States. The arrangement at the Carnegie Company's Duquesne works (Fig. 88) may serve as an example of modern methods of handling.

The standard-gauge cars which bring the ore and coke to Duquesne pass over one of three very long rows of bins, *A, B,* and *C* (Fig. 88), of which *A* and *B* receive the materials (ore, coke, and limestone) for immediate use, while *C* receives those to be stored for winter use. From *A* and *B* the materials as they are needed are drawn into large buckets (*D*) standing on cars, which carry them to the foot of the hoist track *EE,* up which they are hoisted to the top of the furnace. Arrived here, the material is introduced into the furnace by an ingenious piece of mechanism without allowing any of the furnace gas to escape. The hoist-engineer in the house *F* at the foot of the furnace, when informed by means of an indicator that the bucket has arrived at the top, lowers it so that its flanges (*GG,* Fig. 89) rest on the corresponding fixed flanges *HH,* as shown in Fig. 90. The further descent of the bucket being thus arrested, the special cable *T* is now slackened, so that the conical bottom of the bucket drops down, pressing down by its weight the counter-weighted false cover *J* of the furnace, so that the contents of the bucket slide down into the space between this false cover and the true charging bell, *K*. The special cable *T* is now tightened again, and lifts the bottom of the bucket so as both to close it and to close the space between *J* and *K,* by allowing *J* to rise back to its initial place. The bucket then descends along the hoist-track to make way for the next succeeding one, and *K* is lowered, dropping the charge into the furnace.

Thus some 1700 tons of materials are charged daily into each of these furnaces without being shovelled at all, running by gravity from bin to bucket and from bucket to furnace, and being hoisted and charged into the furnace by a single engineer below, without any assistance or supervision at the furnace top.

The winter stock of materials is drawn from the left-hand row of bins, and distributed over immense stock piles by means of the great crane *LL* (Fig. 88), which later transfers it as it is needed to the row *A* of bins, whence it is carried to the furnace as already explained.

268. Handling the Molten Cast Iron.—A great saving of labor was effected by the introduction of "pig-breaking" machines. A whole row or litter of pigs with its sow was lifted

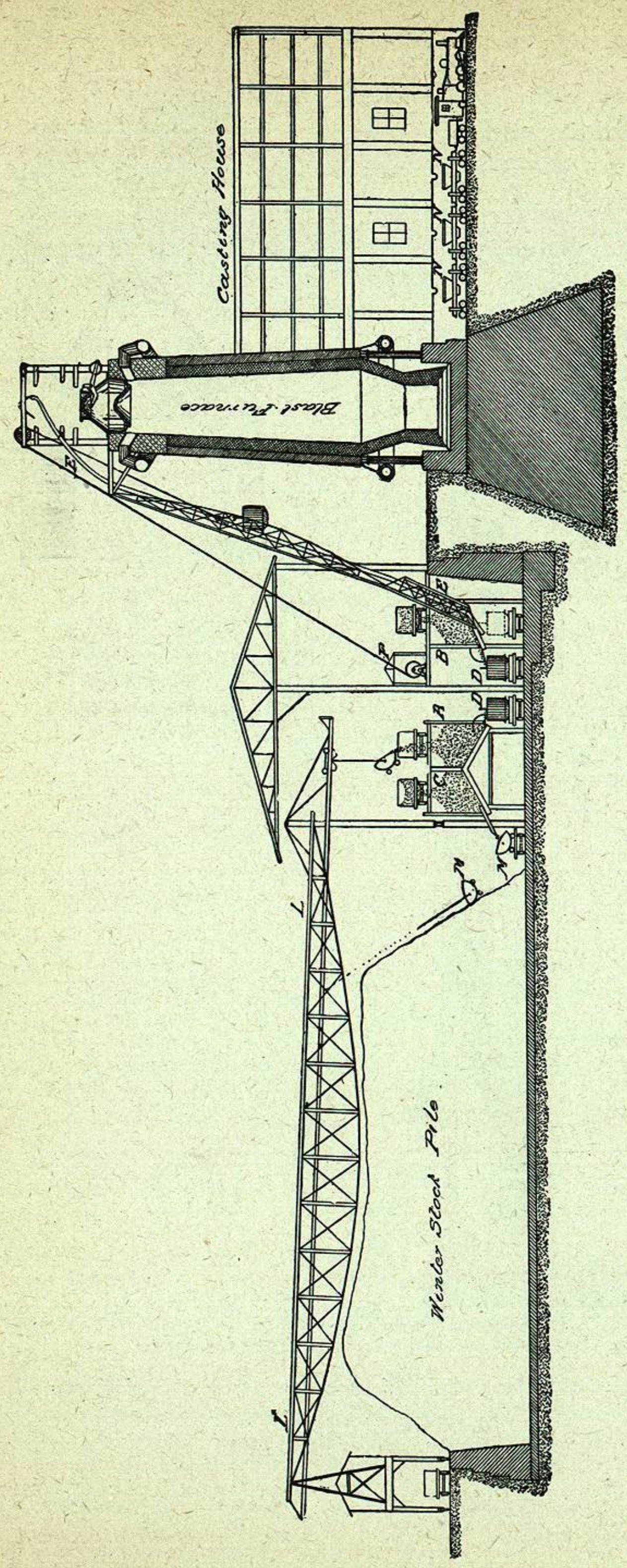

Fig. 88. Diagram of the Carnegie Blast-furnaces at Duquesne, Pa.

A and *B*, bins for stock for immediate use; *C*, receiving bin for winter stock pile; *DD*, ore bucket; *EE*, hoist track; *F*, hoist engine-house; *LL*, travelling crane commanding stock pile; *M*, ore bucket receiving ore for stock pile; *M'*, bucket removing ore from stock pile; *N, N, N*, ladles carrying the molten cast iron to the Bessemer Steel Works, etc.

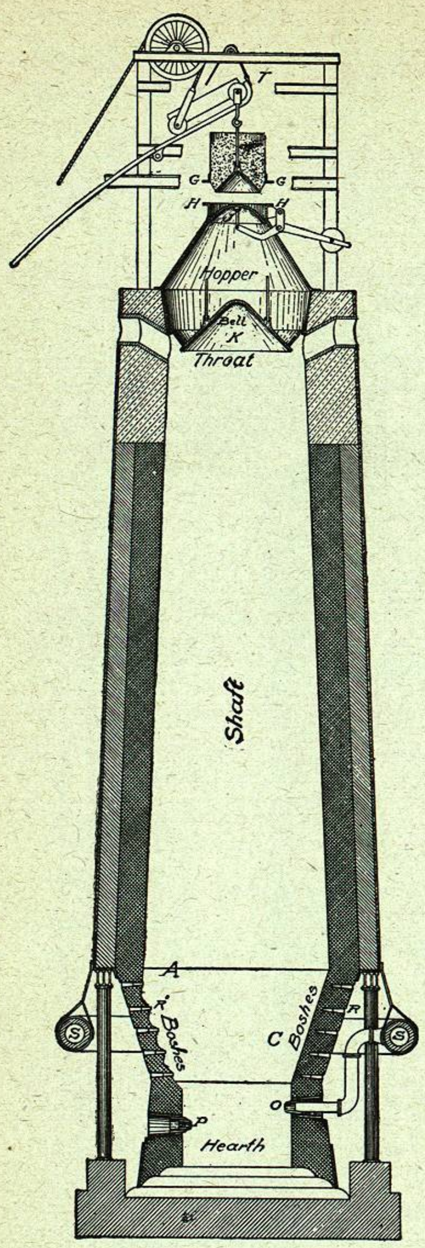

Fig. 89. Section of one of the Duquesne Blast-furnaces.

GG, flanges on the ore bucket; *HH*, fixed flanges on the top of the furnace; *J*, counter-weighted false bell; *K*, main bell; *O*, tuyere; *P*, cinder notch; *R*, *R'*, water-cooled boxes; *S*, blast pipe.

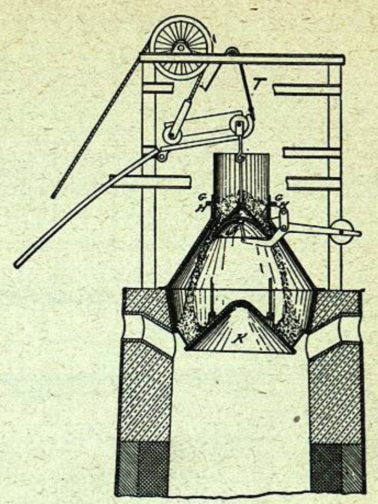

Fig. 90.

The transfer of the ore from the bucket to the main charging-bell. Lettering as in Fig. 89.

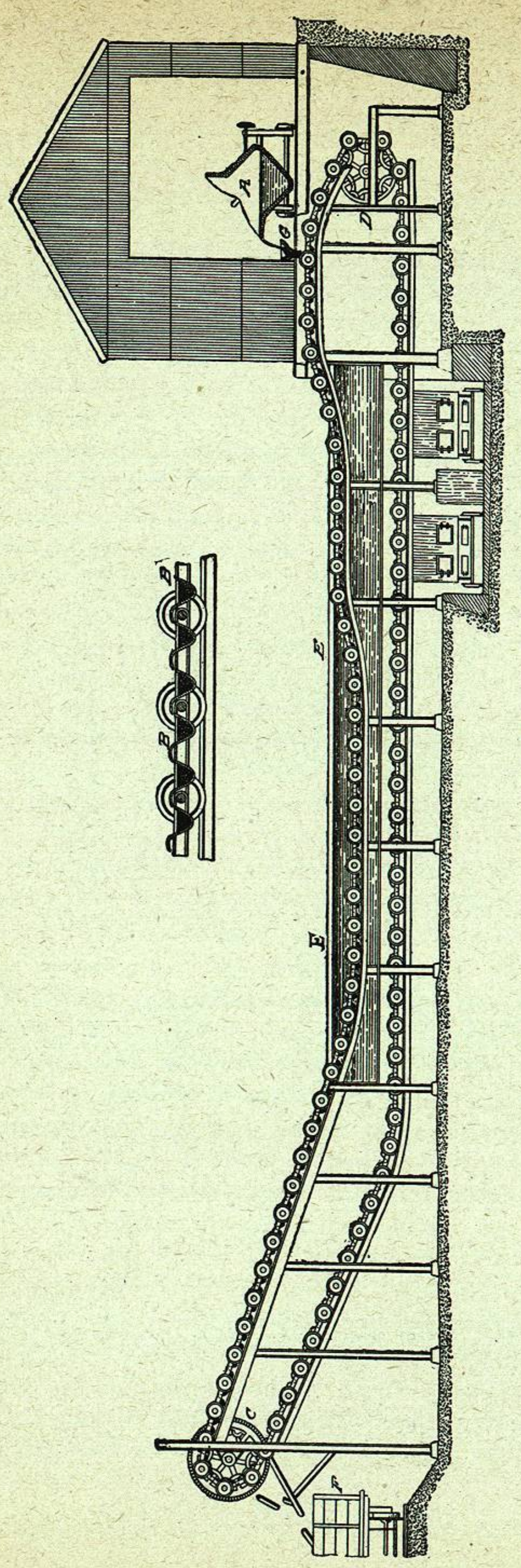

Fig. 91. Diagram of Uehling's Pig-casting Machine.

A, ladle bringing the cast iron from the blast-furnace; *BB*, the moulds; *C*, *D*, sheaves, carrying the endless chain of moulds; *E*, *E*, tank in which the moulds are submerged; *F*, car into which the cooled pigs are dropped; *G*, distributing funnel.

from its moulds by a travelling crane, and placed on rollers which progressively fed it forward, one pig at a time, under a hydraulic press with three plungers, of which one broke off the sow between a given pig and its neighbor, and two others broke the pig itself into three pieces, which slid down into a car beneath. The iron is handled still more cheaply by the Uehling type of casting machine (Fig.91), which consists essentially of a series of thin steel moulds *BB*, carried by endless chains past the lip of a great ladle *A*. This pours into them the molten cast iron which it had just received direct from the blast-furnace. As the string of moulds, each thus containing a pig, moves slowly forward, the pigs solidify and cool, the more quickly because in transit they are sprayed with water, or even submerged in water in the tank *EE*. Arrived at the further sheave *C*, the now relatively cool pigs are dropped into a railway car. Besides a very great saving of labor, which, however, is partly counterbalanced by the cost of repairs, these machines have the great merit of making the management independent of a very troublesome set of laborers, the hand pig-breakers, who were not only absolutely indispensable for every cast and every day, because the pig iron must be removed promptly to make way for the next succeeding cast of iron, but very difficult to replace because of the great physical endurance required.

269. Preservation of the Furnace Walls.—The combined fluxing and abrading action of the descending charge tends to wear away the lining of the furnace where it is hottest, which of course is near its lower end, thus changing its shape materially, lessening its efficiency, and in particular increasing the consumption of fuel. The walls therefore are now made thin, and are thoroughly cooled by water, which circulates through pipes or boxes bedded in them. Mr. James Gayley's method of cooling, shown on a small scale in Fig. 89, and in detail in Fig. 92, is to set in the brickwork walls several horizontal rows of flat water-cooled bronze boxes, *RR'*, extending nearly to the interior of the furnace, and tapered so that they can readily be withdrawn and replaced in case they burn through. The brickwork may wear back to the front edges of these boxes, or even, as is shown at *R'*, Fig. 89, a little farther, so that between the several horizontal rows of boxes the walls are grooved scallopwise, with horizontal furrows. But even in this case the front edges of these boxes still determine the effective profile of the furnace walls, because these furrows become

filled with carbon and scoriaceous matter when the furnace is in normal working. Each of these rows, of which five are shown in Fig. 89, consists of a great number of short segmental boxes.

270. Blast-furnace Gas Engines.—The gases which escape from the top of the blast-furnace are necessarily very rich in carbonic oxide, of which they usually contain between 20 and 26 per cent, and they are thus a very valuable fuel. They have hitherto been used chiefly for heating the blast, and for raising

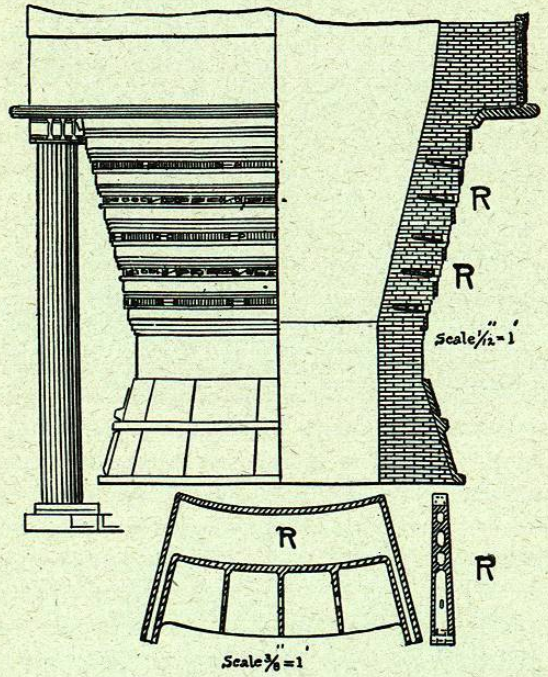

Fig. 92. Gayley's Water-cooling Blocks for Cooling the Inner Face of the Walls of Blast-furnaces.
(*Trans. Am. Inst. Mining Engineers*, XXI, p. 109, Fig. 6.)

steam not only for generating that blast, but also more lately for the rolling-mill and other engines of the establishment. But it has now been shown that these gases can be used directly in gas engines, in which they generate about four times as much power as would be developed by the steam raised by burning them under boilers. It has been calculated that the gas from a pair of old-fashioned blast-furnaces, making 1600 tons of iron per week, would in this way yield some 16,000 horse-power in excess of their own requirements. At that rate a pair of the great American furnaces would have some 70,000 horse-power over and above that which they themselves need for raising steam for their own purposes, and for heating their own blast. Although the quantity may really be much less than this, because the higher efficiency of these furnaces leaves less residual calorific power in the waste gases, it is clear that their importance as sources of power is very great.

This use of the gas engine is likely to have far-reaching results. In order to make use of this power we should place in the immediate neighborhood of the blast-furnaces themselves the works in which their cast iron is to be converted into steel, and also those in which this steel is to be rolled out into finished shapes. The many converting mills which treat pig iron made at a distance will now have the crushing burden of providing in other ways the power which their rivals get from the blast-furnace, in addition to the severe disadvantage under which they already suffer, of wasting the initial heat of the molten cast iron as it runs from the blast-furnace.

271. Hot Blast Stoves.—The cast iron or "pipe" stoves, in which the blast was heated by passing through a long series of cast iron pipes, around and outside which the waste gases of the blast-furnace itself were burnt, are fast going out of use, chiefly because they are destroyed quickly if an attempt is made to heat the blast above 1000° F. (538° C.). In their place the regenerative stoves of the Whitwell (Figs. 93 and 94) and Cowper (Fig. 95) types are chiefly used. With these the regular temperature of the blast at some works is about 760° C. (1400° F.), and the usual blast temperature lies between 480° and 650° C. (900° and 1200° F.)

Like the Siemens furnace, they have two distinct phases—one "on gas," during which part of the waste gas of the blast-furnace is burnt within the stove, highly heating the great surface of brickwork which for that purpose is provided within it; the other, "on wind," during which the blast is heated by passing it back over these very surfaces which have thus been heated. They are heat-filters or heat-traps for impounding the heat developed by the combustion of the furnace gas, and later returning it to the blast.

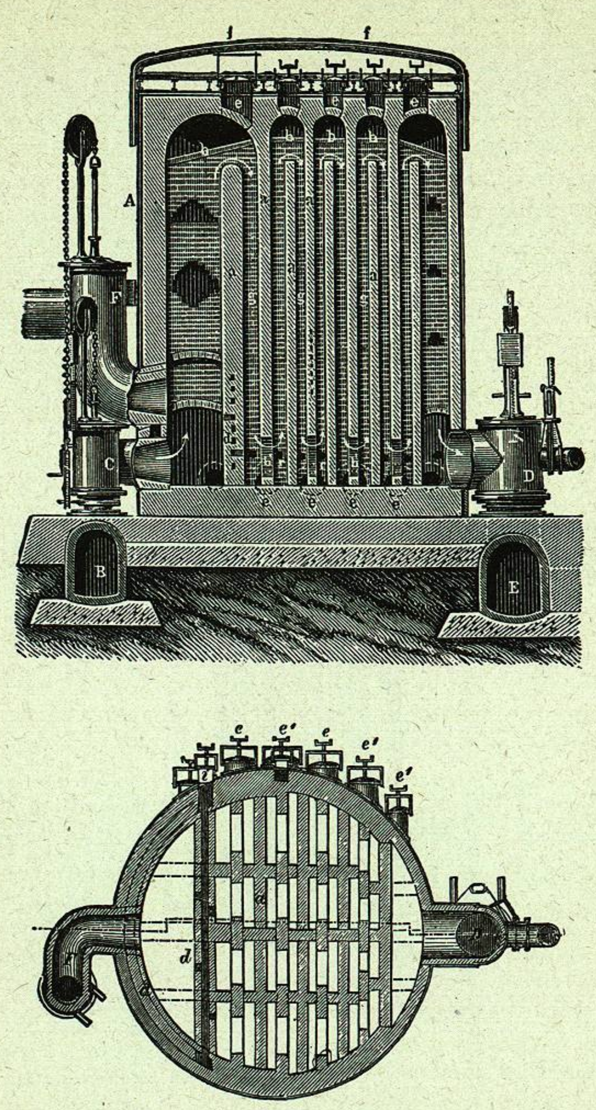

Fig. 93. Early Type of the Whitwell Hot-blast Stove.
(Ledebur, *Handbuch der Eisenhüttenkunde*, 3d Ed., 1899, p. 468.)

Each blast-furnace is now provided with three or even four of these stoves, which collectively may be nearly thrice as large as the furnace itself. At any given time one of these is "on wind" and the others "on gas."

In later examples the Whitwell stove has been simplified by greatly lengthening it and reducing the number of its vertical partitions from nine to three, so that the blast, and also the gas, has only three instead of nine reversals of direction, and the

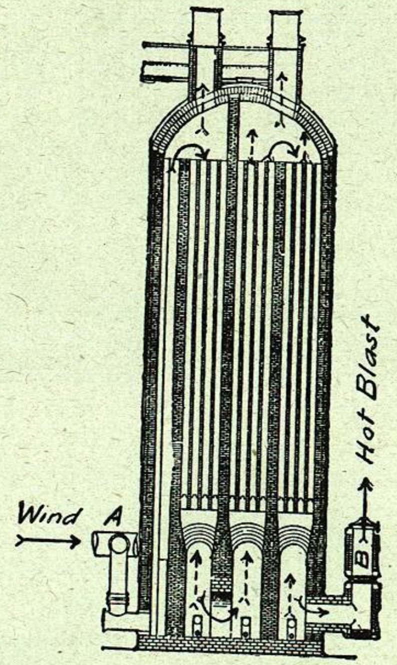

Fig. 94. H. Kennedy Hot-blast Stove.
(Whitwell Class.)

NOTE.—When "on wind," the cold blast is forced in at *A*, and passes four times up and down as shown by means of unbroken arrows, escaping as hot blast at *B*.

When "on gas," the gas and air enter at the bottom of each of the three larger vertical chambers, pass once up through the stove, and escape at the top, as shown by means of broken arrows.

Thus this is a four pass stove when on wind, but a one-pass stove when on gas.

Trans. Am. Inst. Mining Engineers, XXI, p. 722, 1893.

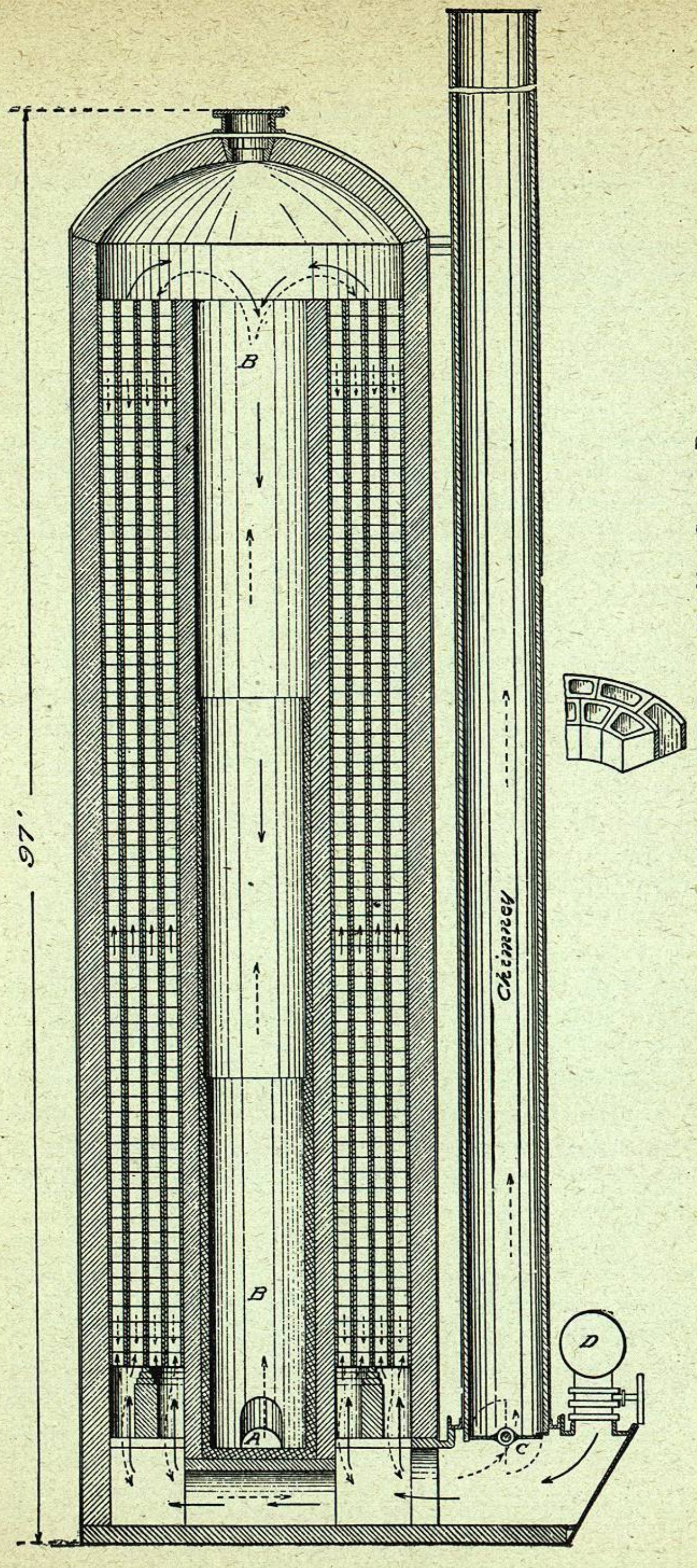

Fig. 95. Diagram of the J. Kennedy Variety of the Cowper Hot-blast Stove at Duquesne.

A, entrance for blast-furnace gas; *B*, *B*, combustion chamber; *C*, chimney valve; *D*, cold-blast main.

Broken arrows show the path of the gas and air while the stove is "on gas," and solid arrows that of the blast while it is "on wind."