STEEL, iron which is malleable at least in some one range of temperature, and in addition is either (a) cast into an initially malleable mass; or (b) is capable of hardening greatly by sudden cooling; or (c) is both so cast and so capable of hardening. Variety A includes also molten iron which if cast would be malleable, as do its two sub-varieties, "ingot iron" and "ingot steel." (Tungsten steel is malleable only when red-hot.)

STEEL CAST (adjective), consisting of solid Bessemer, open hearth, crucible or other slagless steel, and neither forged nor rolled: applied to steel castings. For instance, a "steel cast" gun is a gun which is a steel casting, *i. e.*, which has been neither forged nor rolled. To call it a "cast steel" gun would imply that it was made of crucible steel, to which the term "cast steel" is restricted.

STEEL CASTINGS, unforged and unrolled castings made of Bessemer, open hearth, crucible or any other steel. Ingots and pigs are in a sense castings; the term "steel castings" is used in a more restricted sense, excluding ingots and pigs and including only specially shaped castings, such as are generally used without forging or rolling. They may, however, later be forged, *e. g.*, under the drop press, when they cease to be "castings" and become "drop forgings," or if only part is forged then they are partly forgings and partly castings.

SLAB, a flat piece or plate, with its largest surfaces plane, drawn or sheared from an ingot or like mass for further treatment.

WASHED METAL, cast iron from which most of the silicon and phosphorus have been removed by the Bell-Krupp process without removing much of the carbon, so that it still contains enough carbon to be classed as cast iron. The name "washed metal" is extended to cover this product even if its carbon is somewhat below the proper limit for cast iron.

WELD IRON, the same as wrought iron. Obsolescent and needless.

WELD STEEL, iron containing sufficient carbon to be capable of hardening greatly by sudden cooling, and in addition slag-bearing because made by welding together pasty particles of metal in a bath of slag, as in puddling, and not later freed from that slag by melting. The term is rarely used.

WHITE PIG IRON, and WHITE CAST IRON, pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

WROUGHT IRON, slag-bearing, malleable iron, which does not harden materially when suddenly cooled.

WROUGHT STEEL, the same as weld steel. Rarely used.

335. THE BOUNDARY BETWEEN STEEL AND IRON. — It would be well to decide on a definite carbon-content to serve as a boundary line between ingot iron and ingot steel, between puddled iron and puddled steel, and between any other varieties of wrought iron and weld steel. Two plans have been considered. One is to draw this line at 0.32 per cent carbon or its equivalent in other elements, for the reason that this carbon-content appears to correspond to the critical point *H* in the diagrams of Roberts-Austen and Roozeboom. This has the merit of corresponding to a definite physical boundary.

The other plan is to draw the boundary at 0.20 per cent of carbon, because this is a convenient place to separate the important classes "soft steel" and "half-hard steel"; so that if this point was adopted, "ingot iron" would be synonymous with "soft steel," and "ingot steel" would be the equivalent of the two classes "half-hard steel" and "hard steel."

APPENDIX III

336. THE MAGNETIC PROPERTIES.* — As pointed out in § 193, p. 215, alpha iron, characteristic of slowly cooled iron and steel and normal below A_2 of Fig. 68, p. 192, is strongly magnetic, but the allotropic beta and gamma iron, the former stable between A_2 and A_3 and the latter above A_3, are only feebly magnetic. And of alpha iron, it is probably the alpha ferrite which is the most strongly magnetic form.

The fact that as the carbon diminishes the temporary magnetism increases but the permanent magnetism or retentivity decreases, until in very low carbon steel and wrought iron the temporary magnetism is very great and the permanent magnetism is very low, may conveniently be explained by supposing that

* See Osmond, *Philosophical Magazine*, 5th series, vol. XXIX, p. 511, June, 1890. Also the author, *Trans. American Inst. Mining Engineers*, XXVII, 1897, p. 914.

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-

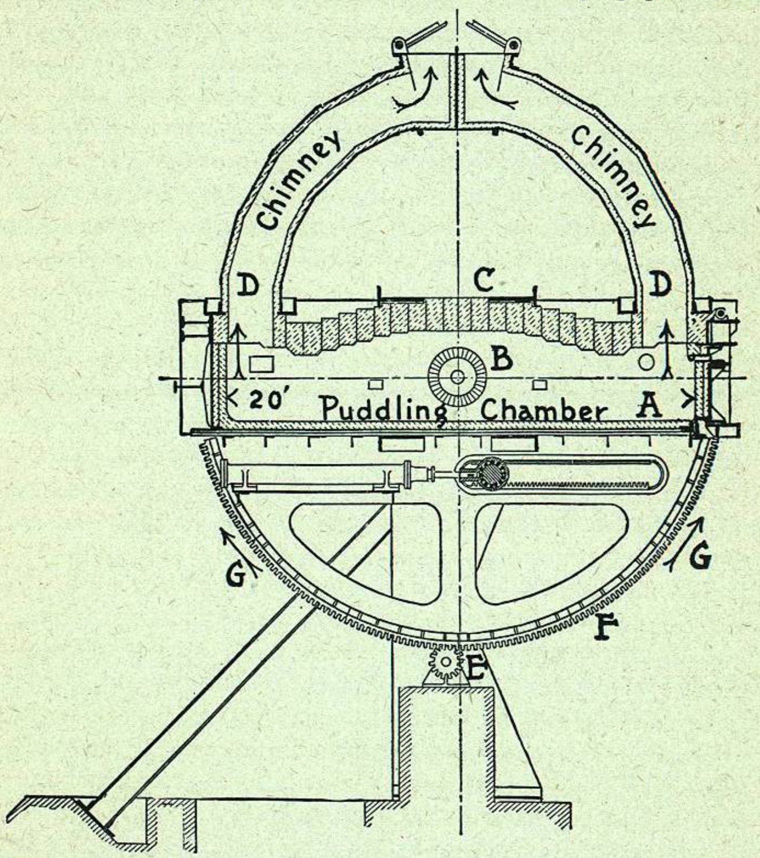

Fig. 121. Longitudinal Vertical Section of Roe's Rocking Puddling Furnace. A, the magnesia brick lining of the puddling chamber, which is about 20 feet long and 8 feet wide. B, hollow trunnion, about which the whole machine, chamber, chimneys and all, rocks. There is of course a second trunnion on the 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;