graphite pots, since they are weaker, and when first used are brought up to heat in the fires very slowly and then filled by means of a long iron funnel. In any case, whether first packed hot or not, they must be heated with extreme care and slowness, and after one heat has been melted are at once recharged hot and returned to the fires. If allowed to cool they will crack. Less steel is usually charged in the pot at each successive heat, owing to the deep cutting of the pot at the slag line. The coke holes often contain but two pots, but otherwise are much like the common anthracite melting hole.

The advantages of the coal or coke hole furnace, are its low first cost, and its suitability for intermittent operation. The chief disadvantage is the high cost of the steel, which is due to the low tonnage produced, the heavy wear on pots, which do not last as long as in gas-furnace practice, the high fuel consumption, and the high labor cost. The pot pullers have more to do than on gas or oil furnaces, so that more of them are needed to handle a given tonnage, and the great amount of coal and ashes that have to be wheeled necessitates the employment of extra men. Another disadvantage is that in making very low carbon steel, which is very hard to melt, the fires, especially on the second heat of the day, often give out completely before the steel is melted; and as it is not possible to raise the pots and shovel coal under them more than twice, it is sometimes impossible to melt this sort of steel on the second heat.

The Oil-fired Furnace.—The direct-fired oil furnaces are very simple in construction and comparatively inexpensive to build. In some furnaces of this type, there is a combustion chamber alongside the melting hole, in which the oil is burned, and the hot gases enter the melting chamber over a bridge. Many styles of oil burners are used. In some of them the oil overflows in a series of shallow pans and is carried into the furnace by a draught of air. In others steam or compressed air is used to atomize the oil. Whatever be the style of burner, the important thing is to secure complete combustion of the oil and proper distribution of the hot gases in the melting chamber.

As there are no coal and ashes to wheel, the crew of an oil furnace is smaller than that of a coal hole plant of equal capacity. One melter and one pot puller, with one or two men to pack pots, can take care of a set of furnaces melting 40 pots a day.

The wear and tear of pots in oil melting is rather severe, yet the

small crew and low fuel costs make these furnaces very economical when cheap fuel oil can be obtained. They have been extensively used in our middle West, where, however, the recent jump in the price of oil has considerably altered conditions. The cost of installation of oil furnaces is higher than that of coal holes, but lower than that of regenerative gas fired furnaces. Oil furnaces are well suited to intermittent operation, as they can be heated up very rapidly, and if built of good clay brick will withstand the heating and cooling involved. The melting is more rapid than in coal holes, and of course the pot pullers have to handle the pots but twice, as they do not have to be raised as in coal hole melting; and as there is no bed of coal to hamper them, the men are able to grasp the pots more easily, and can be surer of avoiding weak places in old pots.

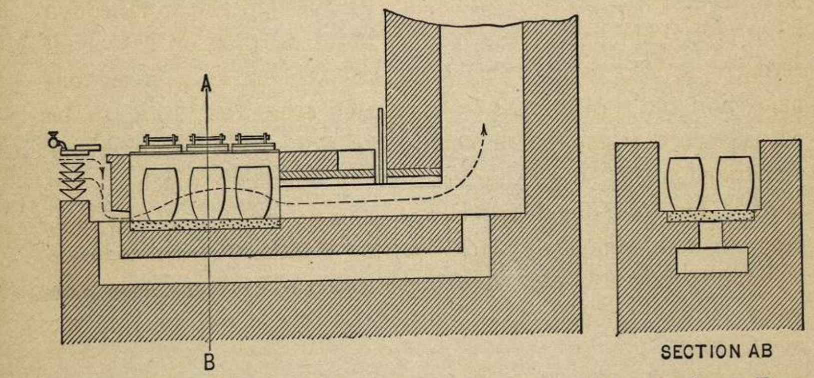

FIG. 2.—Milwaukee type oil furnace. Longitudinal and cross-sections. From "The Iron Trade Review."

The Siemens Regenerative Furnace.—Regenerative gas fired furnaces, using either producer gas or natural gas, are of two types, only one of which (the melting hole design), is extensively used in America. These furnaces are built very much like gas fired soaking pits, with, of course, a smaller chamber, and work on the regenerative principle, which is too well understood to require extended description here. In regenerative furnaces the gas and the air necessary for the combustion enter and leave the furnace through fire brick chambers filled with brick checker work, which alternately are heated by the outgoing gases, and give their heat to the incoming air and gas. In natural gas furnaces only the air is preheated, and both sets of checkers are used for air, or only one set is provided.

The furnaces are sunk below the working floor, generally enough so that the floor of the furnace (level with top of the melting holes), is 2 or 3 ft. above the general level of the shop. The melting holes are covered with covers or "bungs" which are larger than those of coal holes, and therefore cannot easily be lifted off by hand with

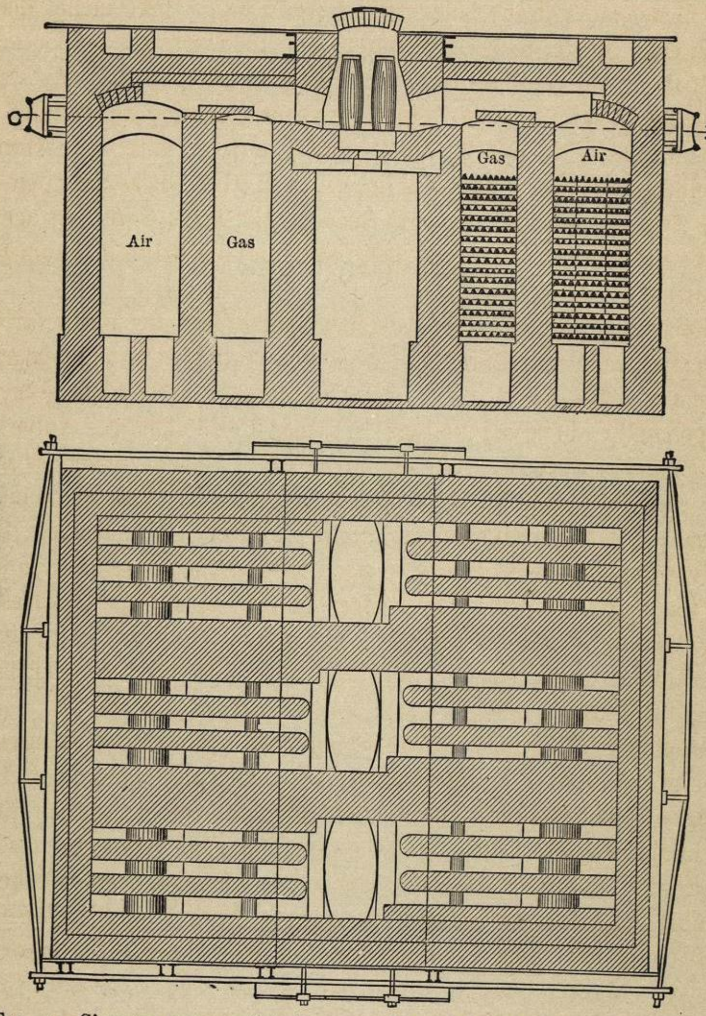

FIG. 3.—Siemens regenerative furnace. Vertical and horizontal sections. From Stoughton, "The Metallurgy of Steel."

a hook, but are swung by a lifting bar suspended from an overhead trolley. Three covers to a hole is the usual and the most convenient arrangement. The holes may be lined with clay brick, especially if the furnace is to be run "single turn" and cooled off considerably

at night to save fuel. In this case the resistance of clay brick to repeated heating and cooling is taken advantage of. Clay brick furnaces last on the average only six months, and then require extensive repairs. Generally, silica brick are used, and the furnace lasts 12 to 18 months.

The bottoms of the holes are covered two or three inches deep with coke breeze, to keep the pots from sticking to the bricks, and to soak up the runnings from the outside of the pots and any steel spilled from cracked pots. Openings about 5 in. wide are provided in the bottoms of the melting holes, which are closed with the bottoms of old pots. After a heat has been melted, these holes are opened, any slag or spilled steel poked through, the holes closed up again and a little more coke breeze shoveled in and leveled to make up for what has been poked out.

Reversing Valves.—The reversing valves used for regenerative crucible steel furnaces are the same as those provided for open-hearth furnaces. For the air, of course, the plain "butterfly" flap valve is generally employed and gives satisfaction. The gas valve is frequently a butterfly, and should be water cooled. There is not the same objection to this style of valve for the gas in crucible furnaces that there is in open-hearth practice. Being smaller, the valves have less opportunity to warp; and as the waste gases going to the stack are somewhat cooler than in open-hearth practice, the warping is considerably less. The more complicated gas valves so valuable in open-hearth work are not often used for crucible steel furnaces.

Producers.—The scope of this book does not permit of a discussion of the types of producers for soft coal that can be used. Great progress is being made in the design of gas producers, with a view both to minimizing the hand poking needed in the old types and to increasing the economy of the producer. Good gas makers will keep almost any producer well poked down to prevent holes in the fire and consequent lean gas, but with the older designs the labor is severe. Many types should be regarded with a wary eye until their success in practice has been demonstrated, because some designers persist in giving great wind box area so distributed that after some months' operation the wind boxes get covered with chilled clinker, which spreads and chokes the whole fire and is very hard to poke out. Such producers give beautiful results on a short run, but kill the gas men after they begin to choke up. Water-sealed producers are thought by some furnace builders to be unsuitable for crucible furnaces, because the gas obtained from them wears out pots more rapidly than that made in dry-sealed producers.

In the lay-out of a shop using one of these furnaces, care should be taken to see that the melting shop and gas house can be thrown open on all sides in hot weather. The space for storing iron, scrap, etc., and packing pots, should if possible be on a level with the furnace floor so that pots can be "buggied" to and from the weighing space on a continuous floor. The pit between the regenerators into which the slag from the holes is poked should be easily accessible, at each end if possible; and at least should be so arranged that a good current of air can sweep through it. Otherwise it will get so hot in the pit as to make it impossible to clean out the accumulation of slag and coke without shutting down the furnace.

Ready access to all parts of the gas mains, valves, etc., is absolutely essential and manhole openings in the gas and air flues between valves and checker works will be found of great advantage in facilitating cleaning out and minor repairs. Checkers, if possible, should be accessible front and back, as when the furnace has been long in operation the checker works become clogged with dust and have to be blown out with compressed air through openings in the end walls. This can best be done if access is to be had from both ends, but when the furnace is deeply sunk only one end is commonly accessible.

If producer gas is used the gas house should be provided with easy means of getting out the great quantity of ashes that have to be handled. If possible, the bottoms of the producers should not be in a pit of small dimensions, as it is in that case uncomfortably hot for the men to work in getting out ashes in hot weather. The ashes have to be removed as they accumulate. With water-sealed producers this can be done at any time; with dry-sealed producers it is customary to do it on Wednesdays and on Saturdays during the general clean-out. On Wednesdays, during the cleaning out of ashes, it is well to open the gas mains and burn out the accumulated soot as much as possible. Saturday afternoon, after the last heat is drawn, is the time for general clean-out and any repairs to brick work that are needed. The top holes of the producers are opened and the gas allowed to burn, all doors in gas mains are opened, the soot is burned out of the mains and valves as completely as possible, and the rest dragged out with wooden scoops. This is the time to give the neighborhood a wide berth unless your duty compels you to boss the job; and in hot weather, all hands especially welcome the feature of an open-sided shop during cleaning out. The floating soot is bad enough even in such a shop.

Starting the Regenerative Furnace.—In starting a new producer, it should be filled up with ashes well over the tuyéres or wind boxes, and the fire kindled upon the ashes, coal being dumped in as soon as the wood fire is burning well, and the blast used only as needed. No gas should be turned into the furnace until good gas is being made.

While the producers are being started, the furnace is dried out with a coke or anthracite fire in each hole. The stack damper is raised, the valves are set on center, the covers of the holes are opened a little, and the draught is taken in the top of the holes, through all checkers, through the flues to the valves, and out the stack flue and stack. In a couple of days the furnace will be hot enough to light, when the valves are thrown over, the covers of the holes swung further apart, and gas carefully admitted, then a little air. Care should be exercised in not turning on gas too rapidly, or too much air, or air first, as a strong "kick" frequently occurs in any case, and a bad one may damage the furnace. After an hour or so the valves are thrown over; it is as well on the first two or three reversals to shut off gas and air before throwing the valves, to avoid strong "kicks." After a few reversals the valves can be thrown over without this precaution and when the furnace has become hot the reversal should take place without any kick at all. As the furnace heats up, the reversals are made at shorter intervals, and when it has reached working heat should be reversed every 15 or 20 minutes.

The crew of a 30-pot gas furnace consists of one melter, two pot pullers, one or two moulders, and when producer gas is used, two gas men per shift. The moulders help pack pots, wheel them to and from the holes and do odd jobs, and one of the gas men is used to swing the covers of the melting holes when pots are being charged or drawn. If the pots are poured one at a time, the moulders wheel them to the edge of the furnace and wipe the slag from them; the pouring gang from the foundry then carry them from the furnace. In pouring into a ladle, speed of drawing is essential; in this work the melter pours the pots as fast as they are brought to him, the moulders run them to him with buggies, and the pot pullers draw as fast as they can, one man pulling six pots while the other gets his breath and wets down his clothes again. In this way 30 pots can be drawn and dumped into the ladle in four or five minutes. Three heats should be melted per shift.

Advantages of the Gas Furnace.—The gas furnace has the advantage of clean and easy handling of pots already mentioned in the description of oil furnaces, and like the oil furnace, gives the melter almost complete control of the temperature at all times. The stack damper, air supply and gas supply valves enable the heat of the furnace to be closely controlled, and in addition by opening the covers of the hotter holes a little, they can be held back when melting too fast and getting ahead of the others. There is, however, no means of controlling the admission of gas and air in each hole, as the whole furnace is handled with one set of valves. Further advantages of this type of furnace are low fuel cost, low labor cost, and speed of melting. The only disadvantages are high cost of installation, and the fact that single turn operation is far from economical. If no steel is melted at night, one or two men have to be kept on to make gas and reverse the furnace every 20 minutes or one-half hour, and though the furnace is not kept up to full heat, fuel is burned and labor paid without return, resulting in a considerable increase of cost, to say nothing of the overhead cost of keeping an expensive furnace idle half the time. The necessity for the employment of pot pullers has been referred to as a disadvantage of these furnaces which does not apply to the Krupp type, in which the pots are lifted out with long suspended tongs and regular pot pullers are not employed. However, melters and pot pullers in this country are clannish and much inclined to stick together, so that a shop using the Krupp furnace often finds it difficult to secure competent melters. This offsets the advantage of pulling pots with cheaper labor.

The Krupp Furnace.—The Krupp furnace, used in one or two shops in this country, is built a great deal like a side-drawn annealing furnace. The pots are set in the furnace and pulled out through doors in the side by means of a long pair of horizontal tongs suspended from a trolley. The bottom of the furnace is nearly flat and commonly slopes toward a tap hole in the back through which slag and spilled steel are run out. The bottom is made of silica sand fused on in thin layers. Except that the bottom is flat and the port construction not at all the same, the furnace resembles in its general appearance a small open-hearth furnace. Its advantages are those of the other type of regenerative furnace. Its disadvantages are, that to see into the pots it is necessary to go up on the top of the furnace and peep through six or more small holes in the furnace roof; that spilled steel exposed to the gases of the furnace soon is "puddled," or in other words the carbon is oxidized out of it and carbonless iron formed, which will not run out the tap hole and has to be pried off the bottom, often taking part of the bottom with it; and that as the furnace is a "freak" in this country, men have to learn to run it instead of going right in and handling the furnace well from the start. The disadvantage that gave the author the greatest trouble when handling one of these furnaces was the spilled steel, which worked its way into the bottom, because the scale formed on it cut out the sand. The "skull" that accumulated often had to be burned out of the furnace from the tap-hole side with an air blast. In Germany, clay pots are used in these furnaces, the pots are never worked to the limit, and few break; but in America we work so constantly to get the last possible pound of steel out of a pot, that some break in almost every heat of old pots, and trouble results.

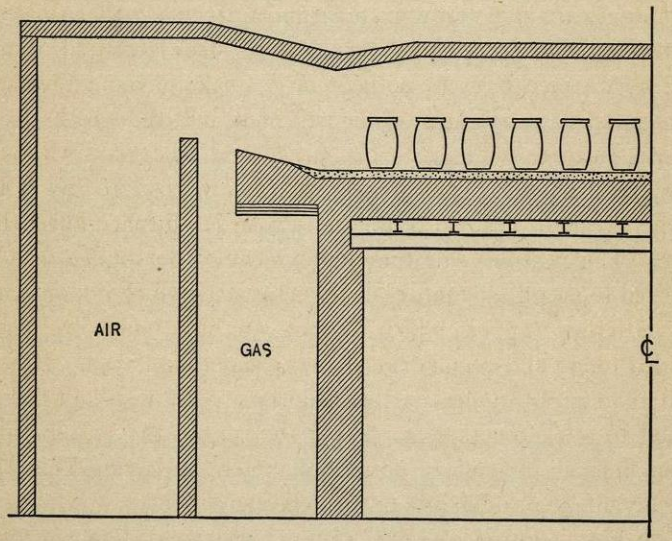

FIG. 4.—Regenerative crucible furnace—Krupp type. Half longitudinal section.

The Pots.—Pots are made either of clay, or of graphite and clay in about equal parts (the common graphite pots). The disadvantages of clay pots already mentioned are so pronounced that graphite pots with a clay lining about $\frac{1}{4}$ in. thick are often used in place of them. These clay-lined pots do not have to be handled so carefully as those made entirely of clay. The reason why in some instances clay, or at least clay-lined, pots are indispensable in good foundry practice will be taken up later, when the control of analysis of crucible steel is considered. Clay pots seldom make over three heats, while graphite pots will sometimes make five or six in foundry practice. Graphite pots should be stored in a dry, and, if possible, warm place; should be dried out on a furnace top for a week or two before using, and when new should be heated around the melting holes before charging. When hot they will stand pretty rough usuage, and can be dropped from the furnace to the ground without breaking if let fall on their butt ends and rolled out of the way. In the rapid work of ladle pouring this generally has to be done. When cool, the pots are examined for thickness, and tested for cracks by tapping them with an iron rod. If all right they ring clear like a bell, if cracked they will not ring. If not cracked, and thick enough for further use they are taken to the packing floor for repacking. If they are cracked or worn out, the bottoms are cut off with a coarse saw, or the sides smashed away with a heavy blunt knife, and the thick bottom parts are used as covers for the pots.

Melting.—In coal holes, a good grade of anthracite coal is used for fuel, and about two heats can be melted per shift. When operating single turn, the fires are lighted early in the morning, and blown up until a good bed of glowing coals about a foot deep is provided. About 6 in. to 1 ft. of coal is then dumped in, and the pots set directly upon it. The pot puller sets each pot firmly into the bed of coal, and when all are in, the moulder fills up around them with coal, heaps it up about 8 in. over the tops of the holes, and puts on the covers. Care must be taken to keep the coal out of the pots, as the steel absorbs carbon and sulphur from it very rapidly. The melter then puts the forced draft on the fires and urges them. At first the fires should be blown rather gently, especially if new pots are being used, because if the pots are heated up too rapidly they will spall and crack.

The melter should not be allowed to rush his fires up to full heat at the very first, because the sides of the pots are a poor conductor of heat, and through them must be driven the total amount of heat necessary to bring the steel up to the melting point, and to melt it; and if the outsides of the pots are brought to white heat very rapidly, leaving the contents of the pots comparatively cold, the heating up of the steel is not greatly hastened, but the pots themselves are exposed to extreme temperatures much longer than necessary, and are melted and slagged away on the outside very rapidly.

After about two hours the fires and pots settle down in the holes,

so that it is necessary to get more fuel in under the pots to keep them off the grate bars. The pot puller goes over the holes and raises each pot with his tongs, while the melter pokes the coal well in under them, and the moulder shovels in more fuel. For this purpose coal is generally used, though sometimes part or all of this extra fuel is coke, which burns up more rapidly and makes a more intense heat than coal but does not last so long. The fuel is bedded up about level with the tops of the pots and well poked in, the covers replaced on the holes, and the fires urged again. In from one to three hours more the steel will be melted.

The melter examines the pots by separating the covers of the holes a little with his poker, and sliding the lid off each pot in succession. If the steel is melted, he thrusts his poker to the bottom of the pot to ascertain the condition of the metal. When first melted the steel boils quite freely and is "cold," so that a layer of it sticks to the poker. The boiling gradually subsides, and when the steel has been held in the pots a sufficient length of time, the bubbles in the slag will be large, and burst lazily, forming the so-called "cats-eyes." When the steel is hot enough not to stick to the poker and is quiet, the melter tosses in the additions of ferrosilicon and ferromanganese in envelopes and after a few minutes the covers are removed from the holes and the pots drawn. The adhering coal is rapidly scraped from the sides of the pots, the lids removed, and the slag wiped off. This is done with a slag "mop," or ball of slag formed on the end of an iron rod, with a ring at the end to start the formation of the slag ball. By wiping around the pot with the mop, at the same time turning it in the hand, a layer of sticky slag is caught on it which is spun off by rapidly whirling the mop along the floor. In a very few moments the steel is wiped clean and is ready to be carried to the moulds. In pouring into the moulds any remaining slag or scum is held back with a skimmer, or "flux-stick."

When a ladle is used the melter rapidly dumps the pots into it without wiping off the slag, which forms a blanket over the steel and protects it from chilling. For this practice, the more slag the better.

In oil and gas furnaces the melting is carried out very much in the same manner as in coal holes, with the exception that the pots naturally do not have to be raised to put extra fuel under them, and that the melting is more rapid. When using the Krupp type of furnace, it is not possible to make final additions to the pots in the