

"Medium carbon steel" in this line mean that the matrix of the cast irons beneath these words has the same ultimate chemical composition and therefore, on our hypothesis, the same microscopic constitution, *i. e.*, the same percentage of ferrite and cementite, and also the same physical properties, which medium carbon steel has.

Below the diagram are given the observed properties of the different kinds of cast iron here represented, and the kinds of uses to which they are fitted.

APPENDIX II

Classification of Iron and Steel with Definitions

333. The classification and the definitions which follow are those used by Professor Albert Sauveur and the author, with much valuable advice from Mr. H. H. Campbell, in their work as a committee of the International Association for Testing Materials, to which thanks are due for permission to use this material here.

CLASSIFICATION

NAMES	APPARATUS IN WHICH USUALLY MADE
SPECIES	
Cast iron . . . . .	Blast furnace.
<i>Varieties</i>	
White cast iron or pig iron . . . . .	Blast furnace.
Gray cast iron or pig iron . . . . .	" "
Mottled cast iron or pig iron . . . . .	" "
Pig iron (white, gray, mottled, etc.) . . . . .	" "
Hot metal or direct metal . . . . .	" "
Basic cast iron or pig iron . . . . .	" "
Hematite cast iron or pig iron . . . . .	" "
Malleable pig iron . . . . .	" "
Washed metal . . . . .	Pernot furnace.
Refined cast iron or plate iron . . . . .	Coke refinery.
Charcoal hearth cast iron . . . . .	Charcoal hearth.
Alloy cast iron . . . . .	Blast furnace, crucible or electric furnace.
SPECIES	
Malleable castings . . . . .	{ Air furnace, open-hearth furnace, or cupola furnace, followed by long annealing.

NAMES	APPARATUS IN WHICH USUALLY MADE
SPECIES	
Steel.	
<i>Variety A</i>	
Called steel because cast initially into a malleable mass . . . . .	Bessemer converter, open-hearth furnace, or crucible furnace.
1, soft or low-carbon steel, or ingot iron . . . . .	
2, half-hard and hard, or medium- and high-carbon steel, or ingot steel . . . . .	
Sub-Varieties	
Bessemer steel . . . . .	Bessemer converter.
Open-hearth steel . . . . .	Open-hearth furnace.
Crucible steel or cast steel . . . . .	Crucible furnace.
Steel castings.	
<i>Variety B</i>	
Weld steel, or wrought steel, called steel because it is capable of hardening greatly by sudden cooling.	
Sub-Varieties	
Blister steel, also called cemented and converted steel . . . . .	Cementation furnace.
Puddled steel . . . . .	Puddling furnace.
<i>Variety C</i>	
Alloy steels . . . . .	Open-hearth furnace, crucible furnace, or Bessemer converter.
SPECIES	
Wrought iron (or weld iron, or in Great Britain malleable iron).	
<i>Varieties</i>	
Puddled iron . . . . .	Puddling furnace.
Bloomary or knobbed iron . . . . .	Bloomary, called also low hearth, charcoal hearth, Lancashire hearth, knobbling fire, etc.

334. DEFINITIONS.—ALLOY CAST IRONS, those which owe their properties chiefly to the presence of an element (or elements) other than carbon.

ALLOY STEELS, those which owe their properties chiefly to the presence of an element (or elements) other than carbon.

BAR IRON, wrought iron in the form of bars, rods, etc.

BASIC PIG IRON. In America, pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open-hearth process. It is restricted to pig iron containing not more than 1.00 per cent of silicon.

BESSEMER PIG IRON, that which contains so little phosphorus and sulphur that it can be used by itself for conversion into steel by the original or acid Bessemer process. In America this term is restricted to pig iron containing not more than 0.10 per cent of phosphorus.

BESSEMER STEEL, steel made by the Bessemer process, whether its carbon content is high, low or intermediate.

BILLET, a small bar drawn from a pile, bloom, or ingot for further manufacture. The Committee recommends that the line between blooms and billets be drawn at the size of 5 inches square, as representing common custom.

BLISTER STEEL, steel made by carburizing wrought iron by heating it in contact with carbonaceous matter. It might also be made by so carburizing a low-carbon steel.

BLOOM. 1. A large bar, drawn from an ingot or like mass, for further manufacture. 2. A rough bar of wrought iron drawn from a Catalan or bloomary ball for further manufacture.

CAST IRON. Generically, iron containing so much carbon or its equivalent that it is not malleable at any temperature. Specifically, cast iron in the form of castings other than pigs, or remelted cast iron suitable for casting into such castings, as distinguished from pig iron, *i. e.*, cast iron in pigs, etc. (See Pig Iron.) For instance, cast iron pigs, *i. e.*, pig iron, like lead in pigs, *i. e.*, pig lead, is remelted and cast into castings, such as columns, locks, gears, etc., of special shape suited to their special purpose; these are specifically called "cast iron," and this is the usual restricted meaning of "cast iron" in trade language.

When we say "the fracture and density are those of cast iron," "the right-hand side of Roberts-Austen's diagram represents cast iron," or "Production of Steel by the Partial Decar-

burization of Cast Iron" (Percy, *Iron and Steel*, XV), we use "cast iron" in its generic sense, including both pig iron in pigs and cast iron in other and shaped castings, whether these are made direct from the molten pig iron running from the blast furnace, or by remelting that cast iron. On the other hand, when we say "cast iron locks, posts, and other hardware," we use "cast iron" in its specific sense of "shaped castings of cast iron," and we exclude pig iron. Exactly in the same way when we say "all men must die" or "the cavalry lacks horses, we use "man" and "horse" generically to include women and mares; when we say "the men are at the war" or "the horses beget colts," we use "man" and "horse" specifically, and exclude women and mares. The meaning of "pig iron," "woman" and "mare" is never in doubt; in which of its two meanings a word like "cast iron," "man" or "horse" is to be taken should be and generally is indicated clearly by the context. Dual meanings might conceivably lead to confusion, but in fact they do not; probably no reader of these present lines has ever been confused, unless intentionally, as to the meaning of "horse" or "man," nor need he be as to the meaning of "cast iron." Were your committee inventing language, it would avoid dual meanings; as our function is not to invent but to record existing language, we have no jurisdiction over the meanings of these words. We only assert our knowledge that the generic sense of "cast iron" is so firmly established in English literature that it cannot and should not be changed. That the trade itself rarely has occasion to make use of the generic meaning of cast iron would not warrant a vain attempt to root that established meaning out of scientific and literary usage. The trade need never use the generic meaning of "cast iron." The truth is that science and letters often need generic terms which trade does not need; "mollusc" is needless to the fish trade, "mammal" is needless to the circus trade, "conifer" is needless to the lumber trade; nevertheless those words and that sense will remain, because they are needed elsewhere.

The committee recommends drawing the line between cast iron and steel at 2.20 per cent carbon for the reason that this appears from the results of Carpenter and Keeling to be the critical percentage of carbon corresponding to the point "a" in the diagrams of Roberts-Austen and Roozeboom. As to the

signification of this critical point the committee is not prepared to express an opinion.

CAST STEEL, the same as crucible steel. Obsolescent, and to be avoided because confusing and because a temptation to fraud.

CEMENTED STEEL, the same as blister steel.

CHARCOAL HEARTH CAST IRON, cast iron which has had its silicon and usually its phosphorus removed in the charcoal hearth, but still contains so much carbon as to be distinctly cast iron.

CONVERTED STEEL, the same as blister steel.

CRUCIBLE STEEL, steel made by the crucible process, whether its carbon content is high, low or intermediate.

GRAY PIG IRON and GRAY CAST IRON, pig iron and cast iron in the fracture of which the iron itself is nearly or quite concealed by graphite, so that the fracture has the gray color of graphite.

HEMATITE PIG IRON, originally pig iron made from the hematite ores of England, which happen to be so free from phosphorus and sulphur that the pig iron made from them can be used by itself for the acid Bessemer process. By association it has come to mean any pig iron thus relatively free from phosphorus and sulphur. The term is not used in America, and is undesirable.

HOT METAL or DIRECT METAL, the molten cast iron from the blast furnace before it has been allowed to solidify.

INGOT IRON, steel cast into an initially malleable mass and containing so little carbon or its equivalent that it does not harden greatly on sudden cooling. The word is rarely used in English, "mild steel" or "low carbon steel" or "soft steel" being generally used in its place. In America the line between soft steel and half-hard steel is usually drawn at a carbon content of about 0.20 per cent.

INGOT STEEL, steel cast into an initially malleable mass and containing so much carbon or its equivalent that it hardens greatly on sudden cooling. The word is rarely used in English, but "hard steel," "high-carbon steel" or "half-hard steel" are used in its place.

MALLEABLE CASTINGS, castings of malleable cast iron, which see.

MALLEABLE CAST IRON, iron which when first made is cast in the condition of cast iron, and is made malleable by subsequent treatment without fusion.

Although the English name of this variety suggests that it

is cast iron, it is not truly a variety of cast iron, but rather forms an independent species of iron, because it lacks the essential property of cast iron, *viz.*, its extreme brittleness. Though the term "malleable castings" is very common, the term "malleable cast iron" is very rarely used. The common but inexcusable term we regret to say is "malleable," pronounced "mallable," used as a substantive. Those with some respect for their mother tongue, if asked of what material a malleable casting was composed, would generally use a circumlocution.

MALLEABLE IRON, the same as wrought iron. Used in Great Britain, but not in the United States, except carelessly as meaning "malleable cast iron" (vulgar "malleable").

MALLEABLE PIG IRON, an American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting. The term should be used with care to avoid confusion. This material is also called in trade in America "malleable iron," but this use should be avoided, because "malleable iron" has the older and (in Great Britain) firmly established meaning of "wrought iron."

MOTTLED PIG IRON and MOTTLED CAST IRON, pig iron and cast iron the structure of which is mottled, with white parts in which no graphite is seen, and gray parts in which graphite is seen.

MUCK BAR, the rough bars, usually 1 inch thick and about 4 inches wide, made by the first rolling of a ball of puddled iron.

OPEN-HEARTH STEEL, steel made by the open-hearth process, whether its carbon content is high, low or intermediate.

PIG IRON, cast iron which has been cast into pigs direct from the blast furnace. This name is also applied to molten cast iron which is about to be so cast into pigs or is in a condition in which it could readily be cast into pigs.

PLATE IRON, a name applied in Great Britain to refined cast iron.

PUDDLED IRON, wrought iron made by the puddling process.

PUDDLED STEEL, steel made by the puddling process, and necessarily slag-bearing. (See Weld Steel.)

REFINED CAST IRON, cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

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.