

temporary magnetism is due to the polarizing or rotating of the particles of alpha iron, especially of alpha ferrite, by the magnetizing force, and permanent magnetism to the locking of those polarized particles in their rotated position. In very low carbon steel there is little except alpha ferrite, little to restrain the particles of alpha iron from rotating under the influence of the magnetic field; hence the great temporary magnetism. But then there is nothing to hold the rotated particles in place after the magnetizing force has been removed, so that their elasticity quickly returns them to their initial position, and the magnetism temporarily induced quickly ceases; hence the small retentivity.

When such steel is quenched even from the austenite region, IV of Fig. 68, thanks to its being nearly free from carbon, which in higher carbon steels acts as a brake to retard the transformation, it changes into ferrite and cementite nearly as fully as if it were cooled slowly; and the completeness of this transformation which prevents such steel from hardening, in like manner prevents it from acquiring retentivity or greatly losing its capacity for temporary magnetism.

But high-carbon steel, even when slowly cooled, has comparatively little temporary magnetism, first because it has much less alpha ferrite, and next and chiefly because the rotation of that alpha ferrite by the magnetizing force is impeded perhaps in part by the cementite, but probably chiefly by the beta or gamma iron which the presence of carbon has prevented from changing into alpha iron, even in the ample time which the slow cooling has offered.

On the other hand, such steel when cooled suddenly has very great retentivity, or permanent magnetism, because, once the particles of its alpha iron have been rotated, the beta or gamma iron, present because restrained by the suddenness of cooling from transforming into alpha iron, acts as a brake to hold those particles in this rotated position after the magnetizing force has ceased to exist.

## APPENDIX IV

## Some Metallurgical Novelties

336 A. ROE'S ROCKING PUDDLING FURNACE,\* Fig 121, consists of a puddling chamber which, with its converging quadrant-

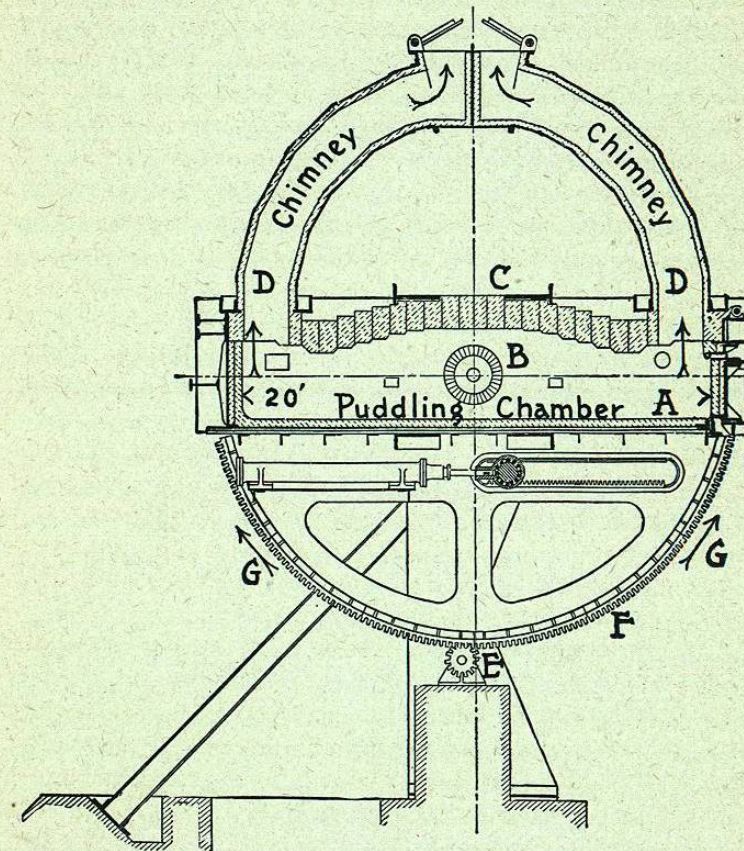


Fig. 121. Longitudinal Vertical Section of Roe's Rocking Puddling Furnace. A, the magnesia brick lining of the puddling chamber, which is about 20 feet long and 8 feet wide. B, hollow trunnion, about which the whole machine, chamber, chimneys and all, rocks. There is of course a second trunnion on the opposite side of the furnace, with its axis in line with the axis of the one here shown. Through these trunnions the oil flame, the only source of heat, is brought. C, fire brick roof of the puddling chamber. D, D, converging chimneys rocking with the furnace. E, pinion which rocks the furnace by means of the semicircular rack F. G, G, arrows to show the direction of rocking.

\* *Trans. Am. Inst. Mining Engineers*, XXXIII, pp. 551-561, 1903;

shaped chimneys, rocks about 65 degrees back and forth in the direction shown by the arrows *GG*, around the hollow trunnions *B*, through which an oil flame to heat the whole is brought. This rocking, varied to suit the different stages of the puddling process, hastens the oxidation and removal of carbon, silicon, etc., the essence of puddling, by repeatedly mixing the very oxidizing slag or "cinder" with the metal, making them run down hill, first to the right and then to the left; and it later rolls or coaxes the resultant pasty wrought iron into one large 4,000-pound ball. This is next shot directly into a special squeezer, in which under a pressure of some 1,800 tons its cinder is squeezed out, and it is then immediately rolled out into billets or slabs, or even, we are told, into finished bars. The puddling chamber is lined with magnesia bricks *A* resting on a water-cooled iron bottom, and wears away but slowly. Molten cast iron, preferably direct from the blast furnace, is treated, and roll scale, the very rich iron oxide which falls from the surface of iron or steel while rolling, is used as the active oxidizing agent, reinforced of course by the atmospheric oxygen, and mixed with puddling "tap cinder," a very basic iron silicate.

Mr. Roe claims a great saving in cost (1) through avoiding the extremely trying and therefore expensive labor of hand puddling; (2) through treating much larger charges, 4,000 pounds against the common 1,100-pound charge of the double hand-puddling furnace; (3) through treating much larger balls, 4,000 pounds against the common 180-pound hand-puddled ball; and (4) through lessening the loss of iron through oxidation, because the great size of the ball implies a correspondingly small proportion of surface exposed to the oxidizing action of the air in squeezing, reheating and rolling. The most evident disadvantage is the cost of installing this costly mechanism.

Why, we may well ask, should this puddler be expected to succeed, when the many mechanical puddlers of the past, including those of Danks and of Pernot which gave such great promise, have failed?

Two fields were open to these older puddlers; first that of turning phosphoric pig iron, which before the invention of the

*Idem*, XXXVI, to appear; *The Iron Age*, June 15, 1905, pp. 1896-1899; U. S. Patent, No. 659,698.

basic Bessemer and open-hearth processes could not be used for steel making, into dephosphorized puddled iron, a product well suited for turning into steel by the acid open-hearth process. Second, of making wrought iron to be used as such, after rolling out into plates or bars.

The first of these fields is no longer open, because since those days the basic open-hearth process has grown to be a much cheaper way of turning phosphoric pig iron straight into steel.

In the second of these fields the older mechanical puddlers failed because their product was too heterogeneous, in that the different parts of a single bar or plate differed too greatly in composition and properties. This in turn was due to three faults, first that the action of the furnace was such as to give a raw centre to each ball; second that the lining of the furnace was of a kind which broke off and became inextricably mixed up with the puddled product; and third that the cinder or slag in which the puddled ball was formed could not be sufficiently squeezed out. These three troubles Mr. Roe promises to overcome, as I will now try to explain.

To study the defects of the many dead puddlers would take us too far; but we may well glance at those of the Danks and Pernot puddlers, in order to see how it is that Roe may hope to win where they lost.

The Danks puddler was like a barrel lying on its side and turning about its own axis; the Pernot like a saucer a few degrees out of level, and spinning slowly around what we may call its axis, the axis about which a juggler spins his saucers and plates. The turning of the furnace exposed fresh surfaces of the initially molten pig iron to the oxidizing cinder, rich in iron oxide, mixed up cinder and iron, and so brought about the oxidation of carbon, silicon, and phosphorus, by means of the oxygen of the iron oxide. All went well as long as the pig iron remained molten; but as soon as any part of it had lost so much carbon that it was no longer quite liquid but had begun to be pasty, these pasty particles stuck together, and now the trouble began.

If the furnace stood still, only the upper surface of the iron would be acted on by the cinder, and this would surely make the product very uneven; therefore the furnace had to be kept turning, in order that the purification through oxidation should go on. But this turning carried things from bad to worse, because it

necessarily made the pasty particles glue together into a crude ball, and the material in the inner part of the ball was well shut off from all further oxidation by the layers outside it. When the iron first begins to glue itself together it is still far from thoroughly purified; it is still relatively raw; so that the middle of the incipient ball was necessarily raw; and this local rawness could not well be cured by any further treatment, but persisted in the bars and plates made by rolling out that ball.

This first trouble Mr. Roe meets by the flatness of his hearth, on which the iron, as it begins to grow pasty, may spread out in a thin layer, exposed with some approach to evenness to the action of the cinder. The iron, as it grows progressively more and more pasty, slides rather than rolls. At least the motion is more of a slide and less of a roll than in the Danks barrel and the Pernot saucer; and in as far as we replace a roll with a slide, in so far do we lessen the tendency to wrap raw parts up and seal them under blankets of impenetrable iron, and thus to cut them off from further cure, from further purification by the oxidizing molten cinder.

The next trouble, that pieces of the lining of the furnace broke off and were mixed up with the puddled iron, out of which they could not be got, Mr. Roe cures easily by substituting for the rough and brittle iron ore lining of the older puddlers a newer material, the magnesite bricks which the progress of steel making has developed into a most valuable material. They are strong, smooth, and coherent. Instead of breaking off they wear away, but only slowly as we are credibly told. This second betterment, then, he owes to the progress of steel making.

The third trouble, that the cinder cannot be well squeezed out of a large single ball, and such a ball the rolling, rocking, or turning puddling furnace almost necessarily makes, Mr. Roe meets first by the bold step of shooting the ball straight from the furnace into the jaws of a traveling squeezer, without chance to cool in going from distant furnace to central squeezer and while waiting its turn there; and second by making this squeezer a real bear, in the strength of its grip. It moves about from puddler to puddler, to swallow the great 4,000-pound ball at the instant when the furnace shoots it forth.

Each ball is so uniform throughout, thanks to the outspreading of the mass on the flat floor of the puddler, and is so free

from cinder, thanks to the high temperature at which the squeeze begins and to the intensity of that squeeze, that Mr. Roe thinks that the squeezed ball ought to be rolled straight into bars or plates, instead of being rolled into muck bar, cut up, piled, reheated, and re-rolled, like the product of the common hand puddler.

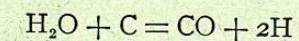
To recapitulate, the chief advantages which the Roe has over the older mechanical puddlers are

(1) that it seeks to avoid having a raw centre in each ball, by spreading out the mass thin and somewhat even on the flat hearth until thoroughly ready for balling and squeezing, and by replacing a roll with a slide;

(2) that the lining is smooth and coherent, so that it does not break off and contaminate the product;

(3) that, thanks to the intensity of the squeeze and to shooting the ball at full heat straight from furnace into squeezer, the cinder is so thoroughly squeezed out that the ball may be rolled at once with its initial heat into bars or plates.

337. THE MOND GAS PRODUCER, Fig. 122, is a modification and elaboration of the common water-sealed air- and steam-blown gas producer,\* yielding a mixture of hydrocarbons from the distillation of the freshly charged coal at the top, and carbonic oxide, hydrogen and nitrogen resulting from final combustion of the coal at the bottom of the producer by a mixed stream of air and steam. The modification consists essentially in keeping the temperature low and the proportion of hydrogen in the gas high by raising to its highest practicable limit the proportion of steam which is mixed with the air blown into the bottom of the producer, and by other means, all with the purpose of having in the gas the largest practicable quantity of ammonia  $\text{NH}_3$ . The steam both lowers the temperature through its endothermic decomposition by the glowing coal,†



and by this same reaction leads to the presence of much hydrogen in the gas; and both the low temperature and this hydrogen favor the formation of ammonia, or at least restrain its decomposition.

The quantity of steam which may be mixed with the air blast

\* See §§ 323-326, pp. 423-430, and especially Fig. 118, p. 429.

† § 326, p. 429.

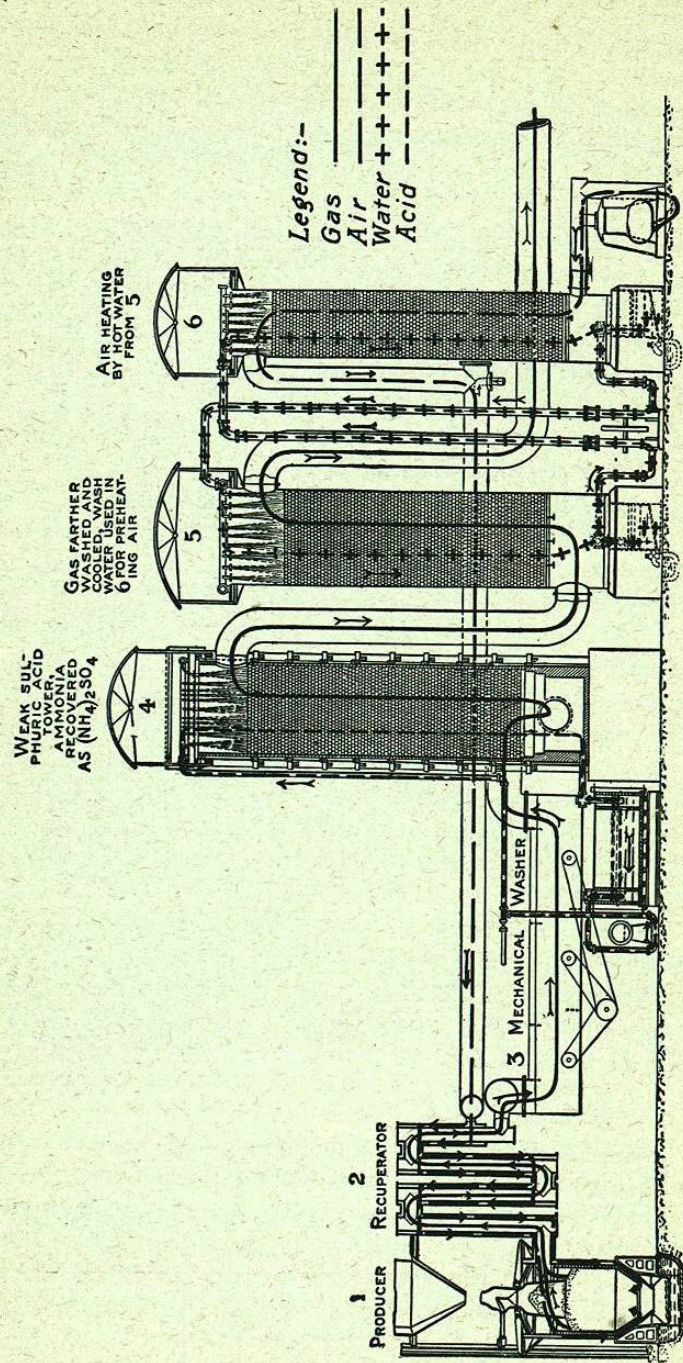


Fig. 122. Diagram of Mond Gas Plant with By-Product Recovery.

is limited only by the consideration that it must not put the fire out by cooling the coal below its ignition temperature. Hence preheating the mixture of steam and air, in that it tends to raise the temperature of the combustion zone at *B*, Fig. 123, enables us to increase the quantity of steam proportionally.

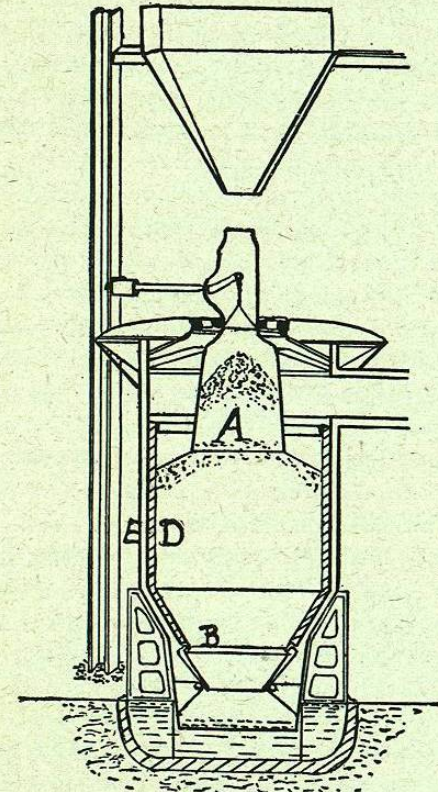


Fig. 123. The Mond Gas Producer.

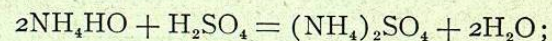
In order to see how the air is mixed with steam, and how this mixture is preheated, we will first follow the passage of the air from right to left in Fig. 122; and to see how the ammonia is recovered from the gas we will then follow the path of that gas from its formation in the producer at the left, to its delivery at the right for burning in metallurgical furnaces.

The air, blown in at the bottom of tower 6, is saturated with steam and receives its initial heating by passing up through this

tower, in which it meets a shower of hot water which has just been preheated by showering down through the rising stream of hot gas in tower 5. The air thus preheated, and the steam with which it has thus been mixed, are further heated, first by passing them through the annular space between the outer and inner concentric pipes of the iron pipe-recuperator 2, while through the inner pipes passes the hot gas direct from the upper part of the producer; and second, by passing them through the annular space between the iron outer wall *E*, Fig. 123, and the cylindrical fire brick inner wall *D* of the producer itself, which they next enter at *B*.

Turning now to the gas, let us first note the deep-reaching central cylinder *A*, Fig. 123, which, with the annular outer space, constitute the chief distinctive features of the producer. In this cylinder the coal lies when first charged, and here its volatile matter is gradually distilled at a very low temperature, thanks to its distance from the combustion region, to its being shielded from the stream of gas rising hot from that region, and to the cooling of the upper part of the producer by the steam and air which circulate through the annular space between *D* and *E*. This low-temperature distillation, as already pointed out, favors the formation and preservation of ammonia.

The gas thus distilled, mixed with the carbonic oxide and hydrogen rising from the region of combustion, sweeps forward from the upper part of the producer through the recuperator 2 already noted; through the mechanical spray washer 3, in which soot and some tar are deposited and the ammonia is converted into ammonium hydroxide,  $\text{NH}_4\text{HO}$ , and mixed with much water vapor; into the tower 4, in which a stream of weak sulphuric acid converts the ammonium hydroxide into ammonium sulphate, which it condenses,



then up through tower 5, in which the stream of gas gives up the rest of its heat, and also of its tar, to the shower of water already described. The water thus heated next passes, after its tar has been removed, to give up to the incoming air in tower 6 the heat which it has just recovered from the producer gas in tower 5, and it continues in this circle, alternately storing heat from the gas in 5 and restoring it to the air in 6.

The ammonium sulphate liquor from tower 4 is passed repeatedly through this same tower until it contains about 36 per cent of this sulphate, which is then recovered in the form of crystals by evaporation and crystallization.

Because the demand for the ammonium sulphate for agricultural purposes ought to be practically unlimited, this by-product should be of great value. But against the great advantage of its easy and nearly complete recovery must be weighed the serious cost of installation and the apparently bad quality of the producer gas, if we may judge from the published analyses.

338. THE GAYLEY DRY-BLAST PROCESS.\*—In order to condense the moisture out of the air or blast used in the iron blast-furnace, and thus to dry it, Mr. James Gayley passes it around large coils of iron pipes through which a freezing mixture circulates, and then heats it in the usual way by blowing it through hot-blast stoves. In order to remove the snow which gradually encrusts the outside of the pipes, he passes hot brine through a few of them at a time, when their snow quickly melts and is drained away. This simple drying of the blast saves about 19 per cent of the fuel, a quantity altogether disproportionate to the apparent reduction of the calorific demands which it brings about; and it also makes the action of the furnace much more regular. It lowers the temperature of the gases which escape from the top of the furnace, and raises their percentage of carbonic acid, natural results and indeed symptoms of the great increase in fuel efficiency.

It has long been recognized that the atmospheric moisture in the blast, because it has to be decomposed by the well-known endothermic reaction (31),  $\text{H}_2\text{O} + \text{C} = \text{CO} + 2\text{H}$ , has a very appreciable cooling effect on the lower part of the furnace, just where the most intense temperature is needed in order to melt the iron and slag, remove the sulphur, and deoxidize the silicon; and it has long been known that the blast-furnace needs more fuel in warm and especially in damp weather than in cold and dry weather, much more in summer than in winter, and that a weather change from cold and dry to warm and damp, unless met immediately by increasing the heat available in the hearth of the furnace, quickly lowers the temperature there and so makes

\* *Jour. Iron and Steel Inst.*, 1904, II, pp. 274-300; 1905, I, p. 256; *Trans. Am. Inst. Mining Engineers*, XXXV, 1905, p. 746.