from the various sources, as well as a feasible dust loading, to the collector, of 3.5 lb of dust per 1,000 lb of flue gas corrected to 50 per cent excess air. Particle size consist, specific gravity and dust resistivity are constant throughout. The variable nature of incineration operations from day to day suggests the deletion of collection efficiency credit to the spray cooling chambers, since the percentage of large particles collectable therein appears to be less than previously assumed by the industry. Thus, dust emissions to atmosphere, following the individual systems, while they might be lower, would rarely if ever be any higher. Gas volume calculations are
based on refuse composition of 77 per cent combustibles, 18 per cent moisture, 5 per cent non-combustibles, requiring 136 per cent excess air to limit refractory-lined furnace temperature to 1800 F. Refuse of higher non-combustible content is usually encountered, but case example results in higher gas volumes. Calculations for gas volumes leaving water-cooled furnace are based on the use of 50 per cent excess air.

Spray water quantities are calculated on entering mixed-fresh and recirculated water at 150 F and dilution air quantities are calculated on entering air at 80 F. Spray chambers are sized for gases entering at a velocity of 3,000 feet per minute. Scrubber water requirements are based on saturated gases leaving the scrubber at 165 F.

**Cost Parameters**

Water and power cost fluctuations, installation labor differentials and other fixed and variable costs germane to a given geographical area are difficult to specify. In order to assist the reader in realistically evaluating the equipment needed to solve his particular problem, certain constants have been assumed, such as dust loadings leaving the furnace and entering the collector(s). Gas volumes are calculated leaving the furnace and spray cooling chambers. Anticipated stack emissions, based on expected equipment efficiencies are then assigned the various systems, thus giving a reasonable analysis of the equipment needed to conform to different air pollution codes. Construction costs (1) include cost of cooling chamber, ash separating cyclones, strainers, pumps, baffles, collector, and I.D. fan, all as applicable to each alternate. Breechings and stacks are not included. Cooling water (2) and power (3) costs are computed on a 5½ day, 24 hours per day week, 52 weeks per year, at $0.30/1,000 gallons and $0.02/kwhr. Maintenance costs (4) include allowance for replacement of short-life equipment such as fly ash slurry pumps, cyclones, refractory and filter bags. Amortization (5) is based on 4 per cent for 20-year equipment life. Cost of owning and operating (6) is then calculated and shown in each figure as related to each ton of refuse burned. A natural corollary may thus be drawn between local air pollution controls and the cost of meeting them.

**Equipment Description**

**Baffle Spray Chambers**

The baffled spray chamber for installation in the flue gas path downstream from the furnace is normally constructed of conventional refractory material using sectionally supported walls, hung flat arch roofs, and castable refractory spray pond bottoms. The chamber is connected to a furnace by conventional refractory-lined breechings. Within the chambers, two double-tier refractory baffles are installed. Three individual spray headers are provided to flood each pair of baffle tiers with water. The uppermost spray header provides the makeup supply and is piped to a city water source. The middle and lower headers deliver recirculated water from the recirculating system described in the next paragraph. Spray headers are fabricated from stainless-steel pipe and water flow is controlled to vary the quantity of makeup water in accordance with the flue gas flow. The valve controlling the flow of makeup water is positioned by a temperature-sensing device installed in the gas stream leaving the spray chamber.

Water coming off the bottom of the baffles is collected in the castable refractory spray pond bottom. Agitating jets are provided in this location to keep the fly ash in suspension. Immediately outside the refractory enclosure a wet well is provided in a separate pump room to which
Spray pond water flows by gravity. Two circulating pumps are installed in the pump room, with each pump sized to handle one-half of the total flow delivered to the spray headers (half the total flow is makeup water; the other half is recirculated water). One pump then is required to be in operation at any given time. The second pump is a standby. Water discharged from the circulating pumps is piped to a battery of three cyclone separators which concentrate the fly ash slurry. The underflow from these separators (the concentrated slurry) is piped to a residue conveyor or ash hopper for disposal with the plant residue. The overflow, or clarified water, is piped to a wet well. From the wet well, a third pump discharges the reclaimed water through a special strainer back to the spray chamber for reuse. In making the cost studies given herein, a separate spray chamber has been provided for each furnace unit, and each spray chamber is provided with a separate fly ash handling and water reclaiming system as above described.

**Spray Cooling Chambers**

Spray cooling chambers are constructed in essentially
FIG. 5 SYSTEM "E" - SPRAY CHAMBER/BAG FILTER

the same manner as are the baffled spray chambers previously described, except that they do not have refractory baffles. The total amount of water circulated in the spray cooling chamber is not so large as was the case with the baffled spray chamber, the removal of fly ash not being a primary function of this device, and there being no baffles installed which must remain flooded [2]. Where in the baffled spray chamber, total water circulated is about double that required for cooling, the data given herein are based on a water circulation rate of 1½ times the water quantity required for cooling alone. The cost data also include allowances for ash slurry handling pumps, cyclone separators, strainers and piping systems.

Induced-Draft Fans

These fans are selected as standard mechanical draft equipment, and prices are based on the use of double width double inlet units. The equipment costs given include the fan, hydraulic coupling variable speed drive, 440 volt electric motor, and motor starter. Fans have been individually selected for each alternate to comply with the pressure drop data pertinent to each case. The pressure drops include furnace draft losses, allowances for losses through breechings and also the actual catalog
pressure drop information for the type of collector involved.

Wet Scrubber System
In general, a wet scrubber removes dust particles from the gas in which they are entrained by thoroughly dispersing the scrubbing liquid, mixing this mist intimately with the gas and, most important of all, causing the collision of dust particles and water droplets. If these collisions are energetic enough the dust particles penetrate the water droplets and are captured. The more frequently impactions take place, of course, the more dust particles are collected by this mechanism. Both the frequency and the energy of the collisions are increased by giving dust particles and water droplets greater velocities with respect to each other and, in practice, the condition of highly turbulent flow is created to bring this about.

A number of different approaches have been employed, but all have one common factor, which is the expenditure of pressure drop across the scrubber to generate the desired turbulence, and all depend on passing the dust-laden gas through a restriction, or orifice, or a multiplicity of these, to accelerate the gas to high velocity and disrupt its flow pattern.

Factors affecting the performance of a scrubber are the liquid rate and the particle size distribution. Adequate liquid must be provided to insure thorough scrubbing action but an excess will only contribute to energy loss in the system and, in fact, may have a somewhat detrimental "masking" effect. As the size of the particles

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**FIG. 6 SYSTEM "F" - WATER-COOLED FURNACE/CYCLONE COLLECTOR**

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**FIG. 7 SYSTEM "G" - WATER-COOLED FURNACE/ELECTROSTATIC PRECIPITATOR**

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WATER-COOLED FURNACE (TYP.) OF 2,000 T.P.D.
GAS VOLUME: 63,800 A CFM
GAS TEMP: 450°F
GAS A.P.: 2.0° W.C.
DUST LOD: 3.5 lbs/1000 lbs F.G. at 50% E.A.

STACK OUTLET <0.035 lbs/1000 lbs F.G. at 50% E.A.

FIG. 8 SYSTEM "H" - WATER-COOLED FURNACE/BAG FILTER

...grows smaller, their kinetic energy available for droplet penetration and capture also diminishes unless their velocity can be increased. This explains why more pressure drop, or scrubbing energy input, is required to collect a very fine fume than a coarse dust. By the same reasoning, it is easy to see that material having a high specific gravity is somewhat more readily collected than a light dust.

The scrubber depicted in this paper is a flooded-disc scrubber, including mist eliminator and contactor, designed and costed on the basis of 6 inch water column pressure drop and 96 per cent collection efficiency.

Mechanical Collectors

In the involute-type mechanical dust collector, centrifugal force separates suspended particles from the gas for high-efficiency gas cleaning. The gas stream is introduced tangentially to produce a spiralling motion which directs entrained solids to the outer wall. The central core of clean gas is extracted through a concentric outlet tube. The dust continues down the wall of the outer tube into a sealed hopper from which it can be removed without disrupting internal flow.

Materials of construction include corrosion-resistant plate for the fabrication steel portion, structural steel which meets ASTM Specification A-7, and cyclone cones made of heavy-duty gray cast iron.

Recognizing the (particle size) selectivity of the cyclone collector, and assigning the same specific gravity, percentage of particle size consist and dust loading to the collector inlet as with all other dust collectors discussed herein, the following selections were made:

- Size of collector tubes = 30 in.; gas pressure drop, 2.5 in. wc to 2.8 in. wc; and expected efficiency = 78 per cent.

Electrostatic Precipitator

Gases to be cleaned are introduced to the electrostatic precipitator at approximately 600 F and at a predetermined velocity to ensure proper residence time. Designated for 95 per cent efficiency, this precipitator anticipates stack emission in the order of 0.175 pounds of dust per 1,000 pounds of flue gas corrected to 50 per cent excess air. Basically, separation of the suspended particles from a gas by the electrical precipitation process requires three fundamental steps:

1. Electrical charging of suspended particles,
2. Collection of the particles by attraction in an electrostatic field to oppositely charged collecting plates, and
3. Removal of the precipitated material from the collecting plates to a receiving hopper external to the precipitator.

The precipitators described herein are designed to allow for maximum limits of gas volumes and dust loadings usually attendant to incinerator operations. Materials of construction have been selected to minimize the effects of internal corrosion. Erected weights will range from approximately 30 tons each to a high of about 100 tons per precipitator, depending upon the volume of gases to be cleaned in the various systems described in this paper.

Bag Filter

Although somewhat limited in incineration gas cleaning to an application in a West Coast pilot plant, certain design and approximate cost data for the bag filter were obtained from this installation and have been incorporated in this paper.

The equipment described is a reverse-flow, fiberglass unit mounted on a spider framework. Cost of installation,
TABLE 1
ECONOMIC APPRAISAL OF THE COSTS OF CONSTRUCTING, OWNING, AND OPERATING AIR POLLUTION CONTROL EQUIPMENT TO MEET VARIOUS MUNICIPAL INCINERATOR STACK EMISSIONS

<table>
<thead>
<tr>
<th>System</th>
<th>Average Construction Cost (dollars)</th>
<th>Dollars per ton of Refuse Burned</th>
<th>Stock Outlet lb/1000 lb Flue Gas at 50% Excess Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$188,200</td>
<td>$0.77</td>
<td>1.75</td>
</tr>
<tr>
<td>B</td>
<td>270,360</td>
<td>1.23</td>
<td>0.77</td>
</tr>
<tr>
<td>C</td>
<td>400,900</td>
<td>2.10</td>
<td>0.14</td>
</tr>
<tr>
<td>D</td>
<td>501,770</td>
<td>1.21</td>
<td>0.175</td>
</tr>
<tr>
<td>E</td>
<td>712,190</td>
<td>2.00</td>
<td>&lt;0.035</td>
</tr>
<tr>
<td>F</td>
<td>91,800</td>
<td>0.38</td>
<td>0.77</td>
</tr>
<tr>
<td>G</td>
<td>210,300</td>
<td>0.39</td>
<td>0.175</td>
</tr>
<tr>
<td>H</td>
<td>243,000</td>
<td>0.65</td>
<td>&lt;0.035</td>
</tr>
</tbody>
</table>

operation and maintenance are based on an air-to-cloth ratio of 5:1, a bag life of in excess of one year, a maximum inlet temperature of 450°F and a pressure drop of 5 in. wc.

Summary

In no way has it been the intention of this combined paper to arbitrate those many areas of specifics which may contribute to the municipal incinerator air pollution control problem.

Furnace practices, gas-tempering devices, dustloadings to the various collectors, the selection of, and assigned collection efficiencies to, the air pollution control equipment herein, the cost parameters, and finally the stack emissions, are calculated and presented as realistic guides.

The results as shown in Table 1 are indeed interesting. It remains then for the reader to relate not just construction first costs, but the actual cost in dollars per ton of refuse burned, to incinerator stack emissions as they pertain to today's air pollution codes — and tomorrow's. This, then, is the answer to "What price incineration air pollution control?"

References