High-Temperature Property Data:

FERROUS ALLOYS

Consulting Editor M.F. Rothman

ASM INTERNATIONAL™

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Foreword

The publication of *High-Temperature Property Data: Ferrous Alloys* represents a new direction in publishing for ASM INTERNATIONAL. This volume was produced entirely on personal computers using available software. All information was captured electronically on disk so that it can be imported into searchable databases in the future.

Ten years ago, the production of a book of this magnitude and scope would have required a small army of people working full time to complete the project within an reasonable time frame. The past decade has seen the widespread use of the copy machine and the introduction of the personal computer. These advances in the work place have made this book possible.

Had this book been published ten years ago, all the artwork and tables would have been taken directly from the source material. The art would have been redrawn by a draftsman or artist, and the tables might have been retyped and marked for typesetting--two very expensive and time-consuming steps. In addition, corrections to the artwork or tables would have added to the cost and time.

The text might have been typed on an electric typewriter and subsequently edited before it was retyped. A clean copy would have been sent to the typesetter, who would have to type it into his machine one more time. And then the galleys would have been proofed against the original copy, and still more corrections would have been made.

Given this scenario, it's surprising anything got published in 1977. In fact, after looking at cost and economic viability, a publisher could well have scrapped a project of this magnitude before production started.

In contrast to the methods of the last decade, this book was produced using personal computers and a total of five available software programs--in particular, ASM's MetSel/2 and EnPlot programs. MetSel/2 is a materials selection package that records alloy information in a searchable format. EnPlot is an engineering graphics package that generates *x-y* plots. EnPlot graphs can be stored in MetSel/2 data files.

Almost no commercial typesetting was used in this volume; text, tables, and captions were printed on a laser jet printer driven by a word processing package. The figures were digitized and produced on a plotter using EnPlot.

The text was word processed in ASM's materials database program MetSel/2. Each alloy has a database file. Once the data were input, the file was saved as an ASCII text file, imported into a word processing package, and edited. This step allowed the database file for each alloy to be initiated.

Each table was input into a spreadsheet program. Using the spreadsheet, conversions were made to provide both metric and English units. Each figure was enlarged, placed on a digitizing pad, and digitized using EnPlot.

Enlarging the figure facilitated the digitizing process, thus ensuring a greater degree of accuracy.

Text and tables were imported into a technical word processing package where type sizes and faces were selected. The table titles, heads, and footnotes were input. Property abbreviations from the MetSel/2 databases were used so that the tabular information could be imported easily into the appropriate MetSel/2 database file. Figures generated from EnPlot were plotted and reduced photographically. Once the material was technically reviewed and corrected, it was keylined into pages.

In addition to speeding up production and saving on costs, it was possible to make corrections easily and inexpensively up to the last possible minute. However, the most important advantage of this new production method is that all of the information in this book has been captured on disks. This information will be integrated into MetSel/2 datadisks so that specific properties can be found easily. Building these materials properties information databases will be a priority for ASM over the next several years. Our ultimate goal is to provide all available property information for each alloy in a searchable electronic format.

Even in 1987, a project of this size needed the input of many individuals to make it successful. ASM INTERNATIONAL would like to acknowledge the contributions of the following people: Don Baxter, for his advice and guidance in the organization and first-pass editing of an endless sea of material; Terri Weintraub, Julia Talsma, and Jane McCullam of Editorial Associated Services, Inc. for undertaking the task of inputting the tables and text and digitizing the graphs; and Mike Rothman, for his able and thorough editing of each data sheet. Many thanks to all the others who assisted.

Sunniva Refsnes
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Preface

In selecting materials for high-temperature applications, it is wise to remember the old adage--"Steel will always work; it's only a question of for how long!" To determine "how long" not only steels, but stainless steels, iron-nickel-chromium alloys, or other high-temperature materials might last, some knowledge of the relative performance characteristics of these materials is required. Of obvious importance are the various high-temperature mechanical and physical properties that determine material performance in service. These are the focus of this book and of the second volume covering nonferrous alloys. Together, these volumes represent the first comprehensive comparative database of its kind.

It is the intent of this first volume to provide information that is useful in the selection of ferrous materials to be considered for high-temperature applications. It is not a detailed collection of design data, and the properties described are not suitable for direct use in final design calculations. Having said this, it should be pointed out that one of the first steps in designing components for use in elevated-temperature service is to reduce the choices of potential materials of construction to a reasonable number.

It is in this step that this book on high-temperature properties of ferrous alloys, and the companion volume on nonferrous alloys, is likely to make its most important contribution to component engineering. First, it will help users to more clearly identify which of the more well-known, traditional materials of construction are the most likely to be capable of providing the required properties for an application, as well as which should be eliminated from consideration because they are obviously inadequate. Secondly, and of key importance, this book will alert users to the capabilities of newer materials with which they may not be completely familiar. Thus, materials and design engineers can focus upon the most qualified alloys for the application in question, without searching through various diverse sources for the necessary information.

Some mention of the manner in which this valuable collection of data was assembled seems appropriate at this point. The property information presented in this volume was gathered from a variety of published sources, including previous tabulations and handbooks, as well as company brochures and data sheets. The information was carefully reviewed to ensure accurate reproduction. On the other hand, no attempt was made to verify or to critically analyze the data, or to trace the pedigree of the material from which the data were generated. Still, the information is perceived to be reasonably typical in terms of describing the relative performance capabilities of the various materials.

Although procurement of the data was a significant undertaking on the part of the ASM International staff, once in hand it was efficiently organized, edited and printed entirely through the use of personal computers; text, tables and captions were all printed on a laser jet printer driven by a word processor, whereas graphs were produced on a computer plotter. The use of typesetting in the production of this book was virtually eliminated, thus reducing the cost of its publication by half. Without this savings, this book would have been too expensive to publish at all, and you wouldn't be reading this now.

The book itself is organized into sections representing basic ferrous alloy families. These include Irons, Carbon Steels, Alloy Steels, ASTM Steels, Low-Alloy Steels, Ultrahigh Strength Steels, Tool Steels, Maraging Steels, Wrought Stainless Steels, ACI Casting Alloys, and Wrought Iron-Nickel Alloys and Iron-Nickel Superalloys. In most cases, each section has an introduction that briefly describes the nature of the compositions described, the roles of various elements in the alloys, the metallurgical characteristics of the alloy type, the typical temperature limits or range of operation, and examples of suitable applications. Following the introduction and general information for some groups, the most common alloys within an alloy group are summarized individually. Summaries include alloy name, alternative designations, relevant specifications, and typical alloy composition or composition ranges. Many descriptions also include some discussion of individual alloy characteristics and pertinent applications.

Following each individual alloy summary, physical and mechanical property data that has been located for that alloy are presented in tabular and/or graphical format. The extent of the data presented varies considerably from alloy to alloy, reflecting in the main the extent to which each alloy is used. It is expected that future editions of this book may contain expanded information on at least some of the alloys as additional data are uncovered through on-going efforts.

One area in which the data are very complete is the realm of physical properties. In most all cases, data are presented for modulus of elasticity, mean coefficient of expansion, thermal conductivity and electrical resistivity, all as a function of temperature. Tensile properties as a function of temperature are also reasonably complete for many product forms.

For many of the most common alloys, and almost all of the more sophisticated materials, data are presented detailing fatigue and creep strength properties. Considerable effort has been expended to present this data in a manner that allows for ready comparison between alloys. Care has been exercised where possible, for example, to avoid inappropriate extrapolation of minimum creep rate data to calculate total creep lives (i.e., time to 1% creep under set temperature and stress conditions), as doing so ignores the considerable impact of primary stage creep.

In examining the data embodied in this book, it will be noticed immediately that there is a singular absence of oxidation-resistance data, or environment resistance data of any kind. This is intentional. Whereas mechanical and physical property measurements more or less conform to relatively well established testing procedures, the same cannot be said for environment resistance tests at elevated temperature. Despite many attempts by the technical community to standardize such seemingly "elementary" tests as oxidation resistance, for example, the fact remains that comparison of the results from different test sources is often dangerously misleading. Rather than present an assortment of apples and oranges, it was felt that environment resistance data be best left to another time.

One final word on the future work of ASM International and its technical committee activity in the area of high-temperature materials properties. This book, and the second volume on nonferrous alloys, although of great utility as they are, in fact provide a framework upon which to build. Efforts are currently underway by the Heat Resistant Materials Committee of ASM to develop sources of input to a more carefully pedigreed database of properties relevant to high-temperature applications. As such information becomes available, these books will be updated, and made even more valuable to designers and materials engineers as definitive sources of the data required for optimum material selection and component design.

Michael F. Rothman
Consulting Editor
October, 1987

Contents

1. Irons

2. Carbon Steels

3. Alloy Steels

4. ASTM Steels