

Standard Handbook of Fastening and Joining

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To the memory of my dad

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Preface

Harnessing natural forces and constructing devices to improve the quality of life has greatly depended upon our ability to fasten and join components together to form useful things. The story of fastening technology parallels the history of civilization, with both developing in concert; each relying upon the other for advancement. Certainly the interchangeability of standardized fasteners is one of the secrets behind the phenomenal advances of Western technology.

A humorist once said that, "if the wheel was the greatest invention of antiquity, the second greatest was the axle." However, it must be pointed out that neither would have achieved much success if someone had not connected them together. It is this principal of fastening, joining, connecting, attaching, securing and locking of various independent components into useful assemblies, designed to perform specific tasks, which has been key to advancing our technology. Remember that the sum of the individual parts of a machine or system is less than the value of the total assembled mechanism.

My thirty-five plus years of compiling data on fastening and joining technology has resulted in massive files and mounds of material. In a way it is unfortunate that the handbook page limit restricts the coverage because there are areas that should be included. However, if a page barrier was not established, I fear we would never reach publication. In any event, we have endeavored to be wise in our selection of material.

This third edition has been significantly updated and expanded and has grown to twenty-five separate sections. While much of the data from previous editions remains in tact because of its time-tested value, over a quarter of the original material has been either revised or expanded. A significant sub-section has been added to Pipe Fastening entitled, Pipe Relining Technology. This recently perfected technology is the successful practice of rehabilitating existing, deteriorated pipelines by in-place relining. The Lumber and Timber section has been expanded to include typical log connections. Both Standard Pins and Locking Components sections have additional material. Five completely new sections have been added. They are: Shafts and Couplings, Seals and Packings, Self-Clinching Fasteners, Robotic Assembly and Innovative Connections. The later is included to stimulate creative fastening using standard components.

The United States has been struggling seriously with metric conversion since the early 1970s, which has produced only marginal results. However, recent legislation may accelerate its use. The 1988 Omnibus Trade and Competitiveness Act and the subsequent Executive Order by President Bush in 1991 mandated federal agencies to use metric measurement in government

contracting and procurement. As a result of these governmental requirements, the General Services Administration began requiring metrication in federal construction projects commencing on January 1, 1994. Additionally, the Federal Highway Administration set a target date of October 1, 1996 to implement the use of metrics in all federally funded highway projects which includes bridges.

The Concrete Reinforcing Steel Institute (CRSI) and the Steel Manufacturers Association (SMA) support a "soft" metric conversion, rather than a "hard" transition. Certainly the established inch-pound sizes could continue to be produced and their dimensions be converted to metric equivalents. This logical compromise would avoid confusion, eliminate the need for new tooling and not force producers and fabricators to maintain extra inventory to supply both the private and government markets.

In an effort to meet the evolving metrication because of an emerging increase of global trade and the governmental mandates, this third edition has continued to sprinkle the text with metric fastening and joining where feasible. We have continued to include a full section on metrication and conversion in this edition. However, the dominant measurement has remained in typical English units. I believe that a "total" conversion to metrics in this edition would be premature at this point in time and would serve no practical purpose.

As with previous editions, our present effort is greatly indebted to the many sources that contributed to producing this handbook. Many technical societies, manufacturing organizations, construction firms, individual engineers and technical research facilities were extremely cooperative in supplying their respective technical expertise. While these individuals and organizations are not listed in this Preface, we have continued our policy to note each source of specific material on the page where it appears throughout the handbook to insure proper credit.

Again, I want to acknowledge the clerical assistance provided by Lana and Ethne throughout the years. A special thanks to Wayne Parmley for producing a top quality book cover design for this third edition.

As long as assembly is a key factor in civilization's development, fastening and joining technology will play a major role. It has a great heritage and an unlimited future affecting all trades, skills and disciplines.

Finally, it is my desire that our original goal of providing a reliable, accurate and practical handbook of standard fastening and joining technology has continued into this latest effort. I hope this edition will serve you well.

Robert O. Parmley, P.E., CMfgE, CSI

Preface to Second Edition

As alluded to in the Preface to the first edition, a second edition of this handbook required a wider coverage of relevant material, to include some peripheral areas as well as an update on advancing fastener technology.

Well, here we are almost 15 years later with an ever expanding collection of technical material which must be culled to fit within the limited number of pages allocated to this second edition. Hopefully, we have been true to the original concept of the first edition and wisely chosen from the current data so that this present effort will be of value.

Almost half of the original text has been revised and updated. Additionally, six new sections have been included. They are: Expansion Joints, Concrete Fastening, Injected Metal Assembly, Sheet Metal Assembly, Retaining Compounds, and Rope Splicing and Tying.

Fasteners have literally held the world together throughout recorded history. The tale of fastening and joining technology parallels the history of humanity's technical advancement, both evolving in harmony and each dependent upon the other. From the ancient mechanic who first connected a wheel onto an axle to the 250,000 fasteners used on the Saturn V rocket, humanity has continued to develop this technology into a highly specialized branch of engineering. According to recognized authorities, the U.S. fastener industry produces an estimated 200 billion fasteners a year in many thousands of different styles, designs, and sizes.

In recent years, more manufacturing companies are seriously looking at the feasibility of integrating robots into their assembly process. Typical or standard assembly methods have historically been one of the areas of highest direct labor costs, in some cases, accounting for more than 50 percent of the total cost of manufacturing. Yet there has been a relatively low use of automation in this area. Products have not been adequately adapted for robotic assembly; existing assemblies generally require human dexterity, visual skills, and judgment to deal with components that an industrial robot may find difficult or sometimes impossible to handle; robotic machinery has not been typically versatile enough to be cost-effective for limited or small production runs; and robots have rarely been either speedy or sophisticated enough for precision assembly. However, I believe that robotic assembly is in its infancy and within a decade or two the previously mentioned problems

will be solved so that automation will become the major method used for manufacturing assembly. Because robotic assembly is not presently an industry norm or considered standard, we have not included any technical presentation in this edition. I predict, however, that a section on robotic assembly will be a major segment in our third edition.

As in the first edition, the reader will find ample tables, data, and standards with applicable illustrations in this expanded second effort. Each section was prepared and/or revised by well-qualified engineers with proven expertise.

The sources of technical data have been properly credited at their respective locations throughout the handbook. The fine cooperation from the many technical institutions, societies, manufacturing firms, consultants, special advisors, and contributors was a repeat of that experienced during preparation of the first edition. I personally thank them and consider each one a partner in this work.

In the same vein, I again want to thank the contributors to the first edition, especially those whose material is also included in this current edition.

Let me add a special note recognizing Wayne's illustrating contributions in various segments of the text and his original conception for the cover, nor can I forget Ethne's untiring efforts in typing portions of the manuscript and related correspondence.

One final note: Recognizing the important and growing role of women in the fields of engineering and industry, every effort has been made in this second edition to present material in gender-neutral language. However, for a few terms such as "manhole," "yoeman," and the names of some knots no generally accepted gender-neutral equivalents exist, and occasionally, to avoid the awkwardness of the "he/she" or "her/his" types of grammatical construction, the older use of the pronouns "he" and "his" to refer to people in general have been allowed to stand. In all such cases, the words should be taken in a purely generic sense, intended to apply to women as well as to men.

Robert O. Parmley, P.E., CMfgE

Preface to First Edition

Fastening and joining is defined as an act of bringing together, connecting, uniting, becoming one, or becoming a unit. Therefore, it is with this technology that *Standard Handbook of Fastening and Joining* is concerned.

From almost the dawn of time, man used his ingenuity to fasten and join components of similar or different materials. In reality, this may well have been his first technology, whether it was used in the fabrication of tools or in connection with other basic skills necessary to survival.

Archaeologists have excavated remains of old civilizations which reveal the uses of this art: statues with separate eyes glued to their sockets, iron pins used as hinge pivots, Roman ships caulked with tars, egg whites used to laminate gold leaf to wood, wooden pegs used as dowels, primitive attempts at threaded bolts, and ancient ways of forging iron.

The Renaissance advanced the technology and widened its scope of application, particularly in the mechanical areas.

With the Industrial Revolution came further-refined techniques. But it was the scientific revolution in the second quarter of this century and the development of new metals, plastics, and synthetic materials, plus the increase of world-wide trade, that created a need for standards to be established, especially in the area of mechanical fastening. The technology of fastening and joining has come of age and has taken its rightful place as a catalyst in modern engineering.

It should be mentioned that modern engineering incorporates quick disassembly features into many designs. This is done for two reasons. First, easy disassembly offers fewer maintenance problems when replacement of a component is required. Second, it assures greater value at the end of a unit's life when basic materials are separated. Reusable parts and fasteners can be recycled into the manufacturing process, thus relieving some of the strain placed on our environment and our natural resources.

This handbook was conceived in an attempt to categorize, define, and list standards and to present the latest engineering data on fastening and joining. The editor, the contributors, the consultants, and the publisher feel that an all-inclusive work on this technology is long overdue.

Fastening technology's multitude of new designs have been developed in such astronomical quantities in recent years that it is an impossible task to mention all fasteners. Therefore, we have illustrated only the "standard" fastening and joining techniques that have proven themselves.

It is hoped that this handbook will be successful enough to warrant revision and updating. At that time, a wider coverage should be considered to include peripheral areas, new designs, and updated technology.

This handbook is intended to be helpful to all engineering disciplines. Since fastening and joining is an all-encompassing term, we have designed this work to be of value to each general area of engineering. There are areas devoted specifically to mechanical, civil, electrical, structural, and manufacturing functions and to their particular fastening problems.

Each section has been prepared by a well-qualified engineer with the expertise to provide a practical presentation. Much research and editing and many long hours of rewriting went with this effort to achieve a useful and long-lasting reference for the entire engineering profession.

Throughout this handbook, the reader will find applicable tables, data, and standards as developed by various institutes, societies, and respected manufacturing firms. Our largest source for this wealth of information was The American National Standards Institute as published by The American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017. We have included extracts of these standards; copies of the complete works or standards may be obtained from the publisher at the address noted above.

The Industrial Fasteners Institute, 1505 East Ohio Bldg., 1717 E. 9th Street, Cleveland, OH 44114, has supplied our project with valuable data; their research on metric conversion has been particularly useful in the preparation of Section 16. In anticipation of the proposed national conversion, we have attempted to include in the text metric measurements where convenient. Section 16 has all the applicable conversion tables as standardized by the International Organization for Standardization (ISO).

The cooperation that I have experienced from the contributors has been fantastic. Their spirit of dedication to our project has kept our ship on course through many troubled waters. I take my hat off to these fellow engineers for a job well done.

The publishers have given me free rein in developing the outline, in selecting the contributors, and in finalizing the text. Their expert guidance throughout the project was most welcome and needed.

A special thanks to the many technical organizations, societies, and manufacturing firms who supplied much tabular data and many illustrations in their specific fields. Their contributions are noted throughout the handbook.

A list of special consultants appear elsewhere, but a particular mention should be made recognizing their yeoman work. Without their tireless effort this handbook would not have reached completion. One of these consultants, G. L. Bradshaw, Sr., not only assisted in the illustrating and preparation of artwork, but provided much encouragement by his enthusiasm for our project and his tireless performance of many peripheral duties.

A well-seasoned engineer with a well-rounded background who is willing to assist and advise a handbook editor is invaluable. George H. Morgan, P.E., performed this function. His wise counsel has strengthened the fiber of the material and ensured the practical format we originally sought.

Rupert LeGrand, Editor of *The New American Machinist's Handbook*; Robert Abbott, Editor of *Product Engineering*; and Robert Kelly, Editor of *Assembly Engineering* were all very helpful in steering me to prospective contributors and to various sources of useful technical material.

My wife deserves much credit for this handbook's completion. Her encouragement and untiring effort in typing letters, memos, and the manuscript were a constant marvel to me. I would like to express my gratitude to her for helping me make a dream come true.

Robert O. Parmley

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of Fastening
and Joining**

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