Waste Gas Cleaning System at Sparrows Point
Plant's No. 4 Open Hearth

By W. A. Dickinson and J. L. Worth*

It is inevitable that basic oxygen furnaces will someday replace open hearth furnaces just as surely as the old Bessemer converters were rendered obsolete. However, it is also apparent that open hearth furnaces will be around for a number of years, especially those able to take advantage of oxygen lancing. But along with the good offered by oxygen lancing, one must also take the bad: that is, the heavy dark reddish iron oxide plume that accompanies the furnace waste gas products. Elimination of this plume is costly, no matter which method is chosen, whether it be by bag house, scrubber or precipitator. Even though there were no air pollution laws governing this type of plume at the Sparrows Point Plant of Bethlehem Steel Company, the management decided that a waste gas cleaning system must be included in an oxygen lance program. This paper will describe the cleaning system installed at No. 4 Open Hearth shop at Sparrows Point, its operation, and required modifications.

No. 4 shop is a relatively new one—having started operation the latter part of 1957. Operation of the shop progressed normally until oxygen lances entered the picture. In 1959, lancing was started on two furnaces on a limited basis. Excellent production records resulted in a decision to install oxygen lances on all furnaces in the shop to increase total plant capacity. It also was decided that installation of electrostatic precipitators for waste gas cleaning would be made.

Initial talks with outside engineering companies concerning waste gas cleaning systems were started early in 1960. A complete test program was run on the two oxygen lance furnaces in No. 4 shop to determine accurately operating data to establish design conditions for the gas cleaning system. Performance tests were made on the existing waste heat boilers and boiler fans to establish system draft losses. The first half of the year was used to establish the type of gas cleaning system required.

Interpretation of the test results conducted on the two oxygen lance furnaces established the initial requirements of the gas cleaning system. On the assumption that five of the seven furnaces might be using lance oxygen at one time, the initial design gas volume was determined to be 950,000 cfm at operating conditions of 575°F. This was equivalent to an average waste gas volume of 135,700 cfm at 575°F from each of the seven furnaces. The dust loading of the inlet gas to the precipitators was established at 5.0 gr per scf. To avoid a visible plume at the discharge stacks, the final gas cleanliness to be obtained was set at a dust loading of 0.045 gr per scf of

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Fig 1—No. 4 Open Hearth shop prior to the installation of the waste gas cleaning system.

Fig 2—No. 4 Open Hearth shop after the installation of the waste gas cleaning system.
cleaned gas. Six electrostatic precipitators, each rated at 158,333 cfm at 575°F, would be provided to handle the design gas load at the specified outlet dust loading.

Engineering of the waste gas system was started in June, 1960 and completed in February, 1961; the precipitators were placed on order August, 1960; construction started October, 1960; the first two units were placed in operation September 6, 1961.

Fig 1 is a view of the original shop looking north. Sufficient space was provided for the future installation of precipitators west of the furnace stack aisle. Fig 2 is the same view after the installation of the waste gas cleaning system. In order to give a complete picture of this system the initial installation will be described, followed by a review of operations and modifications.

Waste Gas System

Products for this system originate from the seven shop furnaces. Each furnace has two oxygen lances using oxygen at a rate of 70,000 cfm per lance for 2 1/2 hr per heat. Heat size is 420 tons and oxygen consumption is 800 to 1000 cfm per ton depending upon availability of oxygen. Maximum firing rate is 1400 gal, oil equivalent, per hr. The fuel ranges from 0 to 600 gal per hr during the oxygen lancing period. Fig 3 shows the relationship of the waste gas cleaning system to the furnace flue gas system.

In the original installation, the furnace waste gas products passed through the double pass regenerative system and flues directly to the furnace stack or through a fire tube waste heat boiler and boiler fan to the stack. For the new system, the furnace stack is bypassed completely by the flue products which pass through the boiler and fan and enter a collecting main. The furnace stack is only used during outages on the furnace, boiler, boiler fan, or entire
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waste gas cleaning system. A coke oven gas burner is used near the base of the stack to maintain a temperature of approximately 400°F so that immediate drafting is available.

Gases from each furnace boiler fan pass through about 20 ft of duct to enter the collecting main. Spectacle valves are located at each of these entrances to isolate a furnace system if necessary. The unlined main is constructed of 3/8-in. circular steel plate with butt-welded seams, and varies in diameter as follows: 7 ft 6 in., at the extreme north and south ends; 10 ft 6 in., at sections toward the center; and 12 ft 6 in., in the center. Except where the main rises over the electrical substation, the bottom of the entire main is kept at the same elevation. Explosion heads are mounted at each end and along the main. Four access doors are located in the main. Design of the main was of sufficient size to keep the over-all pressure drop down to a minimum. It was also evident that there would be dust accumulations in parts of the main during periods of low gas velocity, and blanked connections were installed along the main so that a future steam jet system could be added. Six ducts were provided for carrying the flue gases from the main to the precipitators. Two additional connections were made for future units.

Motor operated mechanical type goggle valves are used to seal individual secondary induced draft fans and precipitators from the main. Gases pass through the goggle valve to the secondary I. D. fan located at ground elevation. Louver dampers located in the inlet duct to the fan are used to control suction in the collecting main and distribution of gas to the precipitators. The I. D. fan is a horizontal, double inlet, centrifugal type, rated at 198,000 cfm and 14 in. w. c. at 575°F and 685 rpm. The fan wheel is 103 in. in diam, radial bladed, and provided with "Stoody Borod" wear protection on the blades. A 600 hp, 720 rpm, 2300 volt ac squirrel cage induction type motor is used. Variable speed hydraulic couplings are used to couple the motor to the fan. The coupling provides a more efficient means of controlling fan speed and reduces fan motor power consumption. Weather protection is provided for the fan motor and coupling by a heated enclosure.

After leaving the secondary I. D. fan, the gases pass upward through straightening vanes into the precipitator inlet, through the precipitator, and up a stack. This stack is 7 ft in diam, 100 ft high, fabricated of 5/16-in. carbon steel plate lined with 2 in. of a gunnite material.

Precipitators

Each of the precipitator chambers measures about 29 ft wide, 27 ft long, and 34 ft in height. Typical of conventional dry, lane-type electrostatic precipitators, the precipitation chamber consists mainly of collecting and discharge electrodes. The collecting electrodes, shown in Fig 4, are suspended flat steel plates in angle frames arranged to form gas lanes from the inlet to the outlet boxes. Discharge electrodes are barbed wires suspended at the center of the gas lanes and held taut and in position by weights attached to their lower end. Both types of electrodes have their individual suspension systems with extensions provided out of the top of the unit for rapping purposes. Even though most of the dust is collected on the plates, both systems must be periodically rapped to keep them clean. After being dislodged by rapping, the dust falls to the bottom of the unit to be removed.
A negative electrical charge of approximately 65,000 volts is used by the discharge electrodes for proper precipitation. Each chamber consists of three fields. Each of the fields has separate electrical power and control units, except for the inlet field which shares a power unit with the inlet field of an adjacent precipitator. The power unit supplies the high voltage with unidirectional current. Each unit consists of a high-voltage transformer, a silicon rectifier system, and a control console. The transformer and rectifier system are located on top of the precipitator and the control console, in the precipitator control house. Automatic power control in the control circuit is used to maintain optimum electrical operating conditions. The discharge electrode systems are supported by insulators which must be kept clean and free of moisture to prevent faulty operation. A pressurized hot air system is provided for the insulator housings to keep the insulators free of dirt and moisture.

Proper gas flow and distribution within the unit itself are essential for good precipitator performance. Thus the duct work before and after the unit plays an important part in maintaining these conditions. In the inlet section a curved perforated plate, turning vanes, and a flat perforated distribution plate were installed. A flat perforated distribution plate was installed in the outlet section.

Dust Removal System

Fig 5 is a schematic of the dust removal system. After falling to the floor of the precipitation chamber, the dust is moved by two sets of drag scrapers
to the inlet of the precipitator where it falls into a trough containing a screw conveyor. The conveyor moves the dust laterally across the front of the precipitator discharging it into a vertical rectangular duct. Two alternately opening tipping valves are located in the duct to provide a means of isolating the precipitator from other system components. After passing through the tipping valves, the dust falls into a surge hopper where it is stored until removal by the vacuum dust conveying system. There are three surge hoppers since each is fed by two precipitators.

Each surge hopper has a capacity of 420 cu ft or about 4 hrs of precipitator operation. These hoppers are rectangular in shape with an inverted pyramidal type bottom. Stainless steel plate and aeration blocks are used on the sloping sides to aid dust flow from the hopper. The hoppers are steam traced and insulated. Additional features are: a fiber glass bag for venting, a 2-in. opening for manually sounding the dust level, and an emergency 8-in. manually operated slide valve outlet for discharging directly to a truck.

A vacuum conveying system with a capacity of 12 tph of 35 lb per cu ft material moves the dust from the surge hoppers to a storage silo 515 ft away. Individual surge hoppers are opened by means of electro-pneumatic controls into the transfer system by a sequential vacuum actuated controller located in the precipitator control house. The dust leaves the hopper through a slide operated mixing valve beneath the hopper which mixes the dust with rapidly moving air, making a dust-air suspension. A 6-in. branch line transfers the dust to an 8-in. main which terminates at the top of the storage silo.

On top of the silo the major portion of the dust is separated from the transport air by a cyclone-type separator. The air is further cleaned by fiber glass bags in a secondary collector, enters a Roots-Connersville blower, and is discharged to the atmosphere. The blower, located at ground level, produces the vacuum for the conveyor system. Dust collected at the bottom of the separators falls by gravity through sequentially operated dump valves into the silo.
The dust silo has a 200-ton capacity of 70 lb per cu ft material. It is fabricated of carbon steel with a bottom cone section of stainless steel plate. Connections are provided near the base for injecting air to aid dust flow from the silo. Dust is removed through a pug mill type conditioner which mixes water with the dust to produce a material suitable for truck disposal. A manually operated slide valve outlet also is provided for emergency discharge to trucks. Fig 6 is a view of the silo and blower building.

Miscellaneous

Several service piping systems are essential for proper operation. These include: 150 psi steam, 100 psi plant air, 30 psi control air, 8 psi control air, salt water, industrial water, and coke oven gas.

Each waste heat boiler is equipped with three retractable-type soot blowers. Two rotating element blowers are installed to clean the superheater section and one vertical traveling blower, to clean the fire tubes. The element of the tube sheet blower resembles an inverted "Tee" with steam-blowing nozzles located along the horizontal portion of the "Tee." The soot blowers are automatically operated through a timed sequence or by high boiler exit gas temperature.
All controls are centralized in the precipitator control house located on the charging floor elevation between two of the precipitators.

In addition to regular plant telephone service, two other methods of communication are used from the control house. An extension to the charging floor P.A. system enables the operator to keep in touch with all stations on the shop system. A sound-powered phone system was installed throughout the entire waste gas cleaning system to aid in the calibration and maintenance of all equipment.

Graphic and Main Control Panel

Fig 7 shows the main panel located in the precipitator control house. Additional space was also provided on this panel for two future precipitators. In the upper three feet is a graphic panel. This panel starts with the ducts from the waste heat boilers to the collecting main and shows the entire precipitator installation and dust removal system through to the removal of the collected dust from the area. Fans, motors, conveyors, etc., are shown by representative colored shapes. In some cases, red and green lights are used to indicate whether a piece of equipment is operating or shut down. At a glance the operator can tell exactly what part of the system is in operation. The graphic panel supplements an alarm system in determining sources of trouble occurring anywhere in the waste gas cleaning system.

The two units of the annunciator alarm system are located beneath the graphic section. This system informs the station operator of abnormal condi-
tions throughout the entire waste gas cleaning system. Instruments are provided for recording dust density measurements, stack temperatures, and precipitator gas temperatures.

Below the alarm units are the controls for the waste gas system. Recording controllers are used to record the vacuum in the collecting main and individual precipitator flows. These controllers, as part of a cascade control system, maintain the proper collecting main vacuum and individual precipitator gas flow by varying the louver openings at each secondary induced draft fan. This system is completely electronic except for the final louver operators which are pneumatic.

Pneumatic regulators are used to position manually the scoop tube control rod of the hydraulic coupling to control the speed of the secondary induced draft fan. Fan speed and motor amperage indicators are also included.

**Operation and Modifications Waste Gas System**

Two-inch W.C. vacuum in the waste gas collecting main was ultimately settled upon as sufficient for providing adequate draft and good furnace pressure control. Individual furnace pressure control is maintained by control louvers located between the waste heat boilers and their respective fans. Several upsets have occurred to the system but with no ill effects. It was found that furnace air infiltration must be held in line or the entire waste gas system will become overloaded and ineffective.

Explosions of a relatively minor nature have occurred in the waste gas system. This was anticipated in the design and relieving devices are built into the system. No loss of production nor equipment damage has resulted and the explosions are not a hazard to personnel. The following has been observed: instantaneous high pressures in the system; precipitator explosion doors and waste heat boiler lance doors blown open; high temperatures entering precipitators; secondary I.D. fan and screw conveyor overload troubles from large accumulations of dust being dislodged. These explosive conditions have been created by furnace ore additions. At times, depending on the practice, a large volume of unburned gas is produced, passes into the waste gas main where it picks up sufficient oxygen to form an explosive mixture, and is ignited by the arcing of a precipitator. The condition requires continual monitoring and attempts have been made to eliminate it by changing the procedure for adding ore. To date this has not been completely successful.

Erosion has presented a problem at several places: namely, at both primary and secondary fans and at the waste heat boiler inlet. Primary fan blade wear is being retarded by building up the blades with a hard surface weld metal. Primary fan casing holes are periodically patched. Inlet cones of the secondary fans were replaced with stainless steel cones. A test is being conducted on the use of a spray metal to reduce wear on the boiler inlet tube sheet.

About eight months after all the furnaces were on the new waste gas system, an outage on the plant oxygen system permitted an inspection of the collecting main. This was an excellent opportunity to inspect for dust accumulations and also verify dust levels believed present, by observing skin temperatures outside the main. Fig 8 shows the location and size of the dust build-ups in the collecting main. It was possible to remove most of the deposits during the outage by air lancing the dust into an air stream between
open access doors and two operating secondary I.D. fans. This dust was then collected by the two precipitators for removal. Steam blowing nozzles were installed at the points of maximum build-up and used periodically to keep the main clear. Fourteen months later another inspection disclosed that the areas equipped with steam jet agitators had remained clean while other areas had large dust accumulations. Plans have been made for installing additional cleaning jets to remedy this situation.

**Precipitators**

It was evident shortly after operation of the precipitators began that guaranteed performance was not being met, and an investigation was immediately started. One and one-half years were to elapse before the guarantee was reached. Considerable time and effort were expended in arriving at the final solution, but it should be pointed out that all work was accomplished without interference with furnace operation.

Most of the initial work was concerned with the elimination of heavy dust build-ups in the inlet and outlet ducts. These deposits changed and disrupted gas flow patterns to such an extent that precipitator performance deteriorated. To study this problem a gas distribution model of the precipitator units was reactivated for testing. Modifications were made to the curved distribution plate and an additional kicker plate and flat perforated plate were added in the inlet duct. It was also necessary to install a new rapping system to clean periodically the two flat perforated inlet plates. The build-ups in the outlet duct were eliminated by removal of closure plates at the bottom of the outlet perforated distribution plate.

After these modifications had been made and the units still had not reached the guarantee, a pilot precipitator was moved to the site and placed parallel to one of the units to confirm design criteria. During the period data were being collected, furnace operating conditions also were followed. It was
found that moisture in the waste gas changed with variations of fuel use and this in turn affected precipitator performance.

Continued testing proved the precipitators to be extremely sensitive to the fine dust being produced and that these particles were more subject to re-entrainment from rapping and gas turbulence. This condition was remedied in the final phase of the modification program by the installation of the following: (1) full wave power on all precipitator fields, (2) selective rapping controls on the center and outlet fields, (3) additional saturable reactors on the center and inlet fields to stabilize the arcing current, (4) increased power input to the outlet fields. Tests performed at the conclusion of this phase confirmed the performance guarantee.

**Dust Removal System**

Drag scrapers and screw conveyors, while initially proving a source of forced precipitator outages, have become relatively trouble free. It must be understood however, that regular preventive maintenance is a must if forced outages are to be held to a minimum. In failures involving drag scrapers or screw conveyors, prompt identification of the failure and prompt corrective action are the keys to avoiding lengthy outages. Sensing elements used to detect failure of drag scrapers have proven unreliable and frequent visual inspections must be made.

Repeated outages of the screw conveyors were found to be caused by dust building up around the tipping valves. It was found that an enlarged section of straight duct could replace the tipping valves. No difficulty has been experienced due to lack of a positive seal between the precipitators and surge hoppers.

All the surge hoppers had to be modified to correct operational inadequacies. The glass bag vents were removed because of excessive bag failures, and vent piping was installed from the top of the surge hoppers into each precipitator. Dust level in the surge hoppers frequently rose as high as the screw conveyor discharge, thus causing the conveyors to fail. A rotating "paddle wheel" type device was inserted into the top of each surge hopper to sense high dust level and sound an alarm.

Initial operation of the vacuum dust removal system disclosed that the dust feed from the surge hoppers to the conveying system was quite erratic, varying from major avalanching to a complete failure to feed. If a controlled feed was obtained, the 8-in. transmission main accumulated dust so that only one quarter to one third of the design tonnage rate could be handled consistently. The consistent reduced capacity of the system contributed greatly to problems of housekeeping and maintenance of system components. It is worth noting at this point that this dust exhibits tendencies to compact, adhere to any surface, and vary its bulb density as much as 80 lb per cu ft.

At present the vacuum conveying system is handling dust at one-quarter to one-half its designed tonnage rate. Secondary factors contributing to poor system performance were corrected. A consistently metered dust flow from each surge hopper was obtained by replacing the initial dust-air mixing valves with rotary feeders. Dust flow within the surge hopper was improved with permanently installed air agitators in place of mechanical vibrators and aeration blocks. The 6-in. branch piping was removed and all of the hoppers emptied through a relocated 8-in. transmission main.
After completion of the above improvements, extensive tests conducted by the vendor convinced all concerned that additional vacuum producing equipment is required to correct system deficiencies. Installation of a second blower is now in progress.

The operation of the cyclone and glass bag filter separators has been satisfactory to excellent; however, it must be remembered that the system has not operated at rated capacity. Maintenance of seals on the separator dust dumping gates has been troublesome.

Operation of the dust conditioner beneath the silo proved it was not capable of producing a suitable dust-water mixture without excessive cleaning, maintenance, and operator attention. It was removed in favor of dry dust unloading via a remotely operated slide valve that has required very little maintenance and no operator in attendance. Approximately 150 tpd of dust are removed. Thus dust is loaded into openbed trucks, the top surface wetted down, and transported to a local dumping area.

Conclusion

Manpower requirements for the operation of the precipitators and auxiliary equipment have been as originally anticipated. Two hourly men, an operator and a helper, man the station each turn—the operator being responsible for activities in and near the control house, and the helper with inspection and proper operation of the more remote auxiliaries. Mechanical and electrical service is provided on a “round the clock” basis using personnel from No. 4 Shop forces. Instrument control service is limited to the daylight turn.

To fulfill obligations to the public and the open hearth, experience has proven that preventive maintenance is the major factor governing successful operation of the waste gas cleaning system. Failures of precipitator components during operation adversely affect performance to such an extent that immediate repairs are necessary. Close coordination between the furnace, boiler, and precipitator operators must be maintained, particularly during periods of abnormal conditions. Site cleanliness is a function of the ability of the vacuum conveying system to successfully handle the precipitated dust.

Discussion

Experience with Precipitators on Republic-Cleveland Open Hearths

F. E. Stephens*—The precipitator installation at the Cleveland District Works of Republic Steel Corporation has been in operation 27 months, with only minor difficulties.

This installation was designed to operate with two oxygen furnaces, tapping 420 ton heats, with tph ranging from 70 to 90, charge to charge. A high oxygen practice is used, with blowing rates as high as 300,000 cfm. The limit for the present equipment is two furnaces on blow at one time.

The installation consists of three precipitators, embodying a total of six units. Each unit, which is 10 ft wide, 24 ft high, and 24 ft long, is divided into 12 lanes, each 10 in. wide. Each lane contains a total of 32 wires.

*Republic Steel Corporation, Cleveland, Ohio.
The units are divided into four sections, or fields in the direction of gas flow. The first, or entrance field, is provided with barbed wire; the others with plain wire.

The total design capacity of the precipitators is 300,000 scfm, operating at 550°F and -15 in. W.C., with an inlet loading of 5.0 gr per scf.

Two fans, each of 310,000 cfm capacity, are used for maximum operation. Dust is discharged from the precipitator hoppers through a ribbon conveyor to a motor operated drop-away seal valve, one for each unit. A ribbon conveyor then carries the dust to the surge bins, which have a combined capacity for about 30 hrs maximum operation.

Solid flight screw conveyors carry the dust from storage to a canvas duct dropping down to a covered dump truck. A pug mill was provided but has never been used. Dust handling is confined substantially to day turn.

As loaded into the trucks the dust is at about 140°F and still very free flowing, but some rodding is required in the storage bins. Extreme care is taken to exclude atmospheric air from the system, and particularly from the conveyors, by keeping the covers tight at all times.

The furnaces are equipped with waste heat boilers and induced draft fans, more than adequate in size for conventional open hearth heats, but only a little more than half large enough for oxygen heats. The furnace stacks are equipped with water sprays, with temperature control for 550°F, similar to the evaporation chamber on a basic oxygen converter. About half the gas is drafted through the boiler; the other half directly to the stack. The spray water is pumped at about 250 psig. The precipitator inlet flue is connected to the stacks about 108 ft above ground, with a butterfly shut-off installed in the stack directly above the connection. Another butterfly valve is provided in the offtake connection at the stack. By this means, it is possible to operate the furnaces on the stack while charging. The stack sprays introduce the right humidity to the gas for good precipitator operation.

The dust separated in the precipitators amounts to 20 to 25 lb per ingot ton. On clean-out there is an additional 20 to 25 lb per ton in the furnace flue, making the dust evolution from the process 40 to 50 lb per ingot ton.

As stated initially, operating difficulties have been minor. The exhaust fans, after a rather protracted shakedown period, are now entirely satisfactory, and will run more than a month between sand blast cleanouts. The dust handling system requires frequent minor repairs, as was expected, but no major breakdowns have occurred. Out of the total of 2304 wires in the precipitators only 50 have been replaced. Of these, 22 burned out because of unexplained buckling of a plate which has since been straightened and secured.

Excellent automatic controls have contributed no small measure to the success of the operation, but the real key to success is intelligent and conscientious operators who scrupulously attend to all details.

Cleaning Open Hearth Waste Gases with a Venturi Gas Scrubber

F. A. Thomas*—Air pollution control is assuming major importance due to the new Air Pollution Act passed by Congress and signed into law by President Johnson, together with current state and local air pollution legislation plus voluntary compliance programs. Thus, smoke control will be

*Edgar Thomson Works, United States Steel Corporation, Braddock, Pennsylvania.
stringently applied at steel producing units throughout the country as a result of this nationwide effort. One method for achieving a satisfactory cleansing of waste gases from an open hearth furnace is the Venturi Gas Scrubber. In 1959, a Venturi Gas Scrubber was placed in operation at United States Steel's Edgar Thomson Works, on No. 4 Open Hearth Furnace. This report outlines the general gas scrubber design, operating principles and results obtained on this installation.

Open hearth waste gases vary considerably in dust content during the progress of the heat as shown below:

<table>
<thead>
<tr>
<th>Heat Period</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging and meltdown</td>
<td>0.1</td>
<td>0.58</td>
</tr>
<tr>
<td>Hot metal addition</td>
<td>0.24</td>
<td>0.66</td>
</tr>
<tr>
<td>*Flushing, lime and ore boils</td>
<td>0.14</td>
<td>1.6</td>
</tr>
<tr>
<td>*Working</td>
<td>0.51</td>
<td>1.2</td>
</tr>
<tr>
<td>Soot blowing</td>
<td></td>
<td>15.0</td>
</tr>
</tbody>
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*Oxygen added during these periods by roof lance.

As is to be expected, the dust loading is increased during the periods when oxygen is used for decarburization.

Particle size variations, presented in Discussion Fig 1, show the size distribution of a composite sample of dust collected during all the periods of an open hearth heat and a sample collected during just the lime boil. Only about 46 pct of the composite sample was less than 5 microns, whereas, about 77 pct of the lime boil sample was less than 5 microns. Obviously, gas
cleaning in the open hearth presents a major challenge due to the variable dust loading, particle size, and temperature of the exhaust gases. The Venturi Gas Scrubber is designed to overcome these obstacles and to cleanse waste gases to a satisfactory level.

**Description of Venturi Scrubber**

The Edgar Thomson Works Venturi Gas Scrubber is outlined in Discussion Fig 2. The basic parts consist of:

1. Entrance flue
2. Converging section
3. Venturi throat section
4. Diverging section
5. Separator
   a. Inlet nozzle
   b. Spin vane
   c. Cooling tower
   d. Outlet nozzle
6. Fan Inlet Damper  
7. Fan and Fan Drive  
8. Recycle Water  
9. Bleed Sludge  
10. Thickener  
11. Filtration

The waste gases from the furnace flues enter the inlet pipe and, at the Venturi, are subjected to right angle scrubbing liquid sprays. The turbulence created by the intermixing of the gas and water causes the gas particles to be wetted. These particles are subsequently removed from the gas stream as the gases pass through an inertial type entrainment separator. The gas is then discharged to the atmosphere from the stack after passing through the induced draft fan. The scrubbing liquid is recycled from the separator to the Venturi, with a portion being constantly drained off to the Thickener and Filtration units, providing for particle removal from the system.

**Detailed Operating Description**

The entrance flue to the Venturi consists of a steel tube lined with high temperature castable refractory. Furnace pressure is maintained by an Askania controlled slide damper at the flue entrance.

The original Venturi, attached to the flue section, was comprised of an 8-ft long refractory lined converging piece, an unlined rectangular throat 1 ft 0 in. wide by 4 ft 8 in. high x 3 ft 6 in. long, and a diverging piece 9 ft long. The Venturi throat section water inlet manifold had a series of water injection nozzles located on a vertical axis on both sides of the throat for scrubbing water injection. Air actuated reamer rods worked as a unit to clear periodically the entire group of water spray nozzles.

The Venturi throat was subsequently revised because of warping encountered with the original throat, clogging of the sprays, and misalignment of the unitized reamer rods. The new adjustable Venturi throat has 64 sprays, a double row of 16 jets or 32 per side. The sprays are set flush with the throat lining, the spray hole in the jet being 9/32 in.-diam. Each spray has an individual reamer rod actuated by air every 15 min.

The new Venturi throat is lined with silicon carbide blocks and Carbofrax and has an adjustable, hydraulically operated throat damper constructed of silicon carbide blocks formed around a damper rod. The throat damper was installed to provide a constant pressure drop across the throat while maintaining the desired furnace draft. The new throat section is 3.5 ft long with a maximum cross-sectional area of 3.4 sq ft with the damper wide open. The diverging section is lined with a high temperature castable refractory, and the converging section is unlined.

From the Venturi section, the wetted gases pass into the separator tower. The tower is constructed of steel plates, and is lined with No. 10 lead, asbestos paper and acid brick. The lead is bonded to the steel with a laminac resin pumped between steel and lead, after installation of the brick.

The separator operates on the principle of using centrifugal forces to spin out water droplets and their collected dust from the gas. The gas and scrubbing liquid from the Venturi are directed against the center spin vane assembly and are given a spin which forces the liquid against the tank walls.
The water and entrapped dust drain to the base of the separator, while clean gas leaves at the top of the separator. The bottom of the separator slopes to one end for flushing and cleanout.

The spin vane assembly is designed to give good separation under all flow conditions and no vane adjustments are required. The separated water and dust are collected in the separator base and recycled to the Venturi through a pump suction line located 3 ft 6 in. above the floor. An emergency high level overflow nozzle and seal are provided so that any excess water can flow to the sewer.

The gas inlet nozzle directs the incoming gas from the diverging section to the spin vane assembly. The outlet nozzle exhausts the gas from the top of the separator to the fan duct work. Both the gas inlet and outlet nozzles are constructed of stainless steel.

The collected dust is constantly removed from the system by bleeding off about 25 to 50 gpm of the recycle scrubbing liquid (sludge) to the waste system. Make-up water to replace the water lost by evaporation, and the above mentioned bleed sludge are introduced automatically into the entrainment separator through a float control system. A drain line is provided at the low point of the sloped separator bottom for cleanout and occasional flushing of any heavy accumulation which may settle from the recycle system.

Slurry sample analyses show a pH of 3 for both the water from the separator and the liquid condensate in the base of the exhaust stack. Due to the corrosive nature of the liquids, AISI Type 316-L stainless steel was used for construction of the Venturi, the exhaust fan, the duct work connecting the water separator and the fan, the duct work connecting the fan and the exhaust stack, and the internal spin-vane elements of the separator.

The separator roof was originally provided with 6 large stainless steel spray nozzles with an alarm located on the panel board, both actuated by high gas temperatures leaving the separator, or low-recycle pump pressure, to protect the separator and fan against pump failure. The scrubber was shut down when this alarm sounded until the reason for the temperature increase was determined and remedied. After construction of the cooling tower described in the following paragraph, the cooling spray nozzles were relocated in the Venturi throat section to protect the Venturi section and the separator from damage in the event of a pump failure.

To reduce the original large steam plume emanating from the stack, a cooling tower was constructed of tile supported on a redwood base inside the separator. Cooling water (up to 1400 gpm at 80°F) is sprayed uniformly through six Bakelite spray nozzles into the top of the separator-cooler section through a manifold spray system and is caught by a stainless steel catch basin at the base of the tile packing, then directed into the sewer system. The cooling tower lowers the gas temperature from 165°F to 110°F, thereby reducing both the steam plume at the exhaust stack and the gas volume the induced draft fan must handle.

A radial vane-type damper is located at the fan inlet to provide additional draft control over the scrubber system. The damper is normally operated through an electric motor drive which is set up to increase or decrease the fan suction by opening or closing the vanes in a stepwise movement of 15° (similar to the movement of a venetian blind) as determined by the position of the scrubbing system slide damper. The scrubber slide damper has upper and lower limit electrical switches mounted on brackets alongside the damper.
The switches will operate the fan inlet damper to give more or less fan draft once the slide damper has moved past a position where it can easily control the furnace draft.

The fan damper can also be controlled manually by: (1) switches located on the scrubber panel board, and (2) in the event of a power failure, by a manual control wheel located on the fan damper unit. The panel board switches bypass the slide damper limit switches although maximum travel limits are maintained.

The induced draft fan, fabricated of type 316L stainless steel, provides enough draft to overcome the entire scrubbing system resistance and to maintain 3 to 4 in. of draft at the flue stack inlet. Control over a wide range is effected by a variable speed turbine drive selected for this installation due to the lack of 60-cycle power sources. The scrubbing liquor is recycled from separator to the Venturi by a centrifugal pump constructed of corrosion resistant chrome nickel alloy. The pump will handle 1060 gpm of water containing 8 pct H₂SO₄, 4 pct iron oxide particles, and a pH of 3.5. A low pressure switch in the pump discharge line protects the scrubbing system against power failure.

The recycle water in the original installation clogged the sprays in the Venturi due to abnormal (15 gr per scfd) dust loadings and pieces of brick and scale introduced during soot blowing periods. This was overcome by (1) installing a self-cleaning screen in the recycle water line and, (2) installing the aforementioned automatic reamers. The automatic screen was designed to screen out all material over 1/8-in. diam, thereby passing material small enough to pass through the 9/16-in. spray openings.

The bleed sludge is removed from the system ahead of the automatic screen. Its flow is regulated by a 2-in. rubber pinch valve. To prevent plugging of this line, an automatic timer is utilized to open the valve 5 sec every 15 min.

The bleed sludge (25 to 50 gpm) from the recycled Venturi spray water flows into a thickener. The tank and parts in contact with the slurry are made of mild steel covered with 3/16-in. rubber coating. The clarified overflow from the thickener is discharged to the sewer. The underflow is pumped to the filtration unit by a diaphragm slurry pump with Hypolon lining.

The filtration unit is an Oliver continuous rotary vacuum filter of plastic construction. It was designed to operate at a temperature of 150°F with 25 pct submergence. The drum is provided with a variable speed drive unit providing a speed of 30 to 180 sec per revolution. A mechanical agitator is installed in the filter tank to keep the solids in suspension. The final sludge currently is discharged into a ground level bin and trucked to the blast furnace stock pile.

Summary

The Venturi Gas Scrubber will clean open hearth waste gases to 0.05 gr per scf of waste gas with a pressure drop of 30 in. of water across the scrubber or to 0.01 gr per scf of waste gas with a pressure drop of 40 in. of water, with an average scrubbing water rate of about 14 gal per 1000 scf of gas.

Bleeding 5 pct of the total scrubbing water, containing 1.5 pct solids by weight, permitted satisfactory operation of the recycle water system.
In the older open hearth shops without waste heat boilers, the Venturi Gas Scrubber, with its ability to handle hot gases directly, provides both satisfactory gas cleaning and increased furnace draft. The lower capital cost, as compared to electrostatic precipitators, makes the scrubber an attractive investment. Also, it is possible to design a scrubber for an open hearth shop so that it can be used for a future O.S.M. installation, thereby attaining a dual benefit from one capital expenditure.

Construction of a Venturi Gas Scrubber should include provisions to protect the installation from freezing, and should provide the cheapest and most dependable form of drive for the fan. An analysis of the capital and operating costs of the steam driven turbine vs. the electric motor should be made.

A thickener and centrifugal type sludge de-waterer will handle the bleed slurry from the Venturi Gas Scrubber. The resultant sludge may be handled by truck to disposal areas. Because of the acid-leaching action of the slurry, the filter cake had some of the undesirable zinc and lead residuals leached out (Discussion Table 1). As presented herein, the Venturi Gas Scrubber should be evaluated beside such open hearth gas cleaning equipment as electrostatic precipitators and baghouses. Under certain economic conditions it will present the most attractive investment for air pollution control in steelmaking.