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Composition of Steel-Reporting Practices for Unspecified Elements

Sometimes the test report shows more chemical elements than we expect. Here's why.

The Certified Test Reports (CTR's), or chem certifications (chemical certs), report the chemical elements and results of other testing of the steel products that we ordered. But in addition to the elements specifically required for a given steel grade, there are small amounts of other elements present. This article will explain the reporting practices and significance (or lack of significance) of these little-understood chemical ingredients or designations.

A steel grade is determined by its chemical composition. Its chemical composition is what makes the development of expected properties and performance possible. Depending on the different chemical elements present, a steel may be designated as a carbon, alloy or stainless steel grade. There are other types of steels — for example, tool steels and heat-resistant steels — but we are focusing on carbon and alloy bar steels most often encountered in our precision machining, production machining shops.

Carbon and alloy bar steels are produced, certified and sold according to a variety of ASTM Standard Specifications. These standards provide not only the requirements for the steels to meet but also the definitions of many terms that describe them and their performance. The three ASTM Standard Specifications that we consulted for this article include ASTM A 29 (latest edition) Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot Wrought; ASTM A 108 (latest edition) Standard Specification for Steel Bar, Carbon and Alloy, Cold Finished; and ASTM A 751 (latest edition): Standard Test Methods, Practices and Terminology for Chemical Analysis of Steel Products.

These are the foundations for defining commercial product compliance and product attributes.

Elements by any Other Name: Specified Elements

Each grade of steel has a list of chemical element ingredients that must be present for the material to be compliant and meet specification; these are called specified elements. Specified elements are present within a specified minimum and maximum range, as listed in the specification. Carbon, manganese, phosphorus and sulfur are specified elements in carbon steels. Lead can be a specified element if the steel is a leaded carbon steel. Note that due to differences in testing and analytical procedures, these minima and maxima can vary based on whether the testing is at time of heat or cast (melt) analysis, semi-finished or in the final product. Due to segregation in different types of steels, variations in some of these elements may not be cause for rejection based on product analysis. In alloy steels, alloying elements including nickel, chromium and molybdenum are common, with lead, vanadium and boron also possibly specified.

There are other chemical elements present that may or may not be reported on the certification documents. In casual conversations, these names are often substituted for one another, but each of these categories of additional chemical make up can have a different origin and, perhaps, impact. ASTM A 751: Standard Test Methods, Practices and Terminology for Chemical Analysis of Steel Products

authorizes the producer to report unspecified as well as specified elements on the test report. This standard defines specified elements, intentionally added unspecified elements, residual elements and trace elements. Not listed, but often used as a name for some of these categories are the terms "incidental elements" and "tramp elements."

Elements by any Other Name: Unspecified Elements

Unspecified elements may be either intentionally added, or unintentionally find their way into the melt as component of the raw materials or process. Intentionally added (in controlled amounts) unspecified elements can include deoxidizers, grain refiners or deliberate, modest additions of other elements to enhance or develop properties. Silicon is an unspecified element (not listed in Table 1 of ASTM A29) as an ingredient but can be added in ranges: 0.10% max; 0.10%-0.20%; 0.15%-0.35%; 0.20%-0.40% or 0.30% to 0.60% (per footnote B). Sometimes the amount of chromium added to a medium carbon, plain carbon steel is increased just to ensure achievement of a minimum hardenability or mechanical property for the customer.

Unspecified elements that are not intentionally added may be called residual elements or trace elements. Residual elements are picked up from either initial raw materials (in the scrap, ores or fluxes) or can be absorbed by the melt from refractories. In electric furnace steels, copper is a prime example. Copper is contained in small quantities in the scrap steel charged into the furnace, showing up as higher quantities in electric furnace melt steels compared to basic oxygen steels, which have a limited scrap charge. However, the electric furnace shop can add quantities of direct reduced iron (DRI) to reduce the level of residuals in the steel by dilution. Occasionally, copper can be specified as a 0.20% minimum.

Trace element is the designation given to residual elements that appear in very low concentrations — less than 0.01% by weight.

According to the Steel Bar Product Manual, Iron and Steel Society, 1994, "Certain elements are present in small quantities in most steels. They are not intentionally added but have been retained from the raw materials used during production of the steel. These elements are considered incidental or residual as long as they do not exceed certain maximum limits."

What's Left?

Sometimes, a test report will show a percentage "all others" or "balance." Typically in steels that value is referring to iron, which makes up the balance of the material.

Conclusion

Zero is a charming artifact of the 20th century, back when there were only three black-and-white TV channels, and when parts-per-million precision required government laboratory levels of equipment and budget. Parts per billion were not even a thought. As analytical methods have advanced, the zero has receded so far that in some commercially common laboratory methods, we can truly "count atoms." Many chemical elements that are naturally occurring can be found in residual, incidental or trace levels or quantities, given a suitably equipped laboratory and budget. They can be found as well in foods, soils, drinks and packaging, as well as in the metallic and polymeric raw materials we machine in our shops.

The reporting of chemical composition is important, but understanding the levels of the chemical elements in terms of weight percent and specification threshold is critical if we are to avoid overreaction at seeing some trace or incidental value as cause for alarm.

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