

	SURFACE VEHICLE INFORMATION REPORT	
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Carbon and Alloy Steels		

RATIONALE

A five year review was completed and the document references were updated.

1. SCOPE

This SAE Information Report describes the processing and fabrication of carbon and alloy steels. The basic steelmaking process including iron ore reduction, the uses of fluxes, and the various melting furnaces are briefly described. The various types of steels: killed, rimmed, semikilled, and capped are described in terms of their melting and microstructural differences and their end product use. This document also provides a list of the commonly specified elements used to alloy elemental iron into steel. Each element's structural benefits and effects are also included. A list of the AISI Steel Products Manuals is included and describes the various finished shapes in which steel is produced.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 AIST: Steel Reference Manuals

Available from Association for Iron and Steel Technology, 186 Thorn Hill Road, Warrendale, PA 15086, Tel: 724-776-6040, www.aist.org.

- Bar Steel: Alloy, Carbon, and Microalloy Steels: Semifinished, Hot-Rolled Bars, Cold Finished Bars, Hot-Rolled Deformed and Plain Concrete Reinforcing Bars
- Plates and Rolled Floor Plates: Carbon, High-Strength Low-Alloy and Alloy
- Carbon Steel Pipe, Structural Tubing, Line Pipe, Oil Country Tubular Goods
- Sheet Steel: Carbon, High-Strength Low Alloy, and Alloy: Coils and Cut Lengths (Including Coated Products)
- Strip Steel: Carbon, High-Strength Low Alloy, and Alloy

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- Tin Mill Products
- Carbon Steel, Wire and Rods
- Cold Rolled Flat Steel Wire
- Railway Track Material
- Stainless and Heat Resisting Steels
- Tool Steels
- Steel Specialty Tubular Products
- Hot-Rolled Structural Shapes, H-Piles and Sheet Piling

3. STEEL

Steel is a malleable alloy of iron and carbon that has been made molten in the process of manufacture and contains approximately 0.05 to 2.0% carbon, as well as some manganese and sometimes other alloying elements.

3.1 Carbon Steel

Steel is considered to be carbon steel when no minimum content is specified or required for aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, or zirconium, or any other element added to obtain a desired alloying effect: when the specified minimum for copper does not exceed 0.40%; or when the maximum content specified for any of the following elements does not exceed the following percentage: manganese, 1.65%; silicon, 0.60%; copper, 0.60%. For fine grain carbon steels, minimum or maximum levels of grain refiners (Al, Cb, V) can be specified. Boron may be added to killed fine grain carbon steel to improve hardenability.

In all carbon steels, small quantities of certain residual elements, such as copper, nickel, molybdenum, chromium, etc., are unavoidably retained from raw materials. Those elements are considered detrimental for special applications, the maximum acceptable content of these incidental elements should be specified by the purchaser.

3.2 Alloy Steel

Steel is considered to be alloy steel when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65%; silicon, 0.60%; copper, 0.60%; or in which a definite range or definite minimum quantity for any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum and chromium up to 3.99%; cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying element added to obtain a desired alloying effect.

4. STEELMAKING PROCESSES

These fall into two general groups: acid or basic, according to the character of the furnace lining. Thus electric processes may be either acid or basic. Basic oxygen, as the name implies, is an exclusively basic process. The choice of an acid or basic furnace is usually determined mainly by the phosphorus in the available raw materials and the content of phosphorus permissible in the finished steel.

Phosphorus is an acid-forming element and, in its oxide form, will react with any suitable base to form a slag in the steelmaking furnace. In basic processes, the metallurgist and steelmaker take advantage of this chemical behavior by oxidizing the phosphorus with iron oxide, which yields up its oxygen to the phosphorus. This permits the iron to remain as part of the steelmaking bath, while the acid phosphoric oxide is separated by floating up into the molten basic lime slag. In acid processes, furnaces are generally lined with silica, which is acid in nature and will not tolerate the use of basic materials for fluxes. Since an acid slag has no affinity for impurities such as phosphorus, the steel cannot be dephosphorized by fluxing and the content of this element remains at the level contained in the raw material, or may be concentrated somewhat in the finished steel due to loss of other materials from the original metallic charge.

Most iron ores in the United States are of a phosphorus content suitable only for basic steelmaking processes: hence, all of the nation's wrought steel is so made. The following are the principal steelmaking processes used in the United States:

4.1 Basic Electric

The principal advantage of this process is optional control in the furnace permitting steel to be treated under oxidizing, reducing, or neutral slags, and pouring off and replacement of slags during the process. In this manner, and depending on specified requirements, objectionable elements may be substantially reduced and a high degree of refinement obtained in the steel bath. Practically all grades of steel can be made by the basic electric furnace, and the process with or without supplementary processes is used for producing SAE Wrought stainless steels.

4.2 Basic Oxygen

The prime advantage of this process is the rate at which steel can be produced. The nature of the process is such that large quantities of molten iron must be readily available, since refining is accomplished by the exothermic reactions of high purity oxygen with the various elements contained in the molten iron.

4.3 Ladle Refining

Today the majority of steels are actually refined to final chemistry and cleanliness requirements in a ladle refining facility. This facility takes the ladle of steel which was tapped from the electric arc furnace (EAF) or basic oxygen furnace (BOF), and through the use of the ladle as a vessel further refines the steel. Through the use of optional electric arc reheating capability, inert gas stirring, and optional degassing capabilities; the ladle of steel is trimmed to the final chemistry requirements and inclusions are removed for cleaner steel. The ladle refining station is the facility which actually makes the specific grade of steel to the customer's specification.

4.4 Other

Another method increasing in use in the production of stainless, tool, and specialty steels is ESR (electroslag refining). In this process, as-cast electric furnace melted electrodes are progressively melted and solidified in a water cooled copper mold under a blanket of molten flux. Melting results from the heat generated by the resistance of the molten flux to electric current passing between the electrode and the solidifying ingot. Refining occurs as the electrode melts and droplets of molten metal pass through the flux and their impurities are removed by reaction with the flux. The progressively solidified ingot thus produced is very homogeneous and sound, and may be directly processed into mill products.

The AOD (argon oxygen decarburization) process has become an important steel refining system for specialty steel grades. Originally employed to replace electric furnace basic slag practice for stainless steels, it is now refining alloy, tool, silicon-iron, electrical, and other specialties. The AOD system refining vessel simply accepts molten iron from whatever source is available, that is, electric furnace, BOF, blast furnace or cupola and completes all chemical and refining stages.

The process is based on the principle that when argon gas is mixed with oxygen and injected into the melt, the inert gas dilutes the carbon monoxide resulting from the oxidation of carbon and reduces its partial pressure. This shifts the reaction equilibrium to favor the oxidation of carbon over other oxidizable metals such as chromium. As a result, a higher chromium content can be charged in the melt allowing the conservation of ferrochromium and making this attractive in the economic production of stainless steel.

AOD melting also allows control of hydrogen in flake sensitive grades to the point that the need for long anneals is eliminated.