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POLLUTION CONTROL OF BLAST FURNACE PLANT GAS SCRUBBERS THROUGH RECIRCULATION

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After the recycle system started operating, gross contaminant discharge decreased to 1,900 tons per year, and net discharge became a negative quantity.

The construction cost of the unified recirculating system was $1,109,400 for this plant producing about 3,200 tons of hot metal and 3,300 tons of sinter per day. Operating costs are about $285,000 per year higher than the costs of operating the old "once-through" water system. Elimination of dredging costs, and increased iron recovery produce savings of about $10,000 per year, so the net increase in plant operating costs is about $275,000 per year, or $.0001 per gallon of throughput.

*Chemical Control, *Contaminants, *Flocculation, *Recirculated Water, *Water Clarification, Acidity, Alkalinity, Ammonia, Anion Exchange, Cation Exchange, Cooling Tower, Corrosion, Costs, Efficiencies, Hydraulic Design, Hydrogen Ion Concentration, Iron, Phenols, Pollution Abatement, Polyelectrolytes, Polymers, Scaling, Sedimentation, Separated Sewers, Suspended Solids, Temperature, Water Quality Standards.

*Blow-down, *Corrosive-Scaling Conditions, *Hydraulic Balance, *Stability Index, Blast Furnace, Chemical Stability, Clarifier, Conservative Substances, Cyanide, Dust Collector, Gas Cleaner, Gas Cooler, Gas Scrubber, High-Energy Gas Scrubber, Hydraulic Load, Make-up, Nalco Aquagraph, Non-conservative Substances, Particulate, Ryznar Stability Index, Scale Formation, Secondary Clarifier, Sinter Plant, Spray Tower, Water Separator.

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SECTION III

PRODUCTION PROCESSES

Interlake's Chicago Plant includes 4 separate parcels of land totaling about 500 acres. Generally, the plant is located on the Calumet River, with iron-making facilities on the east side of the river and coke-making facilities on the west side. A high-level suspension bridge carrying a coke conveyor and gas and steam mains connects the two plant areas. The plant map, Figure 1, shows the facilities and their relative locations.

Coke Plant

The coke plant consists of coal unloading and storage facilities, two batteries of 50 Wilputte underjet ovens each and a by-product plant.

The coal mix for coke making includes 3 main coals normally proportioned as follows:

25% Pocahontas Low-Volatile Coal
60% Illinois Coal
15% Pond Creek Coal

Coal is delivered to the coke plant in unit trains of 100 cars. It is unloaded by car dumper and delivered by conveyors to the storage area. Here the stocking system is served by 3 Euclid Twin-Scraper units which handle coal into or out of stock as received or required. The normal coal storage capacity of 150,000 tons can be readily expanded, if necessary.

Coal going to the ovens is reclaimed from the storage area and conveyor fed to a pulverizer and then the mixer building bins. Next it is blended in the desired proportions and conveyed to the oven storage bins. From these bins it is drawn, as required, into the coke-oven larry car or charging car. The larry car, which is designed to hold the amount of coal needed for charging one oven, runs on

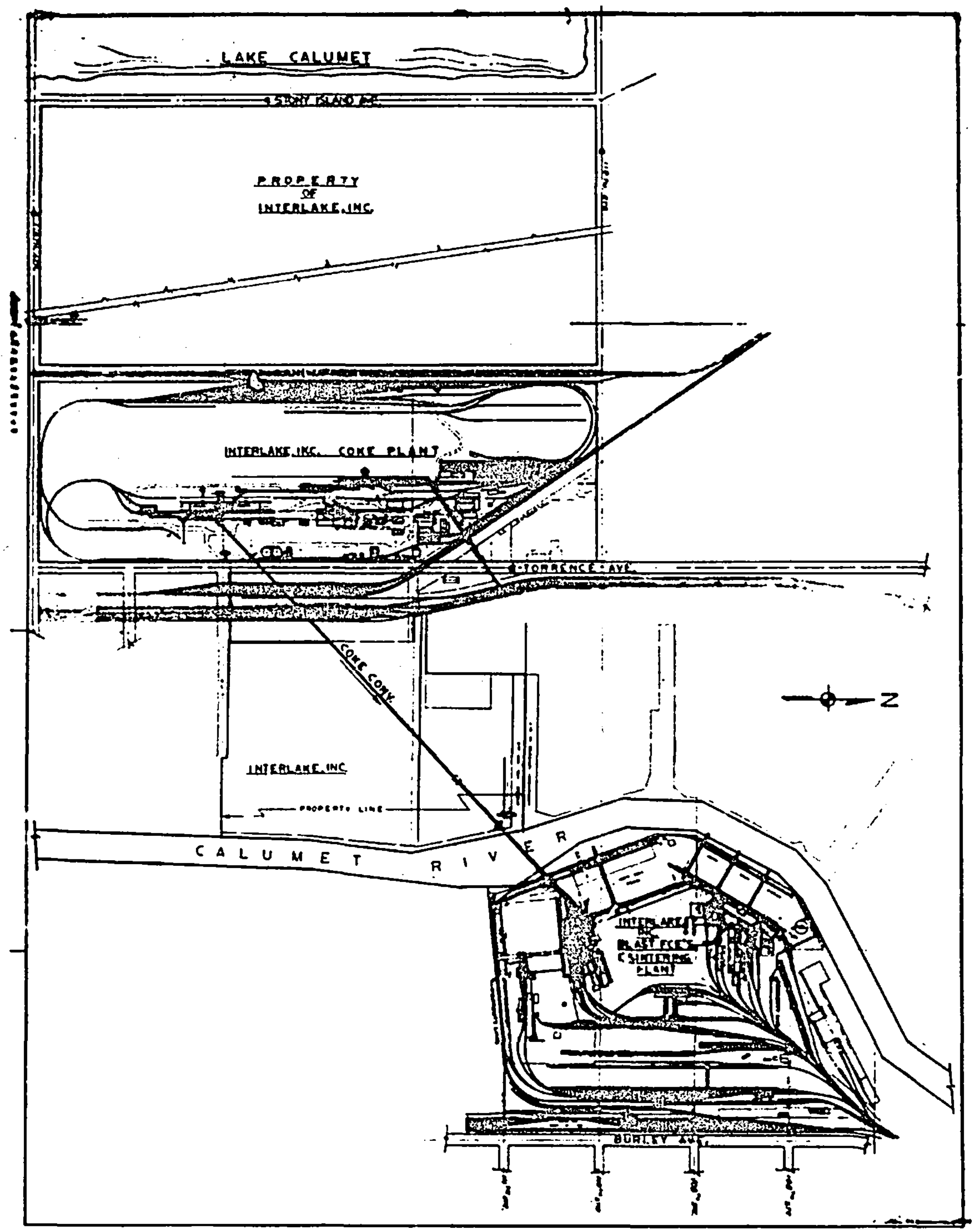

Fig. 1 Interlake, Inc. - Chicago Plant Map

tracks supported on top of the batteries of ovens. Coal is charged into each oven through three holes, which are immediately sealed when the charging operation is completed. As the coal is heated in the oven, it becomes plastic at 660 to 890°F, forming a fused mass irrespective of its form when charged. Through this range of temperature, volatile matter is given off, rapidly at first, then more slowly up to about 1740°F.

The volatile matters evolved are a combination of gases and vapors. Gases include hydrogen, methane, ethane, carbon monoxide, carbon dioxide and unsaturated hydrocarbons such as ethylene, propylene, butylene and acetylene. Other gaseous compounds present are hydrogen sulphide, ammonia, oxygen and nitrogen. The vaporized liquids in the gases exiting from the ovens include a multitude of hydrocarbons which are generally grouped into three categories, ammonia liquor, tar and light oil.

A good metallurgical coke will retain very little volatile matter -- not over 2 percent -- and will contain 85 to 90 percent fixed carbon. The remainder is ash, sulphur, and phosphorus.

A typical analysis of metallurgical coke would be:

Fixed carbon - 90.0%
Volatile matter - 1.3%
Phosphorus - .005%
Sulphur - .75%
Other ash materials - 7.945%

At the Interlake Coke Plant, the two batteries of ovens, built in 1956 and 1957, are of relatively modern design. They are operating presently on a continuous 16-hour cycle basis. Each oven is designed to receive a charge of 17.4 tons of coal. In 16 hours, 11.6 tons of coke are produced per oven. This results in a yearly coal consumption of 900,000 tons and yearly coke production of 620,000 tons, including 575,000 tons of metallurgical coke suitable for blast furnace use.

Coke discharged from the ovens is quenched at a water spray type quench tower which uses river water as a make-up source, and which recirculates the quenching water. There is no blow-down from this system. Coke is then conveyed over a series of belt conveyors to a screening station at the southwest corner of the blast furnace plant. Chemicals volatilized during the coking process are piped to the by-product plant where ammonium sulphate, tar, pitch, and light oil are removed from the coke-oven gas.

There are no special provisions for sulphur removal in the coke plant gas system; the gas leaving the plant has a sulphur content of from 1 to 2 grains per cubic foot.

Sulphur is in the form of H_2S.

Blast-Furnace Plant

In the ironmaking area, east of the Calumet River, there are two blast furnaces, ore unloading and storage facilities, a coke-screening station, a sinter plant, a boiler-house, two 2-strand pig machines, a pig storage yard, and miscellaneous supporting facilities.

Raw Materials

The map of the Chicago Blast Furnace Plant, Figure 2, shows that raw material unloading, storage, processing, and handling are major considerations in a blast-furnace plant. In 1970, the Chicago Plant consumed the quantities of raw materials shown in Table 5.

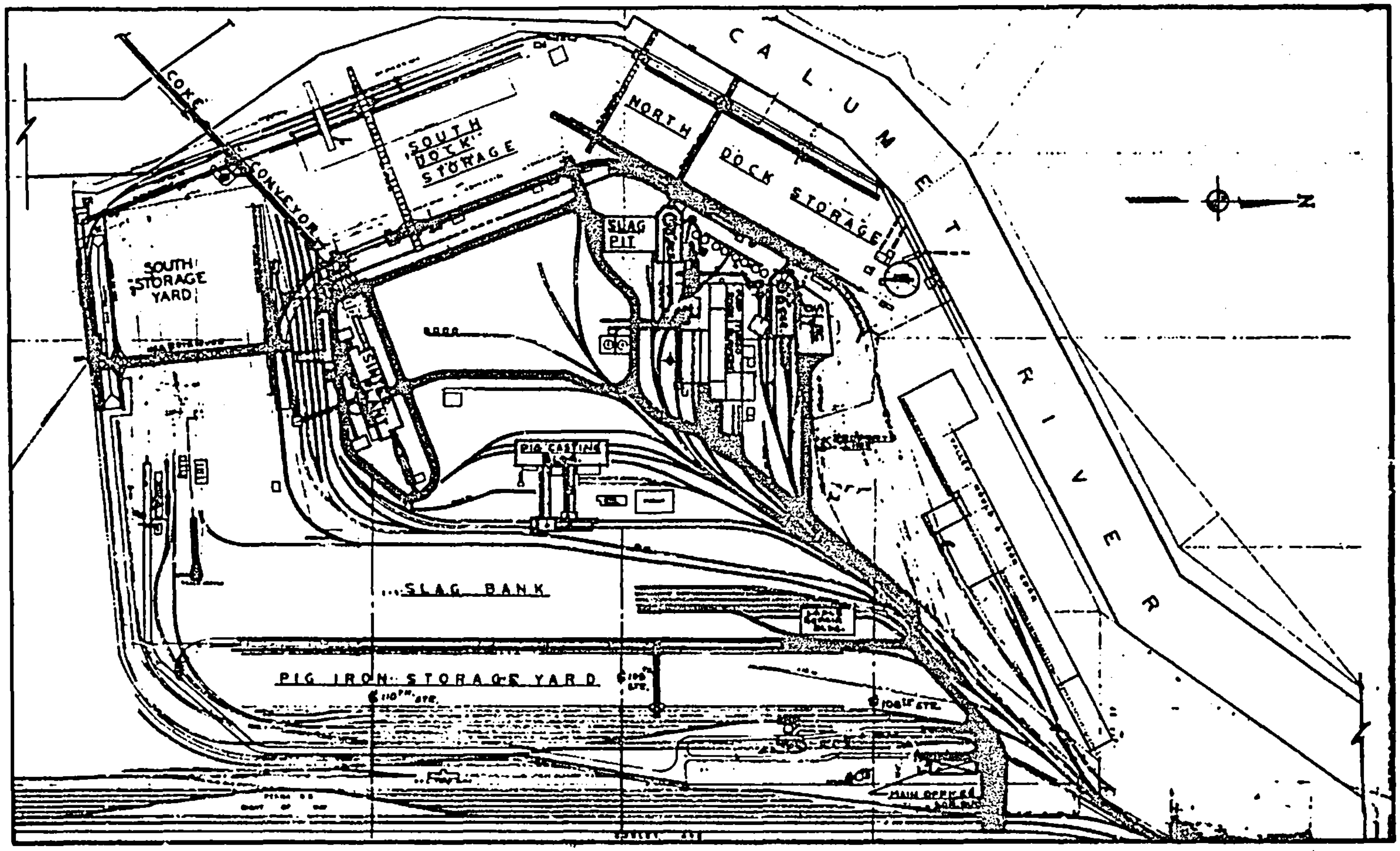

Fig. 2 Interlake, Inc. - Blast Furnace Plant Map

Table 5

Blast Furnace Plant Raw Materials

Coke	680,000 tons
Coke Breeze (Fines)	60,000 tons
Limestone (Coarse and Fine)	120,000 tons
Dolomite (Coarse and Fine)	160,000 tons
Iron Ore (55% Fe)	320,000 tons
Pellets (62% Fe)	1,250,000 tons
Sinter (53% Fe)	500,000 tons
Scrap	60,000 tons
Miscellaneous Iron-bearing Materials	250,000 tons

Inasmuch as the quantities of raw materials handled are so large and deliveries to the plant may be seasonal, control of raw material movement is of utmost importance. The raw material storage capacities are limited, and the optimum quantities of some materials are somewhat unpredictable, due to changes in iron analysis and in raw material prices and availability.

Ore, sinter, pellet and flux (limestone and dolomite) storage is provided in 3 storage yards: the north dock storage, 780 feet long by 210 feet wide; the south dock storage, 650 feet long by 350 feet wide; and the south storage yard, 497 feet long by 390 feet wide. The north and south docks will each accommodate a lake carrier of the longest type. Materials are unloaded from carriers by means of an ore unloading tower and unloading bridges with lifting aprons. Two 5-ton bridges serve the north dock, while the south dock is served by one 10-ton bridge and a 20-ton unloading tower. The south storage yard is served by a 20-ton bridge. A conveyor system serving the entire length of the south dock will accept material from either unloader along this dock and deliver it to a trough under the bridge serving the south storage yard.

Two 50-ton transfer cars operate on a continuous highline track which runs the entire length of each storage yard. A second highline track at the blast furnace stockhouses is used in supplying some coke and most miscellaneous materials to the furnace.

Access to the two highline tracks has previously been provided by a highline approach at the north end of the plant. Now, production facility expansion has necessitated the abandonment of this approach, and an approach connecting into the highline opposite the south storage yard has recently been placed in service.

Sinter Plant

The sinter plant produces an excellent iron-bearing raw material using partly waste materials from Interlake's and other area plants, as well as lower-price fine iron ores which would be impractical to use in their natural condition. The charge material produced, sinter, is also more reducible than ore in the blast furnace and is a desirable furnace burden material in producing even gas flow within the furnace stack and a smoother operating furnace. Alkaline additives to the sinter produce a furnace feed material which can be self-fluxing or even higher in basicity than required for the sinter alone.

The Chicago sinter plant, which is of Dravo-Lurgi design, has a production capacity of 3300 tons per day. The plant does not always operate on a 3-shift, 24-hour basis, and some of its production is sold to other steel companies, so the yearly sinter consumption figure can not be correlated with sinter plant capacity. The plant is of modern design although it was first put into operation in 1960.

Fuel for the sintering operation is brought into the plant, in the form of breeze and fines, by conveyor from the adjacent coke screening station or from ground-level track hoppers. If required, it is ground to the required fineness in a rod mill and then conveyed to a large storage bin. Other raw materials, fine iron ores, flue dust, dolomite and limestone, are brought in through a system of track hoppers and conveyors, screened and stored in large bins. These materials are fed, in closely controlled proportions, onto a system of conveyor belts which carry them to the sinter machine. Flue dust from the blast furnaces, varying from 0 to 10% of the feed, is pugged, or moistened, and also introduced into the system. Filter cake from the slurries collected at the sinter plant clarifier is fed directly onto the sinter feed belt.

Fairly recent additions to sinter plant feed materials include pellet fines, roll scale and several other steel plant offal materials. The proportions of various iron-bearing, flux and fuel materials which are fed to the machine vary over a fairly wide range, depending on the cost and availability of materials, basicity of sinter being produced, and other factors.

The mix is placed on the traveling grates of the sinter machine, where it first passes under an ignition furnace which ignites the coke and other combustibles. An induced draft fan of 290,000 cfm capacity, driven by a 2500 horse-power motor, pulls air down through the bed of material as the grates travel the length of the machine. When the bed reaches the end of the machine, it has been sintered, or burned, to a hard, homogeneous clinker. After discharge, from the machine, the sinter passes through a breaker to reduce it to usable sized pieces. At this point, it is hot-screened and the proper sized portion is carried on the sinter cooler to the load-out tower. The sinter is cooled by having air drawn through the bed of material. At the load-out tower, the sinter product is cold-screened, and material of blast furnace size (+ 1/4") is loaded into a transfer car for transportation to the blast furnace bins, or is conveyed to a storage pile. The -3/8" material separated by hot screens after the sinter breaker, and the -1/4" fines separated at the cold screens after the cooler are recirculated and reintroduced into the mix feed system. Some of the intermediate size material (+3/8"-1") separated at the cold screens, is recirculated as a hearth layer on the sinter grates, to reduce the amount of dust passing into the exhaust system.

Dust produced in the sintering process is drawn down through the wind boxes beneath the traveling grates into the gas main, where the larger particles drop out into a series of dust hoppers. Sinter particles are carried on with the gas and are removed in a series of sixteen parallel high-efficiency cyclone collectors before the gas is emitted from the stack. All dust removed to this point, amounting to about 120 tons per day or over 98% of the total gas solids, is collected on a conveyor and reintroduced into the system. This amounts to about 3% of the raw feed to the sinter machine.

There are in the plant a total of 34 belt conveyors handling raw material and finished product. In order to control the dust generated at the various exchange points and other areas, including the sinter machine discharge, two dedusting systems are operated. System "A" collects air at the sinter machine discharge, hot sinter feeder and screens and other points on the hot and cold fines system. System "B" pickup points are in the cold-screening and load-out building. Both systems utilize wet scrubbers, with the resulting slurry being discharged to the sinter plant clarifier. The dedusting systems exhaust to atmosphere. A more detailed description of these systems is given in Section V.

Blast Furnaces

The focal points of the South Chicago Plant are the two blast furnaces. These furnaces produce the molten iron required by the basic oxygen steelmaking shop at the Riverdale Plant and by the Microdot ingot mould facility located adjacent to the Blast Furnace Plant. The furnaces also produce some iron which is pigged and sold as merchant grades of pig iron. Total iron production of the two furnaces is 1,100,000 tons per year.

Figure 3 is a diagrammatic cross-section of a typical blast furnace, identifying the principal elements of construction and indicating the flow of gases through the material burden within the furnace. The working dimensions of the Interlake Chicago furnaces are shown on this cross-section.

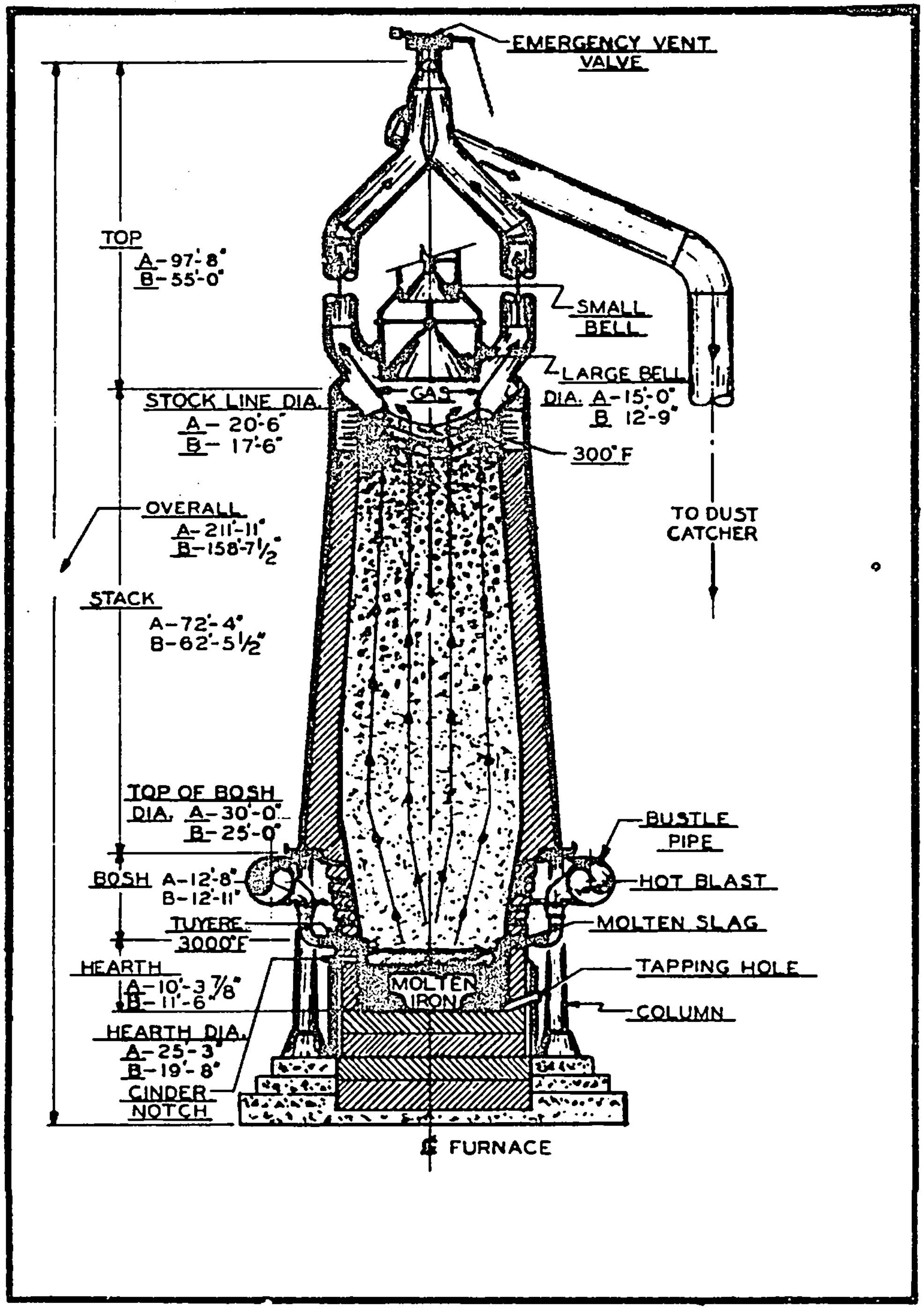

Fig. 3 - Blast Furnaces A & B Working Dimensions

Essentially, the blast furnace process consists of charging iron-bearing materials (ore, sinter, and pellets), fuel (coke) and flux (limestone and dolomite) into the top of the furnace and blowing heated air into the bottom of the furnace. The furnace is a huge steel shell lined with carbon and ceramic refractories. Once started, it runs continuously until all or part of the lining needs renewal, or until demand for the iron drops. Iron-bearing materials, coke and fluxes in alternate layers work their way down from the top, becoming hotter as they sink. In the upper portions of the furnace, reducing gases from the coke and from gaseous or liquid fuels injected with the air blast at the tuyeres react with oxygen released from the heated ore and other iron oxide materials. Midway down the furnace stack, fluxes begin to react with the impurities in the burden to form slag. Next, the iron becomes a porous mass as the burden moves down the stack progressively yielding molten metal which drips down through the burden and collects in the hearth of the furnace. Ash from the coke is absorbed by the slag which drips down to form a pool of molten slag on top of the iron pool. Coke reaches the region of the tuyeres in a white hot condition and reacts vigorously with the oxygen in the hot air blast to produce the heat needed for the blast furnace process, and to form the reducing gases used in the upper portions of the stack.

Periodically (from 5 to 9 times a day) the furnace is tapped, and iron and slag are withdrawn. Iron is conveyed to hot metal cars in which it is transported to the Riverdale BOF shop, the Microdot mould facility or to the pig machine located within the South Chicago Plant.

Figures 4 and 5 are line diagrams of solid material flows at each of Interlake's two Chicago blast furnaces. Material flows shown are based on representative figures for production rates and raw material consumption.

The blast furnace plant blowing facilities include 3 turbo-blowers, each rated 70,000 C.F.M. at 25 p.s.i.g. The blowers are equipped with parallel-blowing and split-wind control, so that the combined capacity of either two or three blowers can be split as required between the two furnaces.

It is interesting to note the changes in pollution and pollution control techniques which have occurred within the past 15 years. 15 years ago, over 100 tons of flue dust per day were discharged in the gases passing from the tops of the two blast furnaces. After cleaning of the gas and settling of solids from the wash water, approximately 7,400 tons of solids per year were discharged to the Calumet River. Through design improvements, refinement in operation, and beneficiation of raw materials, it has been possible to reduce the dust rate (pounds of flue dust discharged, per ton of iron produced) from about 150 pounds per ton to the present 25 pounds per ton. The recirculating water systems have been effective in not only eliminating the solids discharged to the river from the gas cleaning systems, but actually brought about, in 1970, a negative net solids discharge. That is, the water returned to the river was, on the average, cleaner than that taken in and used by the plant. This was accomplished at production rates almost exactly twice as high as those existing 15 years ago.

A high percentage (actually about 99 percent) of the solid materials escaping from the blast furnace in its exhaust gases is captured by the gas cleaning system and reclaimed for use as charge material. This is accomplished by a 3-stage cleaning system including a conventional dry dust-catcher, a high-energy wet scrubber and a counter-current spray tower which acts as a combination gas cooler-moisture eliminator.

The dry dustcatcher dust is taken by railroad car to the sinter plant, where it is conveyed to feed bins and eventually fed into the sinter machine mix. Wetted dust from the high-energy scrubber and gas cooler is pumped, with the discharge water, to a water treatment system. The dust in the form of a thickened slurry is then pumped to two disc-type sludge filters located at the sinter plant. The filter cake feeds directly to the sinter machine feed conveyor.

Blast furnace gas is used as a fuel in the blast furnace stoves and the boilers. The more critical requirements for clean and dry gas exist at the stoves, where maintenance of checkerwork cleanliness is an important factor. Gas which contains more than .01 grain of dust per cubic foot is not desirable for use in the small-hole (2-inch square or smaller) checker tile of a modern stove. Excessive moisture in the gas not only depresses the thermal value of the gas but produces a sloppy condition at the stove burners.

Iron Production Wastes

Based on the variety of constituents in iron ores, fuels and fluxes, and on the temperatures and pressures which exist in an operating furnace, the chemical reactions which are carried out in a blast furnace are multitudinous and to some degree indeterminate.

The reduction of iron oxides to metallic iron proceeds in accordance with a dozen or more reactions involving C, CO, CO_2, Fe_2O_3, Fe_3O_4, FeO and Fe. These reactions have been the subject of many comprehensive studies, but they are not germane to the subject of formation of contaminants in the blast furnace gas.

The significant pollutants in blast furnace gas scrubber water are cyanide, phenols, ammonia, suspended solids, temperature and pH. The source of these pollutants is as follows:

Cyanide

The hot blast of air blown into the furnace at the tuyeres has the usual proportions of O_2 and N_2. The action of the nitrogen of the blast upon the hot carbon in the hearth results in the formation of small quantities of cyanide. Cyanide has a strong affinity for the sodium and potassium present in the fuel ash, and as a result, cyanides of the alkali metals are present in the gases leaving the hearth zone. Typically, this reaction proceeds as shown. (4).

$$K_2 CO_3 + 4C + N_2 = 2KCN + 3CO$$

The cyanide, which is a powerful reducing agent reacts:

$$KCN + FeO = Fe + KCNO$$

The resulting potassium cyanate passes upward in the gases and is decomposed by CO_2 into carbonates with the liberation of nitrogen, thus:

$$2KCNO + CO_2 = K_2 CO_3 + CO + N_2, \text{ or}$$

$$KCN + KCNO + CO_2 = K_2 CO_3 + 2CN$$

The potassium carbonate is largely deposited in the cooler parts of the furnace and carried downward by the descending materials to the hearth, where it can again act as a base for cyanide formation.

The precise mechanism of formation and circulation of cyanides within the furnace is open to speculation, however, it is a fact that a quantity of cyanides escapes from the furnace in the outlet gas and in the flue dust. This is the quantity which pollutes the gas scrubber water.

The discharge of cyanide from a blast furnace occurs in an irregular pattern of flow, and a chemical treatment of the gas is therefore rendered more difficult. It is possible that these variations in cyanide evolution may be a result of channeling of gases through the burden in the furnace stack. This is a factor which cannot be effectively controlled in present-day normal blast furnace practice.

Phenol

The entire list of sources of phenols is not pin-pointed but it is apparent that much of these originate in the volatile residue in the coke, or possibly in other organic gangue constituents of the furnace raw materials.

At some coke plants, a potential source of phenol is introduced by the technique of quenching coke with waters which contain phenolic wastes from coke gas by-product plant operations. Interlake does not use such waters for quenching, but employs a separate recirculating quench water system with river water provided as make-up. Whatever the exact source, some phenols are picked up in the gas scrubber water and carried into the blast furnace recycle system.

Suspended Solids

Fine particles which enter or are formed in the top of the furnace are picked up by the high gas velocities existing in the furnace stack and are conveyed through the raw gas system.

The nature of particulate matter escaping from the stack will vary from furnace to furnace, depending on the composition of the raw materials, furnace operating techniques and other variables. Some of the constituents which are carried over with the gas are Fe_xO_y, $CaCO_3$, CaS, $MgCO_3$, SiO_2, CaO, MgO, KCN, and Carbon. In regard to particle size, one sample of particulate matter analyzed as shown in Table 6.