as would be at first imagined; for the actual weight of air blown per ton of iron produced is six or seven times the weight of the solid materials charged.

The blast furnace itself is a very large structure, circular in section, of a height varying from 60 ft. to 90 ft., and a largest diameter of about one-fourth the height. The contour of the interior is not that of a perfect cylinder, but from the point of largest diameter (technically called the "bosh" diameter) the walls are drawn in both upward and downward, so that at the bottom of the furnace the diameter is only about one-half the bosh diameter, and at the top about 30 per cent. smaller than the bosh. The lowest part of the furnace is called the "hearth" or "crucible," for it is here that the molten iron collects before being drawn off. The walls of the crucible are from 5 ft. to 6 ft. in height and usually perpendicular. From the top of the crucible walls the furnace slopes outward and upward till the bosh is reached. This whole section of the furnace is also known as the "boshes," and it is here that the actual fusion of the materials takes place. From the bosh up to the top the walls slope in again.

The materials, viz., ore, fuel and flux, are charged into the furnace by means of a mechanism known as a "bell and hopper," which at the same time closes the top of the furnace. A heavy cast iron hopper is fitted over the top of the furnace, leaving an opening in its centre of about half the bosh diameter. This opening is closed by a heavy iron bell, fitted into position from the interior of the furnace so that the lower edge of the bell laps over the lower edge of the hopper on its under side for three or four inches. Thus when the bell is drawn up tightly against the hopper, the furnace is tightly closed even to the escape of gas. The materials are then dumped into the hopper until it is full, when the bell is then lowered by means of a mechanically actuated and balanced lever arm, so that a space of 15 in. to 20 in. is opened between the contact edge of the bell and the hopper, and through this space the materials slide over the sloping sides of the bell into the interior of the furnace. This bell shape is used for the purpose of obtaining an equal and uniform distribution of the materials over the area of the furnace, which would not be possible were the materials dumped into an ordinary opening. This uniform distribution in charging is very important to the uniform working of the furnace; for if the materials were all dumped into the centre or to one side, the ascending carbonic oxide gas, seeking the easiest way out, would but imperfectly act upon the great mass accumulated in one locality, and the furnace would work one-sided. The great height of the furnace is required in order to expose the ore for a sufficiently long time to the action of the carbonic oxide. The descent of the ore from the top to the bottom of the furnace occupies from 18 to 24 hours. On a level with the floor of the crucible, on the front side of the furnace, is the situated the "tapping hole." This hole pierces the wall of the furnace to its interior, and through it the molten iron is drawn out. The tapping hole leads directly into a trough which communicates with the casting beds. This hole is stopped up with clay during the time the iron is collecting in the crucible. Tapping takes place usually every six hours. About 3 ft. above the tapping hole and sometimes directly over it, sometimes to one side, is the slag tap or "cinder notch" as it is technically called. The slag formed by the flux, floating upon the surface of the iron, is here drawn off from time to time as it rises to its height. It is usually run directly into buggies or cars constructed for the purpose and hauled of to the cinder dump.

The blast is introduced into the furnace at the top of the crucible, about 5 ft. or 6 ft. above the floor. At six or eight equi-distant points in the circumfrence of the furnace wall openings are made into the interior of the furnace. Into these openings water-cooled "holders" of bronze or iron are fitted. Into these holders are accurately fitted the blast nozzles or "tuyeres," also water-cooled. The water-cooling is accomplished by casting a coil of pipe in the iron holder or tuyere, through which water is continually forced, or in the case of the bronze tuyere and holder the walls are made double, with a space between, in which water is kept circulating. At a sufficient height above the tuyeres a main blast pipe encircles the furnace, from which branches are let down to each tuyere. The tuyere nozzles are inserted from 6 in. to 10 in. beyond the inner wall into the furnace. The water-cooling of the tuyeres and holders, while designed primarily for their maintenance, aid much in preserving the brick work adjacent to them. Following up this hint, the bosh walls of the furnace are now greatly prolonged in life by inserting rows of water cooled plates completely encircling the furnace at distances of about 30 in. between the rows. These are built in the brick work and are invisible, except the outside edge of the plate and the water connections. These plates are removable in case of leak, which is rare.

The accessories to the blast furnace proper are the boilers, blowing engines, hot blast stoves, hoists and water supply. The boilers and stoves are heated by waste gases from the furnace, so that the furnace is practically self-supporting in the matter of power, the only fuel necessary being that put into the furnace for the purpose of smelting. The furnace gases rise to the top of the furnace, and are thence conducted away by a large pipe called the "down-take," which carries the gases down to the main flue which lies underground. This flue conducts the gases to the boilers and stoves. The lower end of the down-take is enlarged just before it enters the flue into a chamber of considerable size known as the "dust-catcher," which name sufficiently describes its function. The gases carry with them considerable quantities of dust which accumulate in the flues, stoves and boilers, seriously impairing their effeciency by choking them. This the dust-catcher is designed to obviate. The boilers and blowing engines need little description, as they speak for themselves. The use and operation of the hot-blast stove is a subject of much interest, and to the furnaceman it is a very considerable factor in the furnace economy.

It is apparent that if air at the temperature of the surrounding atmosphere be blown into the furnace it will require a certain amount of fuel to bring it up to the temperature of the seething mass. If this air could be heated, and that, too, without further expenditure of fuel, before it is delivered into the furnace it is evident a considerable economy of smelting fuel must result. This is what is accomplished by the hot-blast stove. The waste gases of the furnace, which formerly were permitted to escape into the air, are by this apparatus utilized for the heating of the blast. Stoves as constructed nowadays consist of a large shell of tank plate enclosing a mass of fire-brick so disposed as to form a large number of small flues or checkerwork. Each stove measures from 15 ft. to 20 ft. in diameter, and 60 ft. to 70 ft. in height, being nearly as large as the blast furnace itself. A total cross-section area of, say 300 square feet is subdivided by the brickwork into a large number of small flues, of say, 40 square inches, thus multiplying the heating surface enormously. These flues are constructed perpendicularly. The gas is admitted at the bottom of one side into a chamber where it is mixed with the proper proportion of air to produce combustion; thus ignited it rises to the top of the stove, where it is deflected down again through a series of small flues. On reaching the bottom, it is deflected up again and then down, having traversed the height of the stove four times before it passes off by the chimney. The gas having been passed through the stove a sufficiently long time to bring the whole mass of brickwork to a bright red heat, it is then shut off and the blast from the blowing engines is then admitted on the opposite side of the stove from the gas, and is made to travel over the same path through the stove in the reverse direction. During its passage it absorbs the heat from the brickwork, raising its own temperature to from 1,200 to 1,500 deg. F. From the stove the air is then carried by the blast main directly to the tuyeres. There are usually three and sometimes four stoves attached to each furnace. Each stove is kept on gas for two hours and on air for one hour; three stoves, therefore, permit of two stoves being kept continually on gas and one on air, a stove being changed every hour. Of course before the blast is shut off of one stove it is admitted through a fresh one, as the blast must be kept continuously on the furnace.

Another valuable feature of the hot-blast stove is the fact that it places within the control of the furnace manager an amount of caloric or heat energy entirely subject to his manipulation; thus, if the furnace is disposed to work cold, an increase of temperature of the blast will usually act as a corrective, and *vice versa*. In the uniform production of a desired grade of iron, this is of the highest value. In this connection a very brief consideration of the chemistry of pig iron may not be out of place.

In recovering from the ore the iron it contains, we do not obtain that iron chemically pure, nor is it desirable that we should do so. We have seen how the earthy impurities were to a considerable extent removed, viz., the silicates of alumina, lime and whatever of magnesia there might be in the ore. But certain other elements, notably phosphorus and manganese, are not thus removed; nor are they ever completely removed, the second only partially, the first not at all. In addition to the impurities of the ores we are adding with the fuel, especially where coke is used, another lot of impurities, notably silica and sulphur. Silica, or silicic acid, as it is chemically called, being a compound of silicon and oxygen, is not capable of being decomposed into its constituent elements, silicon and oxygen, except at the very highest heat. Therefore out of the very large amount of silica in the form of silicates that is charged into the furnace, we find only a comparatively small proportion appearing in the pig iron as silicon, which has doubtless been decomposed in some areas of very high temperatures before the tuyeres. A portion of the sulphur is carried off in the slag, but enough remains to make a good deal of trouble to the pig iron consumer. In the resulting iron then, we find in addition to the metallic iron such impurities as silicon, sulphur, phosphorus, manganese and carbon. The carbon in pig iron exists in two states, free carbon in the form of crystals or flakes and combined or dissolved carbon which has been taken up by the iron before the tuyeres. The proportions in which these two conditions of carbon exist in the pig iron depend upon the temperature of the furnace; if the furnace is hot, the carbon exists in very large percentage as free carbon or graphite; if the furnace is working cold, the carbon in the iron will be found largely as combined carbon with little graphite. So, too, as might be inferred from what was said before, a cold iron will contain little silicon as the temperature before the tuyeres has not been sufficient to decompose the silicic acid. The temperature also has a marked influence on the behavior of the sulphur. With the furnace working hot, it is nearly all carried off in the slag, but at lower temperatures its greater affinity for the iron asserts itself and a cold iron is found to contain an objectionable amount of sulphur. Cold iron, therefore, will be low in silicion, low in graphite carbon, and high in sulphur; for most purposes an undesirable combination. The value of the hot-blast stoves in enabling the furnace manager to correct the temperatures of his furnace is thus made plain.

The operations of the blast furnace are continuous until the fire brick lining wears out. This occurs in from two to three years under ordinary circumstances; or a better way of stating the life of the lining is that it will generally yield 125,000 to 150,000 tons of iron, though one or two of America's famous furnaces have turned out 300,000 and even 400,000 tons on a single lining. The management of a blast furnace, the proper mixing of the materials, the regulation of the working of the furnace itself for the production of a large, uniform and economical output call for the highest skill, watchfulness, patience, and often courage. An accident to the furnace is almost always expensive and often dangerous; the apparatus is always operated under high pressure and the highest heats known to science. Altogether the management of a blast furnace presents a most intricate problem in economical metallurgy.

Cheaper Steel Rails.—A significant article on the steel rail trade appeared recently in the *Iron Age*. The opinion expressed is that the trade is on the eve of important improvements and that new factors will have to be taken into account next year. The Youngstown mill now nearing completion, may enter the rail trade whenever there is a sufficient difference between billets and rails; and there is the possibility of foreign rails being imported on the Gulf and the Pacific coast. The six great mills, however, may be able to hold their whole territory in spite of any rivals. One has made important important improvements in plant; another has secured a source of supply of cheap raw material; a third has the advantage of a lower duty on foreign ore; and a fourth is extremely aggressive in its management. There is a widespread opinion that lower prices for rails would help the billet market by increasing the consumption, and with present prices of raw materials the rail mills could afford to sell at lower prices than those ruling if they had a larger tonnage. But the financial condition of the railroads is such that the prospect of a tonnage up to anywhere near the capacity of the mills, is not bright.