Water supply and wastewater disposal for a steel mill

Basic oxygen furnace process has varied water requirements and waste treatment needs

Although the subject of this paper is water and waste treatment for a Basic Oxygen Furnace, comments on air pollution abatement are in order. To prevent air pollution, water is needed to clean the gases evolved in the operation of a Basic Oxygen Furnace during steelmaking.

IN STEELMAKING, the operation of a Basic Oxygen Furnace (BOF) involves several steps. The furnace is charged with molten iron, scrap steel, and fluxing materials. High purity, high pressure oxygen is then introduced through a water-cooled lance to remove carbon, silicon, manganese, and phosphorus. The oxidation of these elements provides the heat necessary for the process. During the oxygen-blowing period, iron oxide is formed and is carried out of the furnace along with flue gas and other dust. The facilities for collecting and recovering this dust require more than 90 percent of the water used by the plant.

Inland Steel Co.'s BOF shop has two furnaces which have a nominal capacity of 230 tons; the average heat size, however, is 254 tons. Only one furnace is operated at a time, and the average tap-to-tap time is 37 min, which results in an average production rate of 412 tons per hr. The total water use is approximately 70 mgd, of which 50 percent is in recirculated water and 50 percent is water withdrawn from Lake Michigan.

There are five major water systems in the plant: hood cooling, oxygen

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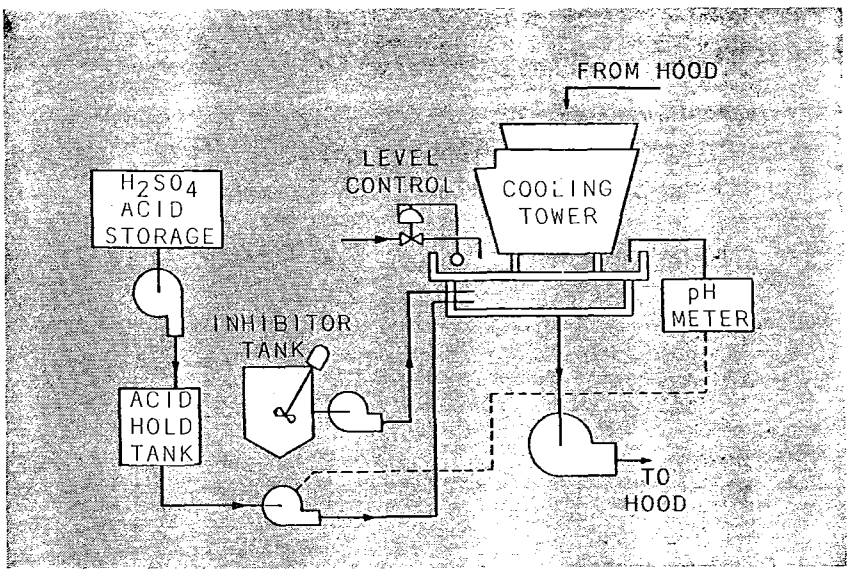

Fig. 1. Hood cooling system

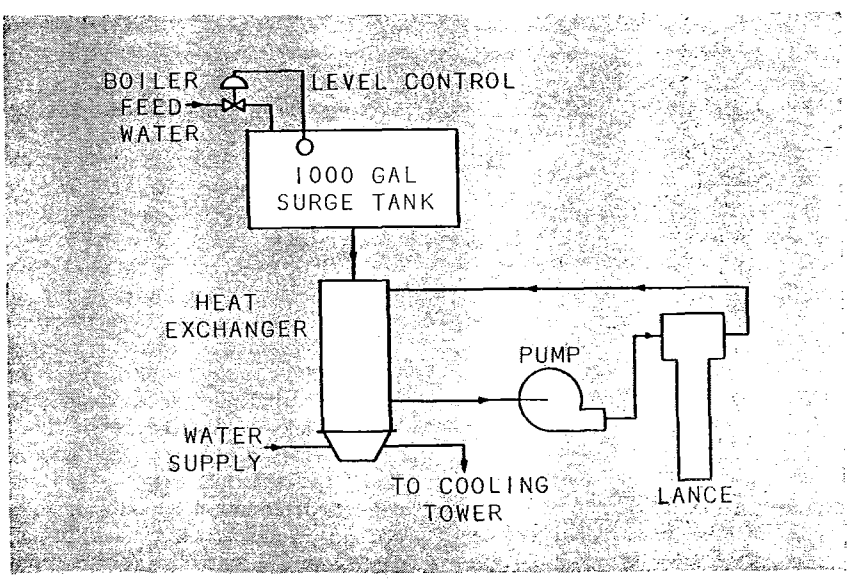

Fig. 2. Oxygen lance cooling system

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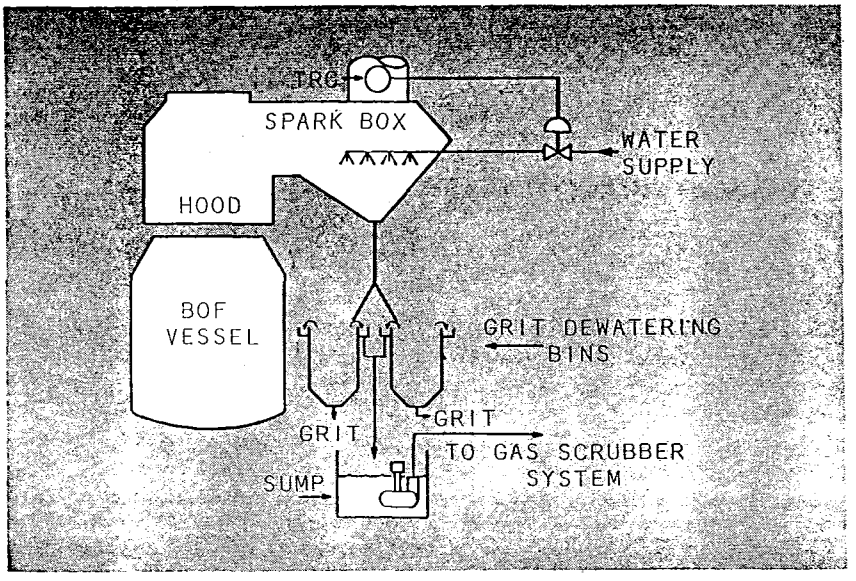

Fig. 3. Spark box spray cooling system

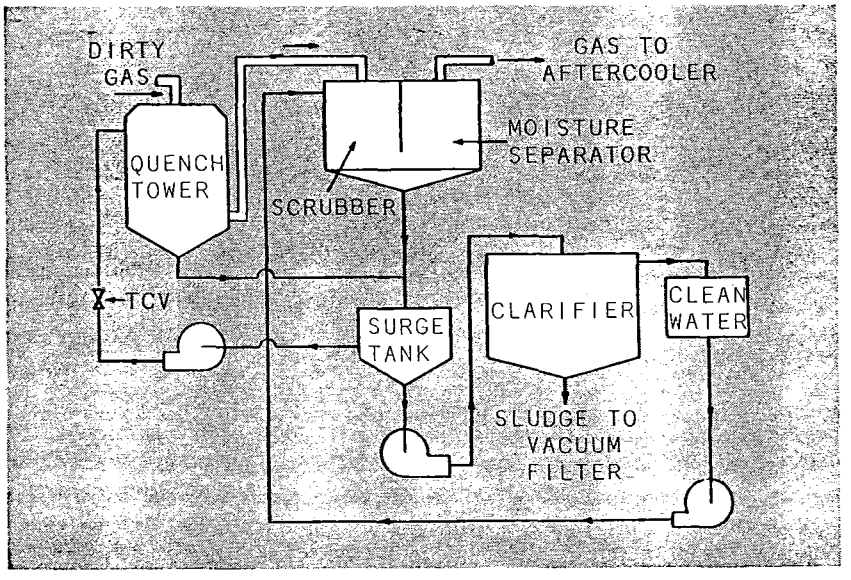

Fig. 4. Gas scrubbing system

lance cooling, spark box spray cooling, gas scrubbing, and gas after cooling.

Hood cooling

The purpose of the hood is to contain the gases which are discharged from the BOF vessel. The gases can then be conveyed into the gas-cleaning system for removal of the iron oxide and other dust. The temperature of the gases leaving the vessel is about 2800°F. Their major component is carbon monoxide, which is converted to carbon dioxide by combustion with air drawn into the hood from the atmosphere in the shop.

The hood is constructed of steel plates with a space for cooling water between the inner and outer plates. Cooling not only keeps the plates from burning up but also cools the gases before they can be cleaned. After the cooling process, which requires 16,000 gpm of water, the water is returned to the cooling tower. The tower is an induced-draft, single-flow-type with four cells. Each cell is rated at 5600 gpm with a 10° approach to the atmospheric dew point. From the cooling tower basin, the water is repumped to the hood cooling system. There are four 5620-gpm pumps, of which three are normally operated.

The treatment for the hood cooling water recirculation system (Fig. 1) consists of adding a biocide for slime and algae control, sulfuric acid for pH control, and a zinc-organic compound for prevention of scale and corrosion. To prevent excessive build-up of dissolved solids due to evaporation in the cooling tower, blowdown is provided. The dissolved solids are limited to about 800 mg per L, which is four to five times that of the raw water. Typical of the daily analyses made on the system is the following:

Item	mg/L
pH 7.5	
Alkalinity ($CaCO_3$)	90
Hardness ($CaCO_3$)	400
Sulfates (SO_4)	300
Dissolved solids	800
Suspended solids	40

The anti-foulant corrosion inhibitor is maintained at 50 to 80 mg per L, and the biocide is slug-fed once a week at a dosage of 35 mg per L. To eliminate problems of water pollution, the corrosion inhibitor contains no phosphates or chromates and the biocide contains no phenol or heavy metals.

It was recognized that, with the high temperature of the BOF operation, the risk of hood failure was substantial if scaling occurred on the water side. For this reason, the cooling water is treated to prevent scaling. By using recirculation rather than a once-through system, the treatment costs less and is more easily controlled.

Oxygen lance cooling

The oxygen lance (Fig. 2), which is used to blow oxygen in order to convert molten metal into steel, is subjected to very high temperatures and must be water cooled. The lance is 76 ft, 8 in. long and consists of concentric 12-, 10-, and 8-in. pipes. Oxygen flows through the 8-in. pipe, and cooling water enters through the 10-in. pipe and discharges out of the 12-in. pipe. The water enters the lance through a manifold by means of a 6-in. flexible hose. From there, the water passes through two heat exchangers in parallel, loses about 15° in temperature, and then is returned to the two 1800-gpm pumps. The water used to cool the lance cooling water in the heat exchanger is from the hood cooling system. Between the lance and the heat exchangers is a 1000-gal surge tank.

Make-up is added to the surge tank to replace water lost during lance changes or leaks in the system. Because of the severe process temperature conditions, high quality water is required to prevent lance failure due to scale deposits or sedimentation in the cooling passages. This requirement is met by using boiler feed water treated with the hot lime zeolite process. There have been no lance failures because of water-side condi-

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tions. A typical analysis of this water is: pH, 10; alkalinity, 20 mg per L; hardness, 0; and dissolved solids, 70 mg per L.

Spark box sprays

To cool the hood gases before they enter the gas-cleaning system and to remove large particles of material which are blown out of the vessel, the gases pass through a refractory-lined chamber called the spark box. There the gases are cooled from 2800° to 800°F by four banks of water sprays. Three banks have ten nozzles each and the fourth, 20 nozzles. One bank of sprays comes on as the oxygen lance is lowered into the vessel; the other banks automatically come on in order to maintain the 800°F gas exit temperature.

The maximum flow of water (Fig. 3) to the spark box is 1550 gpm. Part of this water is evaporated, the rest falling into the spark box along with the solid material washed from the gas stream. The water and grit are discharged to one of two dewatering bins. These bins are small clarifiers with the water entering at the top center and flowing down under a baffle and then across a weir at the top circumference of the tank. When one bin is filled with solids, the water is diverted to the other bin. Upon removal from service, the bin is drained, and the solids are dumped into a slag pot for disposal.

Water from the bins was at first repumped to the sprays. This practice was, however, impractical. Lime dust, carried out of the vessel with the gases, caused severe scaling in pumps, piping, and spray nozzles. A typical analysis of the recirculated water that caused operating difficulties included: pH, 12.5; alkalinity, 1680 mg per L; hardness, 1700 mg per L; dissolved solids, 1950 mg per L; and suspended solids, 600 mg per L.

Efforts to solve these problems by chemical treatment and mechanical changes were not successful. Therefore, fresh water was provided to the spray system and the used water was piped to the clarifiers for the scrubber water system. As a result, reasonable continuity in the operation of the spark box spray water and grit handling system has been achieved. For any new BOF shop, however, an entirely different approach is recommended.

Gas scrubbing system

Waste gases from the steelmaking process are drawn through the gas cleaning plant in the following sequence: Gases are collected in the water-cooled hood and pass through the spark box, up a stack, and into a downcomer, which directs them from the BOF building into the gas-cleaning building. A quench tower serves the dual purpose of cooling the gas entering from the downcomer and of allowing large particles of solid matter to drop out before the gas passes to the scrubbers. A notched weir is provided around the circumference of the tower near the top over which water flows. This water, which is from the gas scrubber system (Fig. 4), cools the sides of the tower and prevents a build-up of solids. The remainder of the water is used in sprays to cool the gas before it leaves the tower by means of ducts connected to four scrubbers.

Each scrubber has a scrubbing section, a moisture-separator section, and 119 small venturi nozzles. Each nozzle has a scrubbing and a flushing spray, each spray operating at different times. When either spray is actuated, approximately 10 percent of the total water flows through the other spray in order to prevent clogging or freezing.

Upon leaving the scrubbers, the gases pass through deflector vanes and moisture-separator elements and the water is collected in two surge tanks. A portion of this water is screened and recycled to the quench tower, and the balance is pumped to the clarifiers.

Two clarifiers, 60 ft in diam by 27.5 ft deep, have a detention time of 3.6 hr. The design criteria called for an effluent quality of less than 200 mg per L suspended solids for recirculation back to the scrubber sprays. This quality could not be achieved by gravity settling alone so a system for adding a polyelectrolyte (0.25 to 0.5 mg per L) was installed. The clarifier effluent quality is generally less than 50 mg per L of suspended solids. Without coagulation treatment the recirculated water would contain as much as 10,000 mg per L of suspended solids. Magnetic flocculation is also being evaluated on one of the clarifiers.

The original clarifiers were of double tray design, but an unusual accumulation of sludge on the upper tray caused the collapse of one clarifier. It was rebuilt without its upper tray, and the upper tray was removed also from the other clarifier. Thereafter, operation was simpler, and the effluent quality was not adversely affected.

The clarifier effluent flows to a clean water tank from where it is pumped to the scrubbers. In the clean water tank, make-up water is received and blowdown is adjusted to maintain the dissolved solids content of the recirculated water below 800 mg per L.

Shortly after the BOF began operating, heavy scale deposits appeared in the venturi scrubbers. This condition was due to lime dust from the lime-handling system, because the system's collectors discharged into the furnace gas-cleaning system. The addition of sulfuric acid and a dispersing agent to the scrubber water was not successful. The problem was finally solved by an independent dust collector using bag filters.

The settled sludge from the clarifiers, which has a solids content of 35 to 40 percent, is pumped to two vacuum filters which produce a filter cake containing 30 to 33 percent moisture. Each filter has an effective area of 170 sq ft and produces about 2 tons per hr of filter cake (dry basis). (At times this is not adequate, and unfiltered sludge must be hauled by tank truck to a disposal site and allowed to air dry.) The filter cake is fed into a rotary dryer which further reduces the moisture content to about 10 percent for use as raw material in the sintering plant.

Gas cooling

Gases leaving the scrubber and moisture separators are passed through aftercoolers (one for each scrubber). Their purpose is to cool the gas, thereby reducing its volume and fan capacity requirements. The aftercooler is a large cylindrical vessel with a 6-in. layer of marbles supported on a screen halfway up the tower. The cleaned gases flow upward through the aftercooler while service water is sprayed downward over the marbles. The bed of marbles serves to increase the surface area and promote more efficient cooling.

Water used in the aftercoolers is discharged without treatment, as it has come into contact only with cleaned gas. Cleaned gases, containing less than 0.05 grains per cu ft of particulates and having been cooled to 160°F, are drawn into the induced draft fans and forced out the stack.

Of the five water systems for BOF, four are recirculating or reuse systems. Recirculation was used in the hood cooling and the oxygen lance cooling systems primarily because of process water quality requirements. The use of recirculation or reuse in the spark box spray cooling and scrubber water systems was based on the need for water pollution control. Ninety percent of the 70 mgd of water required by the company's BOF shop is needed to prevent air pollution by 125 tons of dust a day which is generated in the process.

KEY WORDS
Industrial Water Supply; Industrial Wastes.

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new products

Aeration process

A new oxygen aeration process has been developed by Union Carbide's Linde Division, which was recently awarded a 19-month contract by FWPCA to demonstrate the process in a full-scale treatment plant. A feature of the process is a method of contacting oxygen with wastewater and microorganisms. Results to date have shown that the process produces higher dissolved oxygen levels and lower oxygen transfer costs than with air aeration. Also, biological phosphate and nitrate removal appear to be improved.

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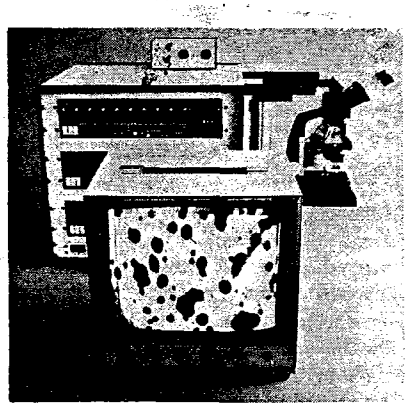

Particle measurement

Millipore Corp. has developed a device, consisting of a microscope, television camera, screen, and computer, for precision particle measurement and analysis and quality control. The πMC particle measurement computer can provide in minutes data that previously required hours to obtain, says the manufacturer. An unskilled operator can instantly make detailed measurements on individual particles or entire fields by pressing a switch. Results are displayed on the television screen and can be classified, sorted, and stored or fed to a printer.

Circle No. 2 on Reader Service Card

Remote meter reader

Engineered Controls, Inc. is offering the Kent remote readout system consisting of a magnetic-pulsed, continuous register meter head, an outside wall receptacle, and either of two types of portable totalizers. The meter head can be installed on any popular make water meter. The outside wall receptable is connected to the meter head by a double-wire cable. By plugging into the wall receptacle, one type of totalizer visually shows the gallonage used since the previous reading. Another type totalizer, which computes and prints out the entire water bill, including gallonage and price, is also available.

Circle No. 3 on Reader Service Card

Chlorination system

Wallace & Tiernan Division, Pennwalt Corp., has announced a new housed chlorination system. It is a complete system in a weatherproof, fiberglass house. With internal piping and wiring completed at the factory, the system is shipped as a self-contained unit. Installation requires placing the house on location and connecting to electric power, water supply, and the point of chlorine application. The house contains a V-notch chlorinator with capacity to 400 lb per day against 100 psi, or higher with an optional booster pump. Operation can be manual or automatic flow proportional. A two-cylinder scale is included in the system.

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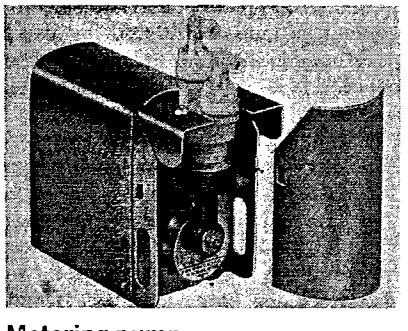

Metering pump

Gorman-Rupp Industries Division has developed an all polypropylene bellows type metering pump. By configuration, the bellows behaves as a positive displacement pump in the low pressure range. Because the bellows generates no friction, it can run dry and handle many abrasive liquids and slurries. The pump is self-priming except at very low pumping rates. Incorporated in the pump are hypalon poppet valves, making hypalon and polypropylene the only materials being exposed to the liquid being pumped.

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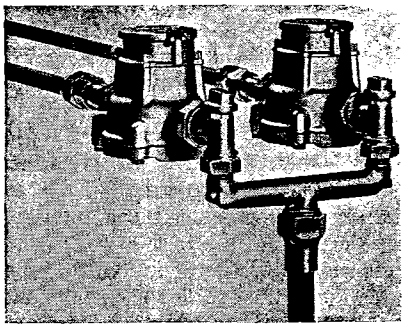

Main connection

A U-branch connection that allows two water meters to be connected to a single water service line has been developed by A. Y. McDonald Mfg. Co. With the new No. 3795 connection, a single tap in the main can accommodate two adjacent services, reducing the cost of both labor and material. Either flat head or lock wing style meter stops can be attached to the outlet sides of the connection. The connection has a 1-in. copper inlet, ¾-in. male iron pipe outlets, and 7½-in. centers on the outlets.

Circle No. 6 on Reader Service Card

Improved boring tool

A new helically grooved nose section for the PneumaGopher is reported by Schramm, Inc. to markedly improve the tool's performance in driving horizontal or inclined boreholes through wet and slippery subsoils, including clays. The spiral grooving gives the air-actuated, impact-boring tool a firmer frictional bite. The new nose section is compatible with units already in service.

A simplified valve assembly, which substitutes two simple rubber bushings for seven separate mechanical components formerly required, and the substitution of wire-braided leader hose for the air line formerly supplied are two more improvements noted.

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