The History of Stainless Steel

Harold M. Cobb
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


Inside Back Cover


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.
Contents

List of Tables and Figures ................................................................. ix
Preface .......................................................................................... xvii
Acknowledgments .......................................................................... xix
Credits ........................................................................................... xxi
About the Author .......................................................................... xxiii

CHAPTER 1 Introduction .................................................................. 1

CHAPTER 2 The Early Discoveries .................................................. 7
  The Discovery of Chromium (1797) .............................................. 8
  Michael Faraday Pioneers the Alloying of Steel (1820) .................... 8
  Iron-Chromium Alloys and the Production of
    Ferrochromium (1821) ............................................................. 10
  Woods and Clark Describe an Acid- and Weather-Resistant
    Alloy (1872) ............................................................................. 11
  Discoveries in the 1890s ............................................................. 11
  The Discovery of Martensitic and Ferritic Chromium
    Stainless Steels (1904) ............................................................. 12
  The Discovery of the Chromium-Nickel Austenitic
    Stainless Steels (1906) ............................................................. 13
  The Discovery of Corrosion Resistance (1908) ............................ 13
  Another Important Ferritic Chromium Stainless Steel
    Is Discovered (1911) ............................................................... 14

CHAPTER 3 Discoveries of the Commercial Usefulness of
  Stainless Steel ............................................................................ 17
  Usefulness of a Martensitic Chromium Stainless Steel
    Discovered in England and America (1911–1912) ................. 17
Usefulness of Ferritic Chromium Stainless Steels Discovered in America (1911–1914) ................................................................. 21
Usefulness of Chromium-Nickel Stainless Steels Discovered in Germany (1912) ........................................................................ 22
Usefulness of Chromium-Silicon Steels ............................................. 23

CHAPTER 4 The Great Stainless Steel Symposium (1924) ............ 25
Data on Stainless Steels Presented.................................................... 26
History and Patents ........................................................................ 28
An Iron-Chromium-Nickel Alloy ....................................................... 28
Continuing Role of ASTM ............................................................... 30

CHAPTER 5 The Life of Harry Brearley (1871–1948) ................. 33
The Early Years ............................................................................. 33
Brearley Becomes Manager of Firth Brown Research Laboratories .................................................................................. 40
The Firth-Brearley Stainless Steel Syndicate ..................................... 47
The American Stainless Steel Company (1918–1936) ....................... 50
Brearley’s Later Years .................................................................... 54

CHAPTER 6 The Early Books and Papers on Stainless Steel
(1917–1949) ............................................................................. 59
Paper by Dr. W.H. Hatfield (1917)................................................ 59
Paper on Stellite and Stainless Steel by Elwood Haynes (1920) ...... 60
Stainless Steel Paper by Marble (1920) .......................................... 61
Firth-Sterling Steel Company Trade Publication (1923) ................. 62
Paper on Cutlery Stainless Steel by Owen K. Parmiter (1924) ...... 66
Stainless Iron and Steel by John Henry Gill Monypenny (1926) ...... 71
The Book of Stainless Steels (1933 and 1935) ................................. 74
Stainless Steels by Carl Andrew Zapffe (1949) ............................... 87
Appendix: Text of 1920 Paper by W.H. Marble ................................ 91

CHAPTER 7 The Chrysler Building (1930) ............................... 101
The First Skyscrapers .................................................................. 103
Nirosta (18-8) Stainless Steel .......................................................... 105
The Groundbreaking and Race ....................................................... 108
Opening Ceremonies ..................................................................... 115
Van Alen’s Vision ......................................................................... 116
The Exterior .................................................................................. 117
List of Tables and Figures

Tables

Table 1 Wrought stainless steel AISI designations listed in The Book of Stainless Steels, edited by E. Thum (ASM, 1935) .......................... 86
Table 2 Cast stainless steel designations listed in The Book of Stainless Steels, edited by E. Thum (ASM, 1935) ............................. 87
Table 3 Example of the Plummer classification system for alloys with 16 to 23% chromium, 7 to 11% nickel, and 0.13 to 0.20% carbon ................................................................................................ 233
Table 4 Primary series of Unified Numbering System (UNS) numbers ................................................................................. 238
Table 5 Examples of Unified Numbering System (UNS) designations ....................................................................................... 239
Table 6 Comparable designations for type 304 stainless steel .............. 245

Captions for Numbered Figures

Fig. 1 Five discoverers. Source: Zapffe, 1949 ............................................. 9
Fig. 2 Six pioneers. Source: Zapffe, 1949................................................ 18
Fig. 3 Harry Brearley. Source: Copyright. Sheffield Industrial Museums Trust. Reprinted with permission ....................................... 19
Fig. 4 Benno Strauss, who promoted the industrial application of chromium-nickel austenitic steels that he developed with Eduard Maurer at Krupp laboratories from 1909 to 1912. Source: Thum, 1933, p 374 ........................................................................................................... 27
Fig. 5 P.A.E. Armstrong, who developed silicon-chromium steels used for gas engine exhaust valves. Source: Thum, 1933, p 486 .............................. 27

Fig. 6 Early Firth advertisement (1915). Designed by Evelyn D. Roberts, Pittsfield, New Hampshire .................................................................................... 29

Fig. 7 Text excerpts from Brearley’s 1916 patent of a stainless steel ........................................................................................................... 44

Fig. 8 Elwood Haynes, who was a pioneer American automobile maker and an inventor of a series of complex alloys from 1907 to 1913 when searching for durable spark plug alloys. Courtesy of the Elwood Haynes Museum, Kokomo, Indiana .................................................. 48

Fig. 9 Text excerpts from the 1919 stainless steel patent of Elwood Haynes ........................................................................................................... 49

Fig. 10 Stainless steel cutlery illustrated in the book *Firth-Sterling "S-Less" Stainless Steel*, published by Firth-Sterling Steel Co., McKeesport, Pennsylvania, 1923 .................................................................................... 64

Fig. 11 Surgical and dental instruments illustrated in the Firth-Sterling book, 1923 ................................................................................................. 65

Fig. 12 Golf clubs illustrated in the Firth-Sterling book, 1923 ............................................................................................................................. 66

Fig. 13 Stainless steel turbine blading illustrated in Firth-Sterling book, 1923 ........................................................................................................... 70

Fig. 14 Chart from Parmiter showing the effect of quenching (hardening) on the stain resistance (comparative efficiency in percent) of chromium cutlery steels. Source: Thum, 1935, p 288 .................. 71

Fig. 15 Prominent contributors in the early developments of stainless steels. Source: Zapfie, 1949, p 22 ........................................................................... 73

Fig. 16 Percentages of chromium and nickel required to produce an austenitic alloy. Source: B. Strauss, Non-Rusting Stainless Steels, *Proceedings of the American Society for Testing Materials*, 1924, p 208–216 ......................................................................................................... 74

Fig. 17 Ernest E. Thum, first editor of *Metal Progress* and editor of *The Book of Stainless Steels* ........................................................................... 76

Fig. 18 Table of contents from the second edition of *The Book of Stainless Steels*, American Society for Metals, 1935 ...................................................... 77

Fig. 19 Carl Zapfie, who authored *Stainless Steels* (1949) and coined the term *fractography* from his original work on the microscopic examination of fracture surfaces. 1968 photo. Courtesy of the Zapfie family ........................................................................................................... 88

Fig. 20 Effect of chromium on corrosion and oxidation resistance of
steel. (a) Iron-chromium alloys exposed for 10 years to corrosion and rusting in an industrial atmosphere. (b) Oxidation penetration of ½ inch cubes exposed to air for 48 hours at 1000 °C. Source: Zapffe, 1949, p 31, 32 ................................................................. 90

Fig. 21 Walter P. Chrysler ........................................................................ 102

Fig. 22 Latticed framework of the spire and needle of the Chrysler Building. After the lattice was raised from within the building, a scaffold was built around it, so that workers could start affixing the stainless steel panels. Reprinted with permission from David Stravitz, Ed., The Chrysler Building: Building a New York Icon a Day at a Time, Princeton Architectural Press, New York, 2002 .................. 112

Fig. 23 Stainless steel sections on the Chrysler Building. Photo taken on June 20, 1930, by the builder Fred T. Ley & Co., Inc. Reprinted with permission from David Stravitz, Ed., The Chrysler Building: Building a New York Icon a Day at a Time, Princeton Architectural Press, New York, 2002 ................................................................. 113

Fig. 24 Chrysler Building (same photo as cover). Courtesy of Catherine M. Houska, TMR Stainless, and the Nickel Development Institute ................................................................. 114

Fig. 25 Nirosta (18-8) stainless steel eagle on the 61st floor of the Chrysler Building in winter 1929–1930. Photo taken by the famous photographer Margaret Bourke-White, whose studio was just behind the eagle. Reprinted with permission from David Stravitz, Ed., The Chrysler Building: Building a New York Icon a Day at a Time, Princeton Architectural Press, New York, 2002 .................. 120

Fig. 26 Edward Gowan Budd. Courtesy of the Hagley Museum and Library ........................................................................ 124

Fig. 27 Cross section of shot weld specimens of 18-8 stainless steel with (left) inadequate fusion due to insufficient heating, (middle) correct heating and fusion, and (right) excessive heating with carbide precipitation in the heat-affected zone of the weld. Source: E.J. Ragsdale, To Weld 18-8 Minimize Time at Heat, Metal Progress, Feb. 1933, p 26 ................................................................. 128

Fig. 28 Budd Pioneer amphibian plane. Reprinted with permission of the Franklin Institute ................................................................. 132

Fig. 29 The Budd-Michelin rubber-tired train, purchased by the Reading Company, was officially named Rail Motor Car 65. Source: Thum, The Book of Stainless Steels, 1935, p 429 .................. 137
Fig. 30 The Burlington Zephyr under construction. Courtesy of the Hagley Museum and Library ............................................................. 141

Fig. 31 The Burlington Zephyr outside the factory. Courtesy of the Hagley Museum and Library ............................................................. 142

Fig. 32 Flying Yankee in Nashua, New Hampshire, March 1935. Courtesy of Brian McCarthy, President, Flying Yankee Restoration Group, Inc. ................................................................................ 149

Fig. 33 Coach cars. (a) Mark Twain Zephyr. Courtesy of the Hagley Museum and Library. (b) Flying Yankee. Courtesy of Brian McCarthy, President, Flying Yankee Restoration Group, Inc. .......... 150

Fig. 34 Observation cars. (a) Mark Twain Zephyr. Courtesy of the Hagley Museum and Library. (b) Flying Yankee. Courtesy of Brian McCarthy, President, Flying Yankee Restoration Group, Inc. .......... 152

Fig. 35 Budd RB-1 Conestoga cargo plane. Courtesy of the Hagley Museum and Library ................................................................. 159

Fig. 36 The first stainless steel aircraft built by the Budd Manufacturing Company on display in front of the Franklin Institute Museum in Philadelphia, Pennsylvania. Courtesy of Craig Clauser .................... 169

Fig. 37 The Gateway Arch. Courtesy of the Jefferson Expansion Memorial Park .................................................................................. 172

Fig. 38 Six ton Heroult-type furnace. Source: A.L. Feild, Manufacture of Stainless Iron from Ferrochromium, from Scrap, or from Ore, *Metal Progress*, Feb. 1933, p 15 ...................................................... 177

Fig. 39 Microstructure of a martensitic stainless steel (type 410; UNS number S41000). (a) Annealed. (b) Tempered after hardening .......... 186

Fig. 40 Microstructure of two ferritic stainless steels. (a) Type 409 (UNS number S40900) muffler-grade strip in annealed condition. (b) Type 430 (UNS number S43000) annealed strip........................ 187

Fig. 41 Microstructure of 304 austenitic stainless steel from three specimens of a fabricated part from welded strip. (a) Annealed location that was unaffected by processing. (b) Region with slip bands caused by roll forming. (c) Heat-affected weld zone with carbides in the grain boundaries. Source: *Atlas of Microstructures of Industrial Alloys*, Volume 7, *Metals Handbook*, 8th ed., American Society for Metals, 1972, p 135 .................................................. 188

Fig. 42 Microstructure of two duplex stainless steels. (a) Solution treated and aged 7-Mo (Fe; <0.1 C; 27.5 Cr; 1.5 Ni; 1.5 Mo). Ferrite is light
gray; sigma phase is dark; austenite is the whitest shade. (b) Type 2205 duplex wrought stainless steel (UNS number S31803). Ferrite (darker) and austenite (white). Composition is balanced to produce approximately equal amounts of ferrite and austenite at room temperature. Courtesy of Buehler Ltd. ............................................. 190

Fig. 43 Microstructure of precipitation-hardening (PH) stainless steels. (a) Martensitic PH stainless steel type 15-5 PH (UNS number S15500) in solution-treated and aged condition. (b) Semiaustenitic PH stainless steel type 17-7 PH (UNS number S17700) in solution-treated and aged condition. (c) Austenitic PH stainless steel type A286 (UNS number S66286) in annealed condition ........................ 192

Fig. 44 Stainless steel Oneida tableware circa late 1960s. Courtesy of D. Gymburch ................................................................................ 195

Fig. 45 U.S. Steel display of stainless steel kitchenware at the Century of Progress exhibition during the 1933–1934 Chicago Centennial Exposition ....................................................................... 196

Fig. 46 Milk truck with a 2700 gallon tank lined with 18-8 stainless steel. Source: Food Handling Advances, U.S. Steel, 1935 ............... 199

Fig. 47 The canopy of the Hotel Savoy. Courtesy of the Nickel Development Institute (1999, Catherine Houska) ............................ 200

Fig. 48 Arcs of the Chrysler Building. Courtesy of the Nickel Development Institute (Tim Pelling) ................................................ 201

Fig. 49 Entrance to the Chrysler Building. Courtesy of the Nickel Development Institute (1996, Catherine Houska) ............................ 202

Fig. 50 Stainless steel spandrel panels on the Empire State Building. (a) Undated photo from the 1930s. (b) 1996 (Catherine Houska) .... 203

Fig. 51 150 East 42nd Street (formerly the Socony-Mobil Building) in New York City. Courtesy of the Nickel Development Institute (1996, Catherine Houska) ................................................... 205

Fig. 52 First cleaning of the Socony-Mobil Building in 1995. Courtesy of J&L Specialty Steel ....................................................... 206

Fig. 53 Ford Tudor stainless sedan ....................................................... 225

Caption for Unnumbered Figure in Chapter 6

Chart of high-temperature scaling of steels in Marble’s 1920 paper on stainless steels ................................................................................ 96
Captions for Photographic Insert

Fig. A Latticelike exterior on the IBM Buildings in Pittsburgh, Pennsylvania (Five Gateway Center). The loaded bearing trusses are sheathed with sheets of stainless steel. Architects: Cutis and Davis, New Orleans. Source: *New Horizons in Architecture with Stainless Steel*, American Iron and Steel Institute, 1965, with permission.................................................................207

Fig. B Water tower at General Motors Technical Center, Warren, Michigan. Constructed from stainless-clad structural steel plate ($16\text{ inch}$ stainless steel on $\frac{3}{8}$ inch structural steel plate). Associated architects: Eero Saarinen; Smith, Hinchman, and Grylls. Photo: Baltazar Korab. Source: *New Horizons in Architecture with Stainless Steel*, American Iron and Steel Institute, 1965, with permission.................................................................208

Fig. C Water intake gate structures at Niagara Power Project, Niagara Falls, New York. The 100 foot high structure was sheathed with stainless steel. Source: *New Horizons in Architecture with Stainless Steel*, American Iron and Steel Institute, 1965, with permission.................................................................209

Fig. D Pittsburgh Civic Arena, Pittsburgh, Pennsylvania. When constructed, it had the world's largest dome and retractable roof. There are no interior supports. The stainless steel dome is 415 feet (126 meters) in diameter and consists of 7800 pieces of stainless steel that were joined with flat lock-and-batten seams to form eight movable leaves of the dome roof, which can be opened in two minutes. Courtesy of the Pittsburgh Civic Arena.........................210

Fig. E Elephant & Castle Substation, Newington Causeway, London. Curtain wall of type 316 stainless steel exterior wall panels with a pressed pattern. Courtesy of the Nickel Development Institute (1999, Catherine Houska)................................................................................211

Fig. F Kearns Communications Group Building, Dayton, Ohio, in 1999. Two sides of the building have type 304 stainless steel curtain walls with no windows. The other two sides are glass curtain walls and doors with solid stainless steel framing. Courtesy of Edward Madden, Kearns Communications Group.................................211

Fig. G Enfield Civic Centre, Enfield Borough, Middlesex, United Kingdom, in 1999. Stainless steel exterior cladding is type 316 with either a bright annealed or an embossed finish. Courtesy of the Nickel Development Institute (1999, Catherine Houska).............212
Fig. H Pier Pavilion, Herne Bay, Kent, United Kingdom, in 1999. This two- and three-story sports center on the end of an ocean pier has corrugated external type 316 stainless steel cladding. Courtesy of the Nickel Development Institute (1999, Catherine Houska)........................................213

Fig. I ICI Building, North York, Ontario, Canada, in 1981. Type 304 stainless steel panel for the curtain wall and four revolving door entrances.....................................................................................213

Fig. J Sun Life Centre, Toronto, Ontario, Canada, in 1999. Curtain wall is type 304 stainless steel face panels with a thickness of 0.06 inches (1.5 millimeters). Courtesy of the Nickel Development Institute (1999, Catherine Houska).................................................................214

Fig. K Michael Fowler Centre, Wellington, New Zealand, in 2000. Curved stainless steel panels cover the top and bottom of the protruding circular center of the building. There are also vertical stainless steel sunshades between the windows. Courtesy of the Nickel Development Institute (1999, Catherine Houska)..............................215

Fig. L Statue of Genghis Khan fabricated of 250 tons of stainless steel. Located 54 kilometers from Ulaanbaatar, Mongolia, this statue is 131 feet tall. .................................................................216

Fig. M Cloud Gate sculpture by Anish Kapoor in Millennium Park, Chicago, Illinois .................................................................................................................................217

Fig. N Stainless steel entrance door designed and executed by Oscar Bach. Plaques represent industries of mining, smelting, fabrication, machining, building, and transportation. Top right plaque in color represents fabrication. Source: Metal Progress, June 1936, p 36 ....218

Fig. O Dramatic façade of Federal Savings and Loan Association in Brookfield, Illinois. Exterior columns are sheathed in stainless steel, and the building is accented by stainless steel mullions. Source: New Horizons in Architecture with Stainless Steel, American Iron and Steel Institute, 1965, with permission ................................................219

Fig. P Escalator, referred to as a “new electric stairway,” uses bright stainless steel stringers, railings, and posts. Sears, Roebuck and Company store in Atlanta, Georgia. Source: New Horizons in Architecture with Stainless Steel, American Iron and Steel Institute, 1965, with permission ..........................................................220

Fig. Q Stainless steel stairwell with single stringer and cantilevered steps. Architects: Daniel Badani, Michael Folliasson, Abro Kandjian, and Pierre Roux-Dorlut. Photo: Baltazar Korab. Source: New Horizons in Architecture with Stainless Steel, American Iron and Steel Institute, 1965, with permission ..........................221
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
Acknowledgments

The author wishes to acknowledge the kind assistance of many individuals and organizations that have been most helpful over a ten-year period in compiling *The History of Stainless Steel*.

Many thanks to Harry W. Weisheit, retired, The Budd Railcar Division, for files of the Railcar Division of the E.G. Budd Manufacturing Co., now of Lansdale, Pennsylvania; R. David Thomas, deceased, former President of Arcos Corp., Philadelphia, Pennsylvania; James D. Redmond, Technical Marketing Resources, Inc., Pittsburgh, Pennsylvania; Ronald Bailey, Plate Division, Allegheny Technologies, Brackenridge, Pennsylvania; Harry E. Lunt, deceased, Burns & Roe, Mendham, New Jersey; and Hubert Langehenke, DIN VDEh, Dusseldorf, Germany.

Many thanks to Alan Harrison, Roger L. Crookes, and David Humphreys, Stainless Steel Advisory Service of the British Stainless Steel Association (BSSA), Sheffield, United Kingdom; William J. Schumacher, A-K Steel Corporation, Middletown, Ohio; Matti Paju, AvestaPolarit, Sweden; Susan Scott, Hotel Savoy, London; David Gymburch, Oneida Ltd., Oneida, New York; The Franklin Institute, Philadelphia, Pennsylvania; The Hagley Museum, Wilmington, Delaware; Valerie Parr, the Kelham Island Industrial Museum, Sheffield, United Kingdom; Louise Fairweather, Outokumpu, Sheffield, United Kingdom; Margaret Lawler, American Society for Testing and Materials International (ASTM), W. Conshohocken, Pennsylvania; and Eleanor Baldwin, ASM International, Materials Park, Ohio. My sincere appreciation also to Catherine M. Houska, TMR Stainless, Pittsburgh, Pennsylvania; Gary E. Coates, Nickel Institute, Toronto, Canada; Evelyn D. Roberts, Pittsfield, New Hampshire; and Kathleen
Moenster, Librarian, Jefferson National Expansion Park, St. Louis, Missouri.

Special thanks to Sonia S. Ralston, Kennett Square, Pennsylvania. The author is indebted to John P. Moran, retired, G.O. Carlson Co., Burlingame, California; Brian McCarthy, President of the Flying Yankee Restoration, Lincoln, New Hampshire; Karl G. Reed, retired, Aviation Division, E.G. Budd Manufacturing Company, Kennett Square, Pennsylvania; and Richard Blanchard of Kennett Square, Pennsylvania. The author thanks Steve Lampman of the ASM International staff for his guidance and for shepherding the work through to publication. And last but not least, many thanks to my wife, Joan I. Cobb, for proofreading the manuscript and for her many suggestions.

Recognition is given to Outokumpu (the successor company to British Steel Stainless), Sheffield, United Kingdom, for granting permission to reprint portions of *Harry Brearley—Stainless Pioneer*.

Harold M. Cobb
Kennett Square, Pennsylvania
October 2009
Credits

The author gratefully acknowledges the following persons and organizations that have given permission to use illustrations and other materials in The History of Stainless Steel. Acknowledgments and permissions for figures are cited in the captions.

- American Iron and Steel Institute
- American Society for Testing Materials, 1924
- Brian McCarthy, President, Flying Yankee Restoration Group, Inc.
- Catherine M. Houska, TMR Stainless
- Craig Clauser, Craig Clauser Engineering Consulting Incorporated
- D. Gymbruch
- Elwood Haynes Museum, Kokomo, Indiana
- Franklin Institute Museum, Philadelphia, Pennsylvania
- Hagley Museum and Library, Wilmington, Delaware
- J&L Specialty Steel
- Jefferson Expansion Memorial National Park
- Kearns Communications Group
- Louise Fairweather, Outokumpu-Sheffield (successor company to British Steel Stainless), in Chapter 5 for use of excerpts from Harry Brearley—Stainless Pioneer, published by British Steel Stainless, 1988
- Nickel Development Institute
- Pittsburgh Civic Arena
- Princeton Architectural Press
- Sheffield Industrial Museums Trust
- Zapffe family
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 Aerospace products 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.
ASM International is the society for materials engineers and scientists, a worldwide network dedicated to advancing industry, technology, and applications of metals and materials.

ASM International, Materials Park, Ohio, USA
www.asminternational.org

This publication is copyright © ASM International®. All rights reserved.

<table>
<thead>
<tr>
<th>Publication title</th>
<th>Product code</th>
</tr>
</thead>
<tbody>
<tr>
<td>The History of Stainless Steel (Softcover)</td>
<td>#05276G</td>
</tr>
</tbody>
</table>

To order products from ASM International:

- **Online**: Visit www.asminternational.org/bookstore
- **Telephone**: 1-800-336-5152 (US) or 1-440-338-5151 (Outside US)
- **Fax**: 1-440-338-4634
- **Mail**: Member Service Center, ASM International, 9639 Kinsman Rd, Materials Park, Ohio 44073-0002, USA
- **Email**: MemberServiceCenter@asminternational.org

**In Europe**

United Kingdom
Telephone: 01462 437933 (account holders), 01462 431525 (credit card)
www.ameritech.co.uk

**In Japan**

Neutrino Inc.
Takahashi Bldg., 44-3 Fuda 1-chome, Chofu-Shi, Tokyo 182 Japan
Telephone: 81 (0) 424 84 5550

**Terms of Use.** This publication is being made available in PDF format as a benefit to members and customers of ASM International. You may download and print a copy of this publication for your personal use only. Other use and distribution is prohibited without the express written permission of ASM International.

No warranties, express or implied, including, without limitation, warranties of merchantability or fitness for a particular purpose, are given in connection with this publication. Although this information is believed to be accurate by ASM, ASM cannot guarantee that favorable results will be obtained from the use of this publication alone. This publication is intended for use by persons having technical skill, at their sole discretion and risk. Since the conditions of product or material use are outside of ASM's control, ASM assumes no liability or obligation in connection with any use of this information. As with any material, evaluation of the material under end-use conditions prior to specification is essential. Therefore, specific testing under actual conditions is recommended.

Nothing contained in this publication shall be construed as a grant of any right of manufacture, sale, use, or reproduction, in connection with any method, process, apparatus, product, composition, or system, whether or not covered by letters patent, copyright, or trademark, and nothing contained in this publication shall be construed as a defense against any alleged infringement of letters patent, copyright, or trademark, or as a defense against liability for such infringement.