APPLICATION OF THE ELECTROSCRUBBER* FILTER TO A MUNICIPAL SOLID WASTE INCINERATION PROJECT

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ABSTRACT
The ELECTROSCRUBBER Filter, a high efficiency electrostatic granular filter used to remove particulate in dry form from industrial gas streams, has been applied for the first time to a municipal solid waste incineration project in Pittsfield, Massachusetts. Following an introduction and a discussion of the principles of operation of the filter, a brief description of the 240 ton/day (217 t/day) Pittsfield resource recovery project followed by the design considerations for the ELECTROSCRUBBER Filter and system operation as of December 1981 will be presented.

INTRODUCTION
In the early 1970's, Combustion Power Company developed a moving bed granular filter in order to solve an emissions problem on a fluid bed combustion test unit burning a combination of municipal solid wastes and sewage sludge in its labs. Originally called the DRY SCRUBBER, the unit was first put into commercial practice in 1973 on a small wood waste fired boiler. The success of that installation in removing particulate from the flue gas resulted in applications on other, larger boilers burning both wood and other solid fuels. Other applications, such as lime kilns, coke calciners and steel sinter processes followed. In 1978, as a result of pressures from ever more stringent particulate emissions codes, the granular filter design was significantly improved, both in reduced outlet loading capabilities as well as in simplicity of its operation.

Renamed the ELECTROSCRUBBER Filter, the new design utilized an electrostatic grid to augment the basic collection phenomena of the granular filter, especially on the fine, submicron particulate. A pneumatic media recirculation and ash collection system was included which replaced the previous design's mechanical system. Refinements were also made to the filter's internal configuration. These improvements, as well as certain perceived advantages over alternative emissions control equipment, such as the elimination of fire or explosion hazard, the reduced concern with acid attack (there are no delicate filter bags in the flue gas stream), the very small floorspace requirements, and the relative insensitivity to expected incinerator excursions in temperature, ash resistivity, gas flow, and particulate loading, led to the selection of the ELECTROSCRUBBER Filter for the Pittsfield project. For this resource recovery project, the additional considerations of reliability and especially the promise of virtually 100 percent availability took on added significance in the owner's selection process.

ELECTROSCRUBBER FILTER
PRINCIPLE OF OPERATION

Conceptually, as shown in Fig. 1, the ELECTROSCRUBBER Filter consists of a
cylindrical vessel containing two concentric louvered cylindrical tubes. The annular space between the tubes is filled with pea-sized gravel media. The particulate-laden exhaust gas enters the filter through appropriate breeching and is distributed to the filter face by the plenum section formed by the vessel wall and the outer louver cylinder. Flue gas is passed through the filter media at velocities ranging from 100-150 ft/min (30-45 m/min) and the particulate is removed from the gas stream by impaction with the media. Filtered gases exit through a free-standing exhaust stack on top of the unit.

(Note: Considerations of system layout and required particulate collection efficiency many times dictate that gas flow direction through the filter be reversed.)

To reduce the potential for formation of a filter cake on the face of the filter, and the resulting potential plugging problems and high pressure drop, the filtering media is continuously moved downward in plug or mass flow at 6-10 ft/hr (2-3 m/hr). The resulting churning action across each louver opening prevents a filter cake from forming. To provide complete cleaning of the louver face, the...
louvers are designed so that some of the media is pushed through each louver opening thus preventing any bridging or buildup of particulate material. The particulate-laden media is continuously removed at the bottom of the module where it is transported by a pneumatic conveying system to the de-entrainment section of the system. The action of the media being transported vertically in the pneumatic lift pipe separates the particulate from the media so that the particulate can be pneumatically removed from the de-entrainment section for pneumatic transport to a particulate separation and storage silo. The cleaned media then drains by gravity from the de-entrainment section and is returned to the top of the unit for recycling.

The ELECTROSCRUBBER Filter module is designed to operate full of media at all times. To accomplish this, the media overflow vessel, as shown in Fig. 1, is used to assure that the freeboard section remains full and to eliminate any differential media flow down to the two media return pipes. Excess media is returned from the media level control section by the media overflow pipe to the media inventory hopper. Media from this hopper is continuously "trickle" fed back into the media lift pipe to provide an oversupply of media to the media overflow vessel to assure that the module is always completely full of media. Air is piped from the media lift air blower into the lower portion of the media overflow pipe to provide purge air up this pipe which prevents any residual dust from re-entering the top of the filter.

An electrical conductor is positioned within the media bed of the unit as shown in Fig. 2. The conductor resembles a cage formed from a series of vertical rods equally spaced between the inlet and outlet louvers. A high voltage (up to 50,000 V for a municipal solid waste incinerator application) is applied to this conductor and the electrical field generated between the conductor and the inlet and outlet louvers enhances the collection of the particulate in the gas stream, greatly increasing the efficiency of the basic granular filter system. This enhancement phenomenon relies on the fact that incinerators (and, indeed, all industrial processes) produce particulate with slight positive or negative charges. Put simply, the electrical field greatly increases the probability that the particulate will impact with a piece of media in its long, tortuous path through the filter. Fig. 3, which depicts fractional efficiency curves for a wood fired boiler application, shows that electrostatic augmentation of particulate collection is especially pronounced on the fine, submicron particulate. Similar curves could be expected for an incinerator application.

**PROJECT DESCRIPTION**

The Pittsfield project was financed in September 1979 with the issuance of Industrial Revenue Bonds by the City's Industrial Development Finance Authority. Construction was initiated that month and start-up of the facility began in February 1981. Rated capacity of the plant is 240 tons/day (217 t/day) of solid waste.
Typical operation is 5.5 days/week at 24 hr/day, although 7 day/week operation is anticipated.

Fig. 4 shows a schematic representation of the system's main process equipment. Three 120 tons/day (108 t/day) controlled air incinerators are provided, two on-line and one on standby. Hydraulic rams push the incoming waste from a charging hopper into the firing chamber. After start-up ignition by auxiliary burners, temperature in the furnace is maintained by controlling feed rates of refuse and air. No fossil fuel is used under normal operating conditions.

The gas from the furnaces pass through a common manifold that connects the two operating furnaces with two waste heat boilers. Operational flexibility is provided with guillotine dampers that serve to isolate, as required, furnaces, boilers, and an emergency bypass stack. Individual 250 hp fans pull flue gas through each furnace, boiler, and economizer and push it through individual ELECTROSCRUBBER Filters. Stacks are fitted to the tops of each of the two filters.

**ELECTROSCRUBBER FILTER DESIGN**

As indicated previously, one ELECTROSCRUBBER Filter module was supplied on the outlet of each of the two waste heat boilers. Process specifications providing the basis of design for each of the filters were as follows:

- **Application:** Controlled air incineration of Municipal Solid Waste (MSW).
- **Elevation:** 1,050 ft (320 m) above mean sea level.
- **Location:** Outdoors.
- **Operation:** 5.5 days/week at 24 hr/day. (Down for 1.5 days/week.)
- **Flue Gas Composition:** Products of combustion from MSW @ 150 percent excess air (XSA) including HCl, SO₂, etc. (MW = 29.6)

Flue Gas Flow:
- 40,000 acfm normal (67,900 m³/hr normal)
- 45,000 acfm maximum (76,400 m³/hr maximum)

Flue Gas Moisture: 15 percent by weight maximum.

Flue Gas Temperature:
- 400 F normal (204 C normal)
- 600 F maximum (315 C maximum)

Flue Gas Particulate Loading Entering Filter:
- 0.4 gr/dscf @ 50 percent XSA normal
- 0.8 gr/dscf @ 50 percent XSA maximum

Particle Size Distribution:

<table>
<thead>
<tr>
<th>Size (µm)</th>
<th>Percent of Total (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 1</td>
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<tr>
<td>1 - 10</td>
<td>20</td>
</tr>
<tr>
<td>10 - 50</td>
<td>20</td>
</tr>
<tr>
<td>greater than 50</td>
<td>30</td>
</tr>
</tbody>
</table>

Required Outlet Loading:

- Massachusetts code is 0.05 gr/dscf @ 12 percent CO₂ (120 mg/nm³ @ 12 percent CO₂)

Based on the above specifications, one model ES400 ELECTROSCRUBBER Filter was selected.
for each of the two operating incinerators. A
general arrangement of that design is shown in
Fig. 5. System design considerations allowed the
incoming gases to be directed into the side of each
unit with a stub stack being placed on the top, thus
saving an auxiliary stack from grade. Fig. 6
provides a profile view of the upper portion of the
two ES400's located side by side at the plant.
Pertinent design features for each ES400 are
all carbon steel construction, a 20 hp media lift
air blower, and a 50kV, 200mA power supply. The
collected ash is transported pneumatically from
each unit under head from the media lift blowers
to 650 acfm (1,100 m$^3$/hr) pulse jet bag filter
separators at air-to-cloth ratios of 3:1 using
Huygas bags. Since ambient air only passes
through the media blowers, no process gas from
the incinerators reach the bag filters. The bag­
houses for each unit are manifolded together with
valves provided for sharing of gas flow and for
maintenance without the need for incinerator shut­
down. Additionally, a backup media lift air blower
was piped into the lines of the two operating
blowers to also allow for "on-line" blower mainte­
ance. The spare blower is also used for periodic
media loading through quick disconnect flex
piping.

A control panel monitors process temperature
at the inlet and outlet of the module as well as pres­
sure drop across the module, the bag filter, as well
as the media lift pipe. The balance of the controls
are equipment on-off switches and alarms for
high or low media recirculation rate. Media lift
pipe pressure drop provides an indication of media
recirculation rate.

Two power supplies separate from the control
panel provide the high voltage controls for the
transformer located on each module. Current and
voltage adjustments and set points are included.

**ELECTROSCRUBBER FILTER OPERATION
THROUGH DECEMBER, 1981**

As of this writing in December, 1981 the
ELECTROSCRUBBER Filters have been in opera­
tion for a total of nine months since first hot gas
was introduced on March 19, 1981. It can be
stated quite categorically that the installation is a
success. The units have caused no incinerator shut­
downs nor curtailments or reductions in steam
production. Continuous operation has been provid­
ed notwithstanding incinerator load swings from
0 - 150 percent full rated capacity and excursions
in inlet flue gas temperatures on two occasions to
levels in excess of 600 F (315 C). Emergency by­
pass has never been required. Most importantly,
the system has been certified as being in compli­
ance with the State of Massachusetts particulate
emissions requirements.

Much has been learned regarding the application
of an ELECTROSCRUBBER Filter to a municipal
solid waste incinerator. Shortly after startup, higher
than design gas flows from the furnace were
encountered which led to pressure drops up to
4 in. of water (1 kpa). Furthermore, the electrical
conductivity of the ash collected in the filter was
higher than expected, thus causing higher than
expected current drains between the electrostatic
grid and the louvers. Because of these units' power
supply design, high current drains prevented the
application of the 20-40kV voltages required for
the collection of the fine ash.

Fortunately, because this system was the first
provided for the application, a good deal of con­servatism was built into the design. To solve the
high pressure drop problem, the media rate was
increased. This increase also reduced the concentra­
tion of ash in the media, thus, in effect, reducing
media bed electrical conductivity. Lower bed con­
ductivity as well as some modifications made to
the high voltage power supplies allowed the
application of voltages up to the sometimes­
necessary 40 kV.
It should be noted that the higher-than-design media rates caused some problems during early operation with the pneumatic media recirculation system. The main seal leg and media injector in each of the two modules developed wear holes causing their replacement with components made from wear resistant materials. In addition, the media attrition (loss) rate for a time approached an extrapolated material cost of approximately $3000/year. Although these problems are considered minor, because of the minimal monies involved, future systems would include selected components of wear resistant materials as well as the more "gentle" media injection systems now being installed on newer ELECTROSCRUBBER Filter systems.

Concerning particulate collection performance of the units on the application, Combustion Power Company in August, 1981 secured the services of an independent testing lab to conduct parametric emissions tests. The results of those tests are shown in Table 1. Note that incinerator firing rate as well as electrostatic grid power supply voltages were varied during the tests. Conclusions to be made from the complete data set (considerations of protection of proprietary information precludes the reporting of specific media recirculation rates or furnace emissions for each data point) are that outlet emissions and particulate collection efficiency were a strong function of electrostatic grid voltage, that design particulate emission levels were met, and that outlet opacities were virtually "clear stack".

### CONCLUSIONS

By December, 1981 much had been learned about the operation of and interaction between the various process subsystems in the Pittsfield project. This increased knowledge allowed for much optimization of operating conditions. As regards the ELECTROSCRUBBER Filter, media rates have been reduced to levels approaching design, thus bringing the media attrition rate to expected levels. Optimized furnace conditions have allowed compliance level emissions at electrostatic grid voltages of 20 kV. In early December, the State of Massachusetts granted a particulate emissions compliance certificate to project.

### ACKNOWLEDGMENTS

Acknowledgment is made to three individuals that contributed significantly to the success of this project. The first is to Mr. Dave Hoecke of Enercon Systems, Inc., in Cleveland, Ohio (the company providing the design for the incinerator) for his belief that the ELECTROSCRUBBER Filter would be best for this MSW application.

The second is to Mr. Lew Clark of Vicon Recovery System, Inc., Butler, New Jersey (the company which designed, built, owns, and operates the Pittsfield system) for his careful attention to the entire system since start-up.

The third, and most important acknowledgment, is to Mr. Joe Domas, president of Vicon Recovery System, Inc., who in fact made the decision to include the ELECTROSCRUBBER Filter in the Pittsfield installation.

### TABLE 1 ELECTROSCRUBBER FILTER PARTICULATE EMISSIONS TEST RESULTS* FOR THE MUNICIPAL SOLID WASTE INCINERATOR, PITTSFIELD, MASSACHUSETTS

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Incinerator Firing Rate**</th>
<th>ESF** Pressure Drop</th>
<th>Flue Gas Temperature</th>
<th>Electrostatic Grid Voltage</th>
<th>Particulate Emissions Uncorrected @12 percent</th>
<th>CO₂</th>
<th>Stack Opacity‡</th>
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<tr>
<td></td>
<td>(percent kW) (kpa) (F) (C) (kV) (gr/dscf) (mg/nm³) (gr/dscf) (mg/nm³)</td>
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<tr>
<td>1</td>
<td>75 2.0 0.50 406 208 18.5 0.018 43.2 0.038 91.2 4.5</td>
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NOTES: *Emissions tests conducted August 18-20, 1981.
**100 percent of Incinerator firing rate is 120 TPD (109 metric ton/day) per each of two incinerators.
†ELECTROSCRUBBER Filter.
‡Single pass opacity.

**Key Words:** Incinerator, Massachusetts, Particulate Matter, Pittsfield, Refuse, Separator

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