

Metallurgy Lane, authored by ASM life member **Charles R. Simcoe**, is a yearlong series dedicated to the early history of the U.S. metals and materials industries along with key milestones and developments.

The History of Alloy Steels: Part I

The widespread use of alloy steels beginning in the early 1900s spurred the need to acquire and share information about heat treating, which previously had been a guarded art.

Carbon is the single most potent element added to iron, even though it is not thought of as an *alloy* because the word “steel” is defined as carbon in iron. Amounts as small as 0.05% have profound effects on the behavior of iron, and 0.15 to 0.25% additions are sufficient to make mild structural steel. Most heat treated alloy steels contain 0.30 to 0.40% C. Carbon has two characteristics that account for its powerful effects from such small amounts: It is very low in density, so therefore a great number of atoms are present in small amounts (by weight), and its atoms are smaller than iron atoms, so they do not substitute for iron in the crystal lattice, but take up a unique position in the holes between the iron atoms. It is this interstitial position of carbon atoms in the iron lattice—along with the crystal lattice transformation from face centered cubic (fcc) to body centered cubic (bcc) on cooling—that makes steel such a marvelous material for construction, power transmission, and tools in the modern era.

The first alloy steel contained chromium and was patented in 1865 by American metallurgist Julius Baur and manufactured by the Chrome Steel

Co. of Brooklyn, N.Y. This alloy steel was never successful, but the publicity prompted an interest in chromium alloy steels by French metallurgist Henri-Ami Brustlein. He soon learned that to alloy chromium with steel, the chromium ore needed to be refined to produce a master alloy of iron-chromium-carbon. This master alloy would readily dissolve into the melt of the cru-

years before anyone else entered the field. For his work in developing alloy steel and related heat treatments and applications, Brustlein deserves to be called the Father of Alloy Steels.

Nickel steel development

While Brustlein was developing chromium steels, other French metallurgists were learning to smelt nickel-containing ore from New Caledonia, a French territory in the South Pacific. The resulting ferronickel was then used to add nickel to steel. The production of nickel steel was observed in France in 1888 by James Riley, an Englishman who made arrangements for similar steels to be made at The Steel Company of Scotland in 1889. He immediately tested these steels and reported their properties in the *Journal of the Iron and Steel Institute*. One of his steels containing roughly 0.2% C and 5% Ni developed strength properties of considerable interest for many different structural and machine applications. This steel, processed by rolling and annealing, was about 40% stronger than similar steel without nickel.

The first alloy steel employed in regular industrial production in the U.S. was 5% nickel steel, used for bicycle chains (1898), followed the next year by bicycle tubing. The first use of alloy steel in the emerging automotive industry was a 5% nickel steel axle by Haynes and Apperson. Somewhat later, nickel steels (3.5%) became popular for the structural components of large bridges, including the Manhattan and Queensboro Bridges in New York City. In 1900, about 3000 tons of alloy steel were produced in the U.S.

Shortly after nickel steels came into use, more complex alloy steels containing both chromium and nickel were being tested by Krupp in Germany and by the Compagnie des Forges de la Marine in France. These nickel-chromium steels could be hardened in large sections by heat treating so they became very popular for armor and large forgings. After the turn of the century, the straight nickel steels rapidly declined in use in favor of the nickel-chromium steels and the newly developed chromium-vanadium steels.



The first use of alloy steel in the U.S. was for the axle of the famous Ferris Wheel at the 1893 Chicago World's Fair. Courtesy of Library of Congress.

cible process, otherwise the recovery of chromium would be too erratic to control the alloy content. Brustlein produced and sold chromium alloy steels for tools, cannon shells, and armor plate over a period of about 15 to 20



Queensboro Bridge made of nickel steel, New York City, circa 1908. Courtesy of Library of Congress.



Henry Louis Le Chatelier of France developed high-temperature platinum-platinum/rhodium thermocouples, useful for measuring critical temperatures in steel.

Automobiles usher in alloy steel era

It was the automobile that initiated the Age of Alloy Steel. The number of alloy steels used in the auto industry increased throughout the decade of 1910-1920. Walter Jominy, a metallurgist from the University of Michigan who worked for the Studebaker Automobile Co., published a list of 12 alloy steels in 1920 that he said filled all the needs for building automobiles.

World War I provided additional emphasis on the use of alloy steels and on the process of heat treatment. The quantity of alloy steel made in the U.S. reached more than 1 million tons in 1918, and the widespread use of alloy steel increased the need to both acquire and share information about heat treating, which previously had been a guarded art. William Park Woodside, a former blacksmith, began holding meetings in Detroit to exchange information among heat treaters in the early auto industry. These meetings lead to the formation of a formal group called the Steel Treating Club, which eventually became the American Society for Steel Treating.

These early groups formed chapters in various industrial regions across the country and published data sheets on the technical aspects of heat treating. Soon they provided a publication called *Transactions* for serious researchers to publish their papers. In 1930, the American Society for Steel Treating published a magazine called *Metal Progress* (now *Advanced Materials & Processes*). It became the most popular source of information in all of metalworking, not just heat treating. The society changed its name in the early 1930s to the American Society for Metals and later to ASM International.

The early science of steel

The first interest in examining the nature of steel came just after the midpoint of the 19th century. Henry Clifton Sorby of Sheffield, England, examined polished and etched surfaces of meteorites and several commercial steels during 1863-1866. Sorby discovered that the microstructure of steel was complex and he found an area that he called "pearly." Later, Floris Osmond of France and Adolf Martens of Germany published their examination of polished and etched surfaces of steel in the *Jour-*



Bicycles at the turn of the century used 5% nickel steel in their chains, the first widespread industrial use of an alloy steel. Courtesy of State Library of Queensland.

nal of the Iron and Steel Institute of Great Britain. Their work reawakened Sorby's interest in an area he had worked on more than 20 years earlier. Sorby immediately began a new examination of the microstructure of steels. He published his work in the *British Journal of the Iron and Steel Institute* in 1887. This new work by Sorby, along with that of Osmond and Martens, is considered the true beginning of the field of metallography, the study of the internal structure of metals. From this point forward, the ever increasing research into how the behavior of metals relates to their structure has been the foundation of our modern technological age.

A second major development at this time was a new measuring tool for high temperatures invented by Henry Louis Le Chatelier of France, which used platinum-platinum/rhodium thermocouples. Osmond immediately put the new thermocouple to use in measuring the so called *critical temperatures* in steel. These temperatures—where changes were noted in the rates of cooling or heating—were first pointed out by Russian metallurgist D.K. Tchernoff. He stated that steel could not be hardened upon quenching until it was first heated above the uppermost critical temperature. These temperatures were believed to represent important internal changes in steel. The study of critical temperatures as a function of a steel's carbon content lead to the field of binary phase diagrams, which was the next advance in understanding the complexity of steel.



Henry Clifton Sorby of England, an early pioneer of metallography. Courtesy of University of Sheffield.

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