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Volume 4A
Steel Heat Treating
Fundamentals and Processes

Prepared under the direction of the
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Foreword

In this 100th anniversary year of ASM International, it is especially fitting to release *ASM Handbook*, Volume 4A, *Steel Heat Treating Fundamentals and Processes*. Since its 1913 origin as the Steel Treaters Club, formed by Detroit blacksmith William Park Woodside, ASM International has grown in scope; yet steel heat treating remains a core subject of the Society. Woodside's vision and recognition of the need to exchange information on steel heat treating are further recognized by many successful publications including the renowned *Metals Handbook*.

The *ASM Handbook* (formerly *Metals Handbook*) series is being expanded into several volumes on heat treatment. This reflects the roots of ASM International, as well as the Heat Treating Society (An Affiliate Society of ASM International) with its ongoing member contributions in the field of heat treating. ASM International and the Heat Treating Society extend a very special thanks to George E. Totten and Jon Dossett as Volume Editors. Their initiatives and contributions were instrumental in the development of this Volume. We are indebted to them and to the subject editors, authors, and reviewers for this publication.

Thomas E. Clements
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Policy on Units of Measure

By a resolution of its Board of Trustees, ASM International has adopted the practice of publishing data in both metric and customary U.S. units of measure. In preparing this Handbook, the editors have attempted to present data in metric units based primarily on Système International d'Unités (SI), with secondary mention of the corresponding values in customary U.S. units. The decision to use SI as the primary system of units was based on the aforementioned resolution of the Board of Trustees and the widespread use of metric units throughout the world.

For the most part, numerical engineering data in the text and in tables are presented in SI-based units with the customary U.S. equivalents in parentheses (text) or adjoining columns (tables). For example, pressure, stress, and strength are shown both in SI units, which are pascals (Pa) with a suitable prefix, and in customary U.S. units, which are pounds per square inch (psi). To save space, large values of psi have been converted to kips per square inch (ksi), where 1 ksi = 1000 psi. The metric tonne (kg $\times$ 10^3) has sometimes been shown in megagrams (Mg). Some strictly scientific data are presented in SI units only.

To clarify some illustrations, only one set of units is presented on artwork. References in the accompanying text to data in the illustrations are presented in both SI-based and customary U.S. units. On graphs and charts, grids corresponding to SI-based units usually appear along the left and bottom edges. Where appropriate, corresponding customary U.S. units appear along the top and right edges.

Data pertaining to a specification published by a specification-writing group may be given in only the units used in that specification or in dual units, depending on the nature of the data. For example, the typical yield strength of steel sheet made to a specification written in customary U.S. units would be presented in dual units, but the sheet thickness specified in that specification might be presented only in inches.

Data obtained according to standardized test methods for which the standard recommends a particular system of units are presented in the units of that system. Wherever feasible, equivalent units are also presented. Some statistical data may also be presented in only the original units used in the analysis.

Conversions and rounding have been done in accordance with IEEE/ASTM SI-10, with attention given to the number of significant digits in the original data. For example, an annealing temperature of 1570 °F contains three significant digits. In this case, the equivalent temperature would be given as 855 °C; the exact conversion to 854.44 °C would not be appropriate. For an invariant physical phenomenon that occurs at a precise temperature (such as the melting of pure silver), it would be appropriate to report the temperature as 961.93 °C or 1763.5 °F. In some instances (especially in tables and data compilations), temperature values in °C and °F are alternatives rather than conversions.

The policy of units of measure in this Handbook contains several exceptions to strict conformance to IEEE/ASTM SI-10; in each instance, the exception has been made in an effort to improve the clarity of the Handbook. The most notable exception is the use of g/cm^3 rather than kg/m^3 as the unit of measure for density (mass per unit volume).

SI practice requires that only one virgule (diagonal) appear in units formed by combination of several basic units. Therefore, all of the units preceding the virgule are in the numerator and all units following the virgule are in the denominator of the expression; no parentheses are required to prevent ambiguity.

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Members of the ASM Handbook Committee (2012–2013)

Chairs of the ASM Handbook Committee

Preface

The *ASM Handbook*, Volume 4A, *Steel Heat Treating Fundamentals and Processes*, represents the first of several Volumes to be published on heat treating. As indicated in the title, Volume 4A focuses on the fundamental aspects of steel heat treating and the many processes of steel heat treating. The Volume 4B, planned for future publication, will cover the heat treating and behavior of the many types of steels and cast irons.

As with the last edition of this Volume, the Volume Editors recognized that the researchers, engineers, technicians and students that will use this Volume 4A have different needs with regard to their level of understanding. Articles on the fundamentals provide in-depth background on the scientific principles associated with steel heat treatment, while articles on the various heat treating processes take a more practical approach. The Volume Editors have also tried to present a comprehensive reference that can be of use to the diverse heat treating community.

All sections of this Volume have been reviewed to be sure that they reflect the current status of the technology. Many sections have been expanded, such as the sections on fundamentals and processing methods for carburizing and nitriding of steels. Coverage on the hardenability of steels is expanded, and several new articles have been added on quenching fundamentals and processes. Updates have been done as appropriate, and efforts were taken to include charts, examples, and reference information from the substantive archives of the Society—and its predecessors—the American Society for Metals, and the American Society for Steel Treating. This Volume is especially fitting in the 100th anniversary year of ASM International.

We wish to thank our many colleagues who served as editors and authors of the individual articles. In particular, the editors also are indebted to the Heat Treating Society (An Affiliate Society of ASM International) and its members, which give the foundation for this publication and other events, conferences, and educational programs. This Volume would not have been possible without their efforts.

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