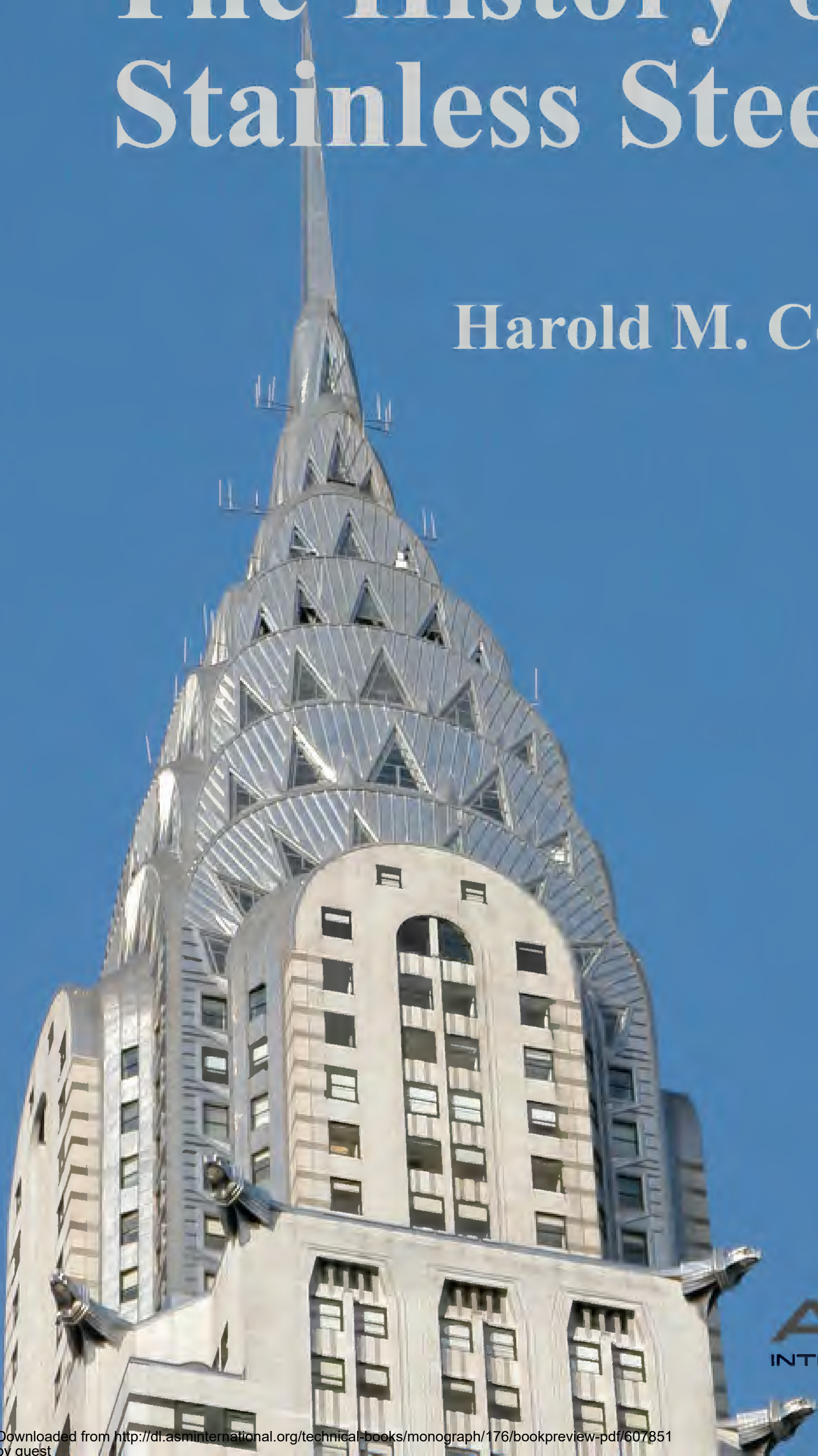
The History of Stainless Steel

Harold M. Cobb



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The History of Stainless Steel
is dedicated to my dear wife
Joan Inman Cobb

Front Cover

The Chrysler Building, erected in New York City in 1930, was once the tallest building in the world, being almost twice as high as the Washington Monument. It is widely acclaimed as the finest skyscraper, with its art deco style and the ornate tower that is clad with stainless steel.

The Chrysler Building was the first major use of stainless steel in architecture. The Nirosta chromium-nickel alloy had first been introduced in America just three years earlier, and the long-term endurance of the metal in the atmosphere was unknown. The building has become an icon of the stainless steel industry, a symbol of endurance and beauty, and a favorite of architects.

The photograph was taken by Ms. Catherine M. Houska, TMR Stainless, Pittsburgh, Pennsylvania, for the Nickel Development Association, Toronto, Ontario, Canada.

Inside Front Cover

1934 photograph of the Burlington Zephyr at the E.G. Budd Manufacturing Company in Philadelphia, Pennsylvania. Courtesy of the Hagley Museum

Inside Back Cover

List of stainless steels given in Carl Zapffe's 1949 book, *Stainless Steels.*

Back Cover

Top. At a height of 630 feet, the Gateway Arch in St. Louis, Missouri, is the world's tallest monument, which surpassed the 555 foot height of the Washington Monument. With an exterior of stainless steel, the shape of the arch is that of an inverted catenary (or the shape of a chain dangling from two points at the same level). Courtesy of the Jefferson National Expansion Memorial National Park Service, St. Louis, Missouri.

Bottom. The Ford Tudor, one of six Ford Deluxe sedans manufactured by Allegheny Ludlum in 1935 to demonstrate the formability of 18-8 stainless steel and to show its beauty.

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Preface

What is stainless steel? The average person has no inkling, but it is all around us, and readers will be surprised to learn some of the stories of this remarkable material that one prominent metallurgist called "the miracle metal."

Every day, most of us use stainless steel tableware and wear a wristwatch with a stainless steel case and band. There are stainless steel racks in refrigerators and ovens, and there are stainless steel toasters, tea kettles, and even kitchen sinks. Cars have stainless steel exhaust systems that last for ten years instead of three when they were made of ordinary steel.

The amazing story is told of Harry Brearley, who rose from poverty, became a self-taught metallurgist, was one of the early discoverers of stainless steel, and received the Bessemer Gold Medal.

In the early days of stainless steel, the metal was often used when the goal was to produce the finest, the most durable, and the most beautiful product that money could buy. The Rolls-Royce Motor Car Company, for example, was one of the first to use stainless steel on an automobile. Their 1929 car displayed the most striking radiator grille imaginable in silvery stainless steel.

In America in 1930, the office building of automaker Walter P. Chrysler opened in New York City. The Chrysler Building was the tallest and most ornate skyscraper in the world. The top 100 feet of the tower was clad in Nirosta stainless steel, making it the most beautiful and most visible building on the New York City skyline.

In 1934, a Philadelphia autobody company tried their hand at building a stainless steel train for the Chicago, Burlington, & Quincy Railroad. It was a streamlined, lightweight, luxurious, silvery train that became the world's fastest. It traveled 3.2 million miles in 25 years and is now on display at the Chicago Museum of Science and Industry.

Eero Saarinen designed the St. Louis Gateway Arch, which was completed in 1965. The 630 foot, stainless-clad arch is the tallest monument. Saarinen wanted the arch to last for a thousand years.

Stainless steel was an expensive material, costing as much as 15 times that of ordinary steel. The story is told of how one young metallurgist in 1970 discovered, in the laboratory, a process that would cut the cost of stainless steel in half and produce better steel. The other part of the story was that it took 12 years to discover how to develop the process for large-scale production.

How it was possible for things like these to happen and the story of how stainless steels were discovered are explained in this first history of stainless steel. Stainless steels have become the third most widely used metals, following aluminum and steel.

Harold M. Cobb
Kennett Square, Pennsylvania
March 2009

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Harold M. Cobb
Kennett Square, Pennsylvania
October 2009

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About the Author

Harold M. Cobb graduated from Yale University in 1942, receiving a B.E. degree in metallurgical engineering. He has had a broad background in the stainless steel industry, where he was involved in the development of new stainless steel products, including watch screws, hollow stainless steel aircraft propeller blades, roll-formed compressor blades and vanes for jet engines, boron carbide stainless steel for moderating nuclear reactors, and sinter-bonded porous stainless steel fiber-metal products.

Cobb's industrial experience included positions at the Edward G. Budd Manufacturing Co., Westinghouse Aviation Gas Turbine Division, United Nuclear Corp., and as chief metallurgist at Clevite Aeroproducts and Pratt & Whitney.

He was chairman of the Philadelphia and Connecticut sections of the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME). He holds a patent on a manufacturing process for nuclear fuel elements.

After 22 years in the metals industry, Cobb became a manager at the American Society for Testing and Materials (ASTM) in Philadelphia, working with many of the metals technical committees, including Committee A-10 on Stainless Steel. He was one of the principal promoters and developers of the Unified Numbering System (UNS) for metals, which was organized jointly by the Society of Automotive Engineers (SAE) and ASTM in 1970. For many years, Cobb developed and served as the number assigner for the miscellaneous steels series of UNS numbers, the K series. He has been the principal editorial consultant for the last four editions of *Metals and Alloys in the Unified Numbering System (UNS)*.

Cobb served as Secretary of the U.S. Secretariat for the International Standards Committee ISO/TC17/SC12 on Carbon Steel Sheet and Strip for 15 years. He has edited 22 books on steel, including works on carbon, alloy and coated steel sheet and strip, tool steels, stainless steel specifications, and a *Pocketbook of Standard Wrought Steels*. In 1999, he became editor of the *Stainless Steels Products Manual*, one of the 16 steel products manuals that the American Iron and Steel Institute (AISI) initiated in the 1950s. In 2008, Cobb edited and substantially revised his second edition of *Stainless Steels*, now published by the Association for Iron and Steel Technology.

He has written the articles "Development of the Unified Numbering System for Metals," "The Naming and Numbering of Stainless Steels," and "The 75th Anniversary of the Burlington Zephyr Stainless Steel Train." Cobb is a member of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is a Life Member of ASM International.

CHAPTER 1

Introduction

"Starting from rust, men have produced something which looks like platinum and resists chemical attack like gold, and yet a square inch can support a quarter of a million pounds . . . this is the crowning achievement of metallurgy."
Stainless Steel—The Miracle Metal
Carl Zapffe, metallurgical consultant, 1960

AS LATE AS the year 1910, the following statement appeared in the British journal *The Corrosion and Preservation of Iron and Steel* (Cushman and Gardner): "The tendency to rust is a characteristic inherent in the element known as iron, and will, in all probability, never be totally overcome."

As the first hundred years of what may well be called "The Stainless Steel Age" draws to a close, it seems an appropriate time to tell the story of the remarkable discoveries of stainless steels and their myriad applications.

There were quite a number of nonferrous metals that were available for use under certain corrosive conditions. They included nickel, nickel silver (the nickel-copper-tin alloy that contained no silver but resembled it somewhat), copper, brass, and bronze. There were also two new alloys, aluminum and Monel, a nickel-copper alloy discovered in 1905 that was used for roofing the new Pennsylvania Railroad Station in New York City.

The nonferrous metals served well, but they were more expensive than steel and not as strong. As a result, there was extensive use of ordinary steels with coatings to resist corrosion, coatings that often consisted of nonferrous metals such as zinc and tin, which could be applied by dipping the steel into the molten metals or by electroplating the steel with copper, brass, tin, nickel, chromium, or zinc. Painting, of course, was frequently used. Sinks were mostly made of heavy, porcelain-enameled cast iron. The life of the coated steels depended on the thickness of the applied coating, the quality of the work, and the environment in which the coated material was used. Unless the coated steel products were used indoors, the coating eventually broke down over a period of years, usually by cracking or pitting, which exposed bare steel.

In the Middle Ages, alchemists tried to turn lead into gold, but no thought had ever been given to the possibility of turning iron into a rustproof noble metal, nor were any rewards offered for such an accomplishment. Iron rusts, and that is the nature of it.

In the 19th century, at least 25 scientists, working in England, France, Germany, and the United States, were conducting experiments and writing papers about alloys of iron and varying amounts of chromium, nickel, and carbon. It was generally noticed that alloys with more chromium were somewhat more resistant to corrosion in many environments than carbon steel, but not a single person had experimented with an alloy having chromium and carbon contents similar to the alloys that would become known as stainless steels.

However, Robert A. Hadfield had created samples with up to 9.18% chromium. Because he had tested his samples in sulfuric acid, they all dissolved. He concluded that chromium decreases the corrosion resistance of steel, and he discontinued his experiments with chromium. Chromium-containing alloys that we now call stainless steel are not resistant to sulfuric acid.

Seven men, unknown to each other and living in four different countries, inadvertently discovered alloys that we now call stainless steel in the period from approximately 1905 to 1912. The discoverers thought that alloys with greater corrosion resistance must have some useful applications, but it was only a guess. There were also quite a few difficulties: The alloys were quite expensive, as compared to common steel, and quite a lot of the chromium was lost in the slag during melting. In fact, practically every step of the manufacturing process was different from ordinary steelmaking and usually more difficult. One book that was written some years after the discoveries advised that "melting should be performed with care" and that "forging was difficult," cautioning that "the billets are best cooled on the floor out of draughts." The scale needed to be removed by grinding, because pickling did not work with these alloys. However, grinding had to be performed carefully to avoid the formation of hot spots that would lead to cracking. Machining was particularly difficult.

Despite the problems mentioned, there were some notable successes in finding buyers for the alloys. After several tries, Harry Brearley eventually found a cutler in Sheffield who succeeded in making some fine knife blades out of Firth's iron-chromium alloy. There was a brief demand for the alloy in the cutlery industry, and a short announcement of the development appeared in the *New York Times*. Use of the alloy for knifemaking came to a halt with the beginning of World War I, but the Royal Air Force had found that the cutlery steel was just the ticket for making "aeroplane" exhaust valves and immediately ordered that every pound of the metal Firth could make should be shipped to the aircraft engine factories. Firth soon began selling the metal under the name Firth's Aeroplane Steel, or FAS, and the stainless steel business was indeed off to a flying start.

The Krupp Works in Germany had developed an iron-chromium-nickel alloy that was highly resistant to acids. They soon made large sales of the metal to a chemical company for building nitric acid storage tanks.

A great new industry had been launched that, within 20 years, would produce 60,000 tons of the alloys a year in America alone.

What to call the alloys was something of a problem, because each of the three original classes needed to be named. The alloy for cutlery was called, appropriately enough, cutlery steel or rustless steel. Legend has it, though, that the cutler who made the first successful knife blades of the alloy was heard to say, "It stains less." Firth then started calling it stainless steel, and the cutlers began proudly stamping their knife blades with those words.

The relatively soft iron-chromium alloy that, unlike the cutlery steel, could not be hardened by heat treatment became known as rustless iron or stainless iron.

In Germany, the Krupp Steel Works called their alloy that was remarkably resistant to most acids iron-chromium-nickel corrosion-resisting alloy or, probably more often, Krupp V2A alloy. It was the custom of each producer to give every different alloy a name, especially one that they thought customers might easily remember. Names cropped up such as Anka, Staybrite, and Vesuvius in England and Enduro S, No-Kor-O-H, and Circle L No. 19 in America.

In the 1920s, metallurgists in this business decided that the naming of these alloy classes should be on a more scientific basis, which was according to their crystal structure. When a sample of a metal is polished and etched, the crystal structure can be determined when the sample is examined with the aid of a high-powered microscope.

The crystals of the cutlery steels are recognized by their shape as what metallurgists call martensite, and the alloys in this class can all be called martensitic alloys. The crystals of the class described earlier as stainless irons are known as ferrite, and the alloys are called ferritic alloys. For the third class, which is the iron-chromium-nickel corrosion-resisting alloy, the crystals are austenite, and the alloys are called austenitic alloys. These three names—martensitic, ferritic, and austenitic—are used frequently throughout this book to identify the alloy class under discussion.

For quite a few years, only the cutlery alloys were called stainless steel, the name originally adopted by Firth. This made sense, because these were the only alloys that had similar characteristics to low-alloy steel, with the exception that they did not rust. The popular names for the other two classes became stainless iron and nonrusting chromium-nickel alloy. The committee established by the American Society for Testing Materials (ASTM) in 1929 was named Committee A-10 on Corrosion-Resistant and Heat-Resistant Alloys.

In 1933, when the first major publication in America was written about these alloys, Ernest Thum called his book *Stainless Steels* and gave his rationale for this title in the introduction:

> "Probably most attentive readers of these first few pages have sensed the difficulties which arise with respect to the classification and nomenclature of high chromium alloys. Especially is the latter badly cluttered up with trade names and loose terminology. Even though laying himself open to the charge of taking the line of least resistance, the Editor has grouped all the high chromium heat and corrosion resisting steels under the term 'stainless steel.' Few of them are really stainless, many of them are not steels in the sense that they do not harden very much during quenching. Likewise, an attempt has been made by commercial organizations in England to restrict 'stainless steels' to the cutlery types, and in America to high chromium-iron alloys. Nevertheless, common usage, which grows with a fine disregard of industrialists, scientists and even grammarians, has broadened the term to include all steely colored metals that do not tarnish readily. We might as well bow to usage!"

Thum's classic work eventually had almost everyone in the industry calling all of these high-chromium alloys stainless steels. The usage caught on worldwide, being changed only slightly in the translation. In France, for example, it is *acier inoxydable* (nonoxidizing steel), and in Germany it is *nichtrostende Stahl* (nonrusting steel).

How is stainless steel defined? Until recently, dictionaries that included a definition for stainless steel defined the term approximately as follows: "An alloy of iron containing at least four percent of chromium and having good corrosion resistance." This definition is unfortunate because it should state "at least 10.5 percent of chromium," which is the percentage at which there is a dramatic increase in the corrosion resistance. With only 4% chromium, the alloy has enough corrosion resistance for only some mildly corrosive applications in oil refining. How the dictionaries got started with the 4% chromium definition is a fairly long story that is explained in Chapter 16, "The Naming and Numbering of Stainless Steels."

This book covers a broad spectrum of historical events, many of which have not been touched upon in other works on stainless steel. It includes the discoveries of the various metallic elements that are used in the various alloys of stainless steel and discusses numerous experiments conducted during the 19th century with iron-base alloys containing chromium and carbon. The actual discoveries of stainless steel during the period from 1905 to 1912 are discussed, and the very important beginnings of commercial production in approximately 1913 are covered in greater detail.

In addition to the discovery of the alloys, the book recounts events important in the overall history of stainless steel, including the first great meeting in 1924 that was attended by virtually all of America's stainless steel producers as well as Dr. Benno Strauss, the German inventor of stainless steel. Also discussed are the important books and journals, the steelmaking processes, why stainless steel is stainless, the numbering and naming systems, the greatest promoters of stainless steel, the committees and associations, the standards and specifications, the discovery of the precipitation-hardening grades and the duplex alloys, the invention in 1970 of a melting and refining system that improved the quality and slashed the cost of stainless steel by half, the dates when many stainless steel products entered the marketplace, and some interesting stories surrounding the use of stainless steel in architecture, trains, automobiles, the aerospace industry, cookware, and tableware.

A final section, Appendix 2, "A Stainless Steel Timeline," lists 460 events of interest concerning stainless steel.

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Chapter 7: The Chrysler Building (1930)

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