

Marks'

Standard Handbook for Mechanical Engineers

Revised by a staff of specialists

EUGENE A. AVALLONE *Editor*

Consulting Engineer; Professor of Mechanical Engineering, Emeritus
The City College of the City University of New York

THEODORE BAUMEISTER III *Editor*

Retired Consultant, Information Systems Department
E. I. du Pont de Nemours & Co.

ALI M. SADEGH *Editor*

Consulting Engineer; Professor of Mechanical Engineering
The City College of the City University of New York

Eleventh Edition



New York Chicago San Francisco Lisbon London Madrid
Mexico City Milan New Delhi San Juan Seoul
Singapore Sydney Toronto

عنوان و نام پدیدآور : Marks' standard handbook for mechanical engineers /
editors Eugene A. Avallone, Theodore Baumeister,

Ali M. Sadegh

مشخصات نشر : تهران: نوپردازان، ۱۳۸۷ = ۲۰۰۸ م.

مشخصات ظاهری : ۱۹۹۸ ص.

وضعیت فهرست نویسی : فیا

یادداشت : انگلیسی.

یادداشت : اقتست از روی ویراست یازدهم ۲۰۰۷: نیویورک

آوانویسی عنوان : مارکس استاندارد هندبوک...

موضوع : مکانیک — مهندسی — دستنامه‌ها

شناسه افزوده : مارکس، لیونل سایمون، ۱۸۷۱ م.

شناسه افزوده : Marks, Lionel Simon

شناسه افزوده : آوالون، یوجین ا، ویراستار

شناسه افزوده : Avallone, Eugene A.

شناسه افزوده : باومیستر، تئودور، ۱۸۹۷ - م. ویراستار

شناسه افزوده : Baumeister, Theodore

شناسه افزوده : صافق، علی م، ویراستار

شناسه افزوده : Sadegh, Ali M.

رده‌بندی کنگره : TJ۱۵۱/م۲ ۱۳۸۷

رده‌بندی دیویی : ۶۲۱

شماره کتابخانه ملی : ۱۵۳۶۸۵۵



نوپردازان

Marks' Standard Handbook for Mechanical Engineers (Volume: 1)

Eugene A. Avallone - Theodore Baumeister III - Ali M. Sadegh

نوپردازان

رحلی

اول

بهار ۱۳۸۸

۱۵۰۰

۱۰۵۲

۴۵۰۰۰ تومان

● کتاب

● نالیف

● ناشر

● قطع

● نویت

● تاریخ

● تیراژ

● صفحات

● قیمت دوره

مراکز پخش

کتابیران: میدان انقلاب، ابتدای خیابان آزادی، خیابان دکتر قریب، بعد از فرصت شیرازی.

پلاک ۷، تلفن: ۱۸ - ۶۶۵۶۶۵۰۹

نوپردازان: خیابان لبافی‌نژاد، بین اردیبهشت و فروردین، پلاک ۲۰۶.

تلفن: ۶۶۴۱۴۴۷۲ - ۶۶۴۱۴۵۱۵ - ۶۶۴۱۱۱۷۳ - ۶۶۴۹۳۲۰۹

Library of Congress Cataloged The First Issue
of this title as follows:

Standard handbook for mechanical engineers. 1st-ed.;
1916-

New York, McGraw-Hill.

v. Illus. 18-24 cm.

Title varies: 1916-58; Mechanical engineers' handbook.

Editors: 1916-51, L. S. Marks.—1958— T. Baumeister.

Includes bibliographies.

I. Mechanical engineering—Handbooks, manuals, etc. I. Marks,
Lionel Simeon, 1871— ed. II. Baumeister, Theodore, 1897—
ed. III. Title; Mechanical engineers' handbook.

TJ151.S82 502'.4'621 16-12915

Library of Congress Catalog Card Number: 87-641192

MARKS' STANDARD HANDBOOK FOR MECHANICAL ENGINEERS

Copyright © 2007, 1996, 1987, 1978 by The McGraw-Hill Companies, Inc.

Copyright © 1967, renewed 1995, and 1958, renewed 1986, by Theodore Baumeister III.

Copyright © 1951, renewed 1979, by Lionel P. Marks and Alison P. Marks.

Copyright © 1941, renewed 1969, and 1930, renewed 1958, by Lionel Peabody Marks.

Copyright © 1924, renewed 1952 by Lionel S. Marks.

Copyright © 1916 by Lionel S. Marks.

All rights reserved.

Printed in the United States of America. Except as permitted under the United States Copyright Act of 1976, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a data base or retrieval system, without the prior written permission of the publisher.

1 2 3 4 5 6 7 8 9 0 DOW/DOW 0 1 0 9 8 7 6

ISBN-13: 978-0-07-142867-5

ISBN-10: 0-07-142867-4

The sponsoring editor for this book was Larry S. Hager, the editing supervisor was David E. Fogarty, and the production supervisor was Richard C. Ruzycka. It was set in Times Roman by International Typesetting and Composition. The art director for the cover was Anthony Landi.

Printed and bound by RR Donnelley.

This book is printed on acid-free paper.

The editors and the publisher will be grateful to readers who notify them of any inaccuracy or important omission in this book.

Information contained in this work has been obtained by The McGraw-Hill Companies, Inc. ("McGraw-Hill") from sources believed to be reliable. However, neither McGraw-Hill nor its authors guarantee the accuracy or completeness of any information published herein, and neither McGraw-Hill nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that McGraw-Hill and its authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

Contents

For the detailed contents of any section consult the title page of that section.

<i>Contributors</i>	<i>ix</i>
<i>The Editors</i>	<i>xiii</i>
<i>Preface to the Eleventh Edition</i>	<i>xv</i>
<i>Preface to the First Edition</i>	<i>xvii</i>
<i>Symbols and Abbreviations</i>	<i>xix</i>

1. Mathematical Tables and Measuring Units	1-1
1.1 Mathematical Tables	1-1
1.2 Measuring Units	1-16
2. Mathematics	2-1
2.1 Mathematics	2-2
2.2 Computers	2-40
3. Mechanics of Solids and Fluids	3-1
3.1 Mechanics of Solids	3-2
3.2 Friction	3-20
3.3 Mechanics of Fluids	3-29
3.4 Vibration	3-61
4. Heat	4-1
4.1 Thermodynamics	4-2
4.2 Thermodynamic Properties of Substances	4-32
4.3 Radiant Heat Transfer	4-63
4.4 Transmission of Heat by Conduction and Convection	4-79
5. Strength of Materials	5-1
5.1 Mechanical Properties of Materials	5-2
5.2 Mechanics of Materials	5-14
5.3 Pipeline Flexure Stresses	5-51
5.4 Nondestructive Testing	5-57
5.5 Experimental Stress and Strain Analysis	5-63
5.6 Mechanics of Composite Materials	5-71
6. Materials of Engineering	6-1
6.1 General Properties of Materials	6-3
6.2 Iron and Steel	6-12
6.3 Iron and Steel Castings	6-34
6.4 Nonferrous Metals and Alloys; Metallic Specialties	6-46
6.5 Corrosion	6-92
6.6 Paints and Protective Coatings	6-111
6.7 Wood	6-115
6.8 Nonmetallic Materials	6-131
6.9 Cement, Mortar, and Concrete	6-162

6.10	Water	6-171
6.11	Lubricants and Lubrication	6-180
6.12	Plastics	6-189
6.13	Fiber Composite Materials	6-206
7.	Fuels and Furnaces	7-1
7.1	Fuels	7-2
7.2	Carbonization of Coal and Gas Making	7-30
7.3	Combustion Furnaces	7-43
7.4	Municipal Waste Combustion	7-48
7.5	Electric Furnaces and Ovens	7-54
8.	Machine Elements	8-1
8.1	Mechanism	8-3
8.2	Machine Elements	8-10
8.3	Gearing	8-83
8.4	Fluid-Film Bearings	8-111
8.5	Bearings with Rolling Contact	8-127
8.6	Packings, Gaskets, and Seals	8-133
8.7	Pipe, Pipe Fittings, and Valves	8-138
9.	Power Generation	9-1
9.1	Sources of Energy	9-3
9.2	Steam Boilers	9-29
9.3	Steam Engines	9-56
9.4	Steam Turbines	9-58
9.5	Power-Plant Heat Exchangers	9-78
9.6	Internal-Combustion Engines	9-93
9.7	Gas Turbines	9-127
9.8	Nuclear Power	9-138
9.9	Hydraulic Turbines	9-154
10.	Materials Handling	10-1
10.1	Materials Holding, Feeding, and Metering	10-2
10.2	Lifting, Hoisting, and Elevating	10-4
10.3	Dragging, Pulling, and Pushing	10-22
10.4	Loading, Carrying, and Excavating	10-26
10.5	Conveyor Moving and Handling	10-42
10.6	Automatic Guided Vehicles and Robots	10-63
10.7	Material Storage and Warehousing	10-69
11.	Transportation	11-1
11.1	Automotive Engineering	11-3
11.2	Railway Engineering	11-18
11.3	Marine Engineering	11-40
11.4	Aeronautics	11-58
11.5	Jet Propulsion and Aircraft Propellers	11-83
11.6	Astronautics	11-104
11.7	Pipeline Transmission	11-139
11.8	Containerization	11-149
12.	Building Construction and Equipment	12-1
12.1	Industrial Plants	12-2
12.2	Structural Design of Buildings	12-19
12.3	Reinforced Concrete Design and Construction	12-37
12.4	Air Conditioning, Heating, and Ventilating	12-49
12.5	Illumination	12-88
12.6	Sound, Noise, and Ultrasonics	12-96
13.	Manufacturing Processes	13-1
13.1	Foundry Practice and Equipment	13-3

13.2 Plastic Working of Metals	13-9
13.3 Welding and Cutting	13-29
13.4 Machining Processes and Machine Tools	13-50
13.5 Surface Texture Designation, Production, and Quality Control	13-72
13.6 Woodcutting Tools and Machines	13-77
13.7 Precision Cleaning	13-80
14. Fans, Pumps, and Compressors	14-1
14.1 Displacement Pumps	14-2
14.2 Centrifugal Pumps	14-15
14.3 Compressors	14-26
14.4 High-Vacuum Pumps	14-39
14.5 Fans	14-46
15. Electrical and Electronics Engineering	15-1
15.1 Electrical Engineering	15-2
15.2 Electronics	15-68
16. Instruments and Controls	16-1
16.1 Instruments	16-2
16.2 Automatic Controls	16-21
16.3 Surveying	16-52
17. Industrial Engineering	17-1
17.1 Operations Management	17-3
17.2 Cost Accounting	17-11
17.3 Engineering Statistics and Quality Control	17-18
17.4 Methods Engineering	17-25
17.5 Cost of Electric Power	17-31
17.6 Human Factors and Ergonomics	17-39
17.7 Automatic Manufacturing	17-43
18. The Regulatory Environment	18-1
18.1 Environmental Control	18-2
18.2 Occupational Safety and Health	18-18
18.3 Fire Protection	18-22
18.4 Patents, Trademarks, and Copyrights	18-27
19. Refrigeration, Cryogenics, and Optics	19-1
19.1 Mechanical Refrigeration	19-2
19.2 Cryogenics	19-26
19.3 Optics	19-41
20. Emerging Technologies	20-1
20.1 An Introduction to Microelectromechanical Systems (MEMS)	20-3
20.2 Introduction to Nanotechnology	20-13
20.3 Ferroelectrics/Piezoelectrics and Shape Memory Alloys	20-20
20.4 Introduction to the Finite-Element Method	20-28
20.5 Computer-Aided Design, Computer-Aided Engineering, and Variational Design	20-44
20.6 Introduction to Computational Fluid Dynamics	20-51
20.7 Experimental Fluid Dynamics	20-63
20.8 Introduction to Biomechanics	20-79
20.9 Human Injury Tolerance and Anthropometric Test Devices	20-104
20.10 Air-Inflated Fabric Structures	20-108
20.11 Robotics, Mechatronics, and Intelligent Automation	20-118
20.12 Rapid Prototyping	20-132
20.13 Miscellany	20-135

Contributors

Abraham Abramowitz* Consulting Engineer; Professor of Electrical Engineering, Emeritus, The City College of The City University of New York (ILLUMINATION)

Vincent M. Altamuro President, VMA Inc., Toms River, NJ (MATERIAL HOLDING, FEEDING, AND METSING; CONVEYOR MOVING AND HANDLING; AUTOMATED GUIDED VEHICLES AND ROBOTS; MATERIAL STORAGE AND WAREHOUSING; METHODS ENGINEERING; AUTOMATIC MANUFACTURING; INDUSTRIAL PLANTS)

Charles A. Amann Principal Engineer, KAB Engineering (AUTOMOTIVE ENGINEERING)

Farid M. Amirouche Professor of Mechanical and Industrial Engineering, University of Illinois at Chicago (INTRODUCTION TO THE FINITE-ELEMENT METHOD; COMPUTER-AIDED DESIGN; COMPUTER-AIDED ENGINEERING; AND VARIATIONAL DESIGN)

Yiannis Andreopoulos Professor of Mechanical Engineering, The City College of the City University of New York (EXPERIMENTAL FLUID MECHANICS)

William Antle* Technical Director, Maynard Research Council, Inc., Pittsburgh, PA (METHODS ENGINEERING)

Glenn E. Asauskas Lubrication Engineer, Chevron Corp. (LUBRICANTS AND LUBRICATION)

Dennis N. Assanis Professor of Mechanical Engineering, University of Michigan (INTERNAL COMBUSTION ENGINES)

Eugene A. Avallone Consulting Engineer; Professor of Mechanical Engineering, Emeritus, The City College of The City University of New York (MECHANICAL PROPERTIES OF MATERIALS; GENERAL PROPERTIES OF MATERIALS; PIPE, PIPE FITTINGS, AND VALVES; SOURCES OF ENERGY; STEAM ENGINES; MISCELLANY)

Klemens C. Baczewski Consulting Engineer (CARBONIZATION OF COAL AND GAS MAKING)

Glenn W. Baggley* Former Manager, Regenerative Systems, Bloom Engineering Co., Inc. (COMBUSTION FURNACES)

Frederick G. Bailey Consulting Engineer; Steam Turbines, General Electric Co. (STEAM TURBINES)

Robert D. Bartholomew Associate, Sheppard T. Powell Associates, LLC (CORROSION)

George F. Baumeister President, EMC Process Corp., Newport, DE (MATHEMATICAL TABLES)

John T. Baumeister Manager, Product Compliance Test Center, Unisys Corp. (MEASURING UNITS)

E. R. Behnke* Product Manager, CM Chain Division, Columbus, McKinnon Corp. (CHAINS)

John T. Benedict* Retired Standards Engineer and Consultant, Society of Automotive Engineers (AUTOMOTIVE ENGINEERING)

Bernadette M. Bennett, Esq. Associate; Carter, DeLuca, Farrell and Schmidt, LLP Melville, NY (PATENTS, TRADEMARKS, AND COPYRIGHTS)

Louis Bialy Director, Codes & Product Safety, Otis Elevator Company (ELEVATORS, OUMSWATERS, AND ESCALATORS)

Malcolm Blair Technical and Research Director, Steel Founders Society of America (IRON AND STEEL CASTINGS)

Omer W. Blodgett Senior Design Consultant, Lincoln Electric Co. (WELDING AND CUTTING)

B. Douglas Bode Engineering Supervisor, Product Customization and Vehicle Enhancement, Construction and Forestry Div., John Deere (OFF-HIGHWAY VEHICLES AND EARTHMOVING EQUIPMENT)

Donald E. Bolt* Engineering Manager, Heat Transfer Products Dept., Foster Wheeler Energy Corp. (POWER PLANT HEAT EXCHANGERS)

G. David Bounds Senior Engineer, Duke Energy Corp. (PIPELINE TRANSMISSION)

William J. Bow* Director, Retired, Heat Transfer Products Department, Foster Wheeler Energy Corp. (POWER PLANT HEAT EXCHANGERS)

James L. Bowman* Senior Engineering Consultant, Rotary-Reciprocating Compressor Division, Ingersoll-Rand Co. (COMPRESSORS)

Walter H. Boyes, Jr. Editor-in-Chief/Publisher, Control Magazine (INSTRUMENTS)

Richard L. Brazili Technology Specialist, ALCOA Technical Center, ALCOA (ALUMINUM AND ITS ALLOYS)

Frederic W. Buse* Chief Engineer, Standard Pump Division, Ingersoll-Rand Co. (DISPLACEMENT PUMPS)

Charles P. Butterfield Chief Engineer, National Wind Technology Center, National Renewable Energy Laboratory (WIND POWER)

C. L. Carlson* Late Fellow Engineer, Research Labs., Westinghouse Electric Corp. (NONFERROUS METALS AND ALLOYS; METALS AND ALLOYS FOR NUCLEAR ENERGY APPLICATIONS)

Scott W. Case Professor of Engineering Science & Mechanics, Virginia Polytechnic Institute and State University (MECHANICS OF COMPOSITE MATERIALS)

Vittorio (Rino) Castelli Senior Research Fellow, Retired, Xerox Corp.; Engineering Consultant (FRICTION; FLUID FILM BEARINGS)

Paul V. Cavallaro Senior Mechanical Research Engineer, Naval Underwater Warfare Center (AIR-INFLATED FABRIC STRUCTURES)

Eric L. Christiansen Johnson Space Center, NASA (METEOROID/ORBITAL DEBRIS SHIELDING)

Robin O. Cleveland Associate Professor of Aerospace and Mechanical Engineering, Boston University (SOUND, NOISE, AND ULTRASONICS)

Gary L. Cloud Professor, Department of Mechanical Engineering, Michigan State University (EXPERIMENTAL STRESS AND STRAIN ANALYSIS)

Ashley C. Cockerill Vice President and Event Coordinator, nanoTech Business, Inc. (ENGINEERING STATISTICS AND QUALITY CONTROL)

Timothy M. Cockerill Senior Project Manager, University of Illinois (ELECTRONICS)

Thomas J. Cockerill Advisory Engineer, International Business Machines Corp. (COMPUTERS)

Aaron Cohen Retired Center Director, Lyndon B. Johnson Space Center, NASA; Zachry Professor, Texas A&M University (ASTRONAUTICS)

Arthur Cohen Former Manager, Standards and Safety Engineering, Copper Development Assn. (COPPER AND COPPER ALLOYS)

D. E. Cole Director, Office for Study of Automotive Transportation, Transportation Research Institute, University of Michigan (INTERNAL COMBUSTION ENGINES)

James M. Connolly Section Head, Projects Department, Jacksonville Electric Authority (COST OF ELECTRIC POWER)

Alexander Couzis Professor of Chemical Engineering, The City College of the City University of New York (INTRODUCTION TO NANOTECHNOLOGY)

Terry L. Creasy Assistant Professor of Mechanical Engineering, Texas A&M University (STRUCTURAL COMPOSITES)

M. R. M. Crespo da Silva* University of Cincinnati (ATTITUDE DYNAMICS, STABILIZATION, AND CONTROL OF SPACECRAFT)

Richard A. Dahlin Vice President, Engineering, Walker Magnetics (LIFTING MAGNETS)

Benjamin C. Davenney Acoustical Consultant, Acentech Inc., Cambridge, MA (SOUND, NOISE, AND ULTRASONICS)

William H. Day President, Longview Energy Associates, LLC; formerly Founder and Board Chairman, The Gas Turbine Association (GAS TURBINES)

Benjamin B. Dayton Consulting Physicist, East Flat Rock, NC (HIGH-VACUUM PUMPS)

Horacio M. de la Fuente Senior Engineer, NASA Johnson Space Center (TRANSHAB)

Donald D. Dodge Supervisor, Retired, Product Quality and Inspection Technology, Manufacturing Development, Ford Motor Co. (NONDESTRUCTIVE TESTING)

Andrew M. Donaldson Project Director, Parsons Ed&C, Reading, PA (COST OF ELECTRIC POWER)

Joseph S. Dorson Senior Engineer, Columbus McKinnon Corp. (CHAIN)

James Drago Manager, Engineering, Garlock Sealing Technologies (PACKING, GASKETS, AND SEALS)

Michael B. Duke Chief, Solar Systems Exploration, Johnson Space Center, NASA (DYNAMIC ENVIRONMENTS)

F. J. Edeskuty Retired Associate, Los Alamos National Laboratory (CRYOGENICS)

*Contributions by authors whose names are marked with an asterisk were made for the previous edition and have been revised or rewritten by others for this edition. The stated professional position in these cases is that held by the author at the time of his or her contribution.

- O. Elan*** *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. ORBITAL MECHANICS)
- Robert E. Eppich** *Vice President, Technology, American Foundry Society* (IRON AND STEEL CASTINGS)
- C. James Erickson*** *Retired Principal Consultant, Engineering Department, E. I. du Pont de Nemours & Co.* (ELECTRICAL ENGINEERING)
- George H. Ewing*** *Retired President and Chief Executive Officer, Texas Eastern Gas Pipeline Co. and Transwestern Pipeline Co.* (PIPELINE TRANSMISSION)
- Helmir Fanner** *Chief Design Engineer, Ariel Corp.* (COMPRESSORS)
- Erich A. Farber** *Distinguished Service Professor Emeritus, Director Emeritus of Solar Energy and Energy Conversion Lab., University of Florida* [STIRLING (HOT AIR) ENGINES, SOLAR ENERGY, DIRECT ENERGY CONVERSION]
- Raymond E. Farrell, Esq.** *Partner, Carter, DeLuca, Farrell and Schmidt, LLP, Melville, NY* (PATENTS, TRADEMARKS, AND COPYRIGHTS)
- D. W. Fellenz*** *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. ATMOSPHERIC ENTRY)
- Chuck Fennell** *Program Manager, Dalton Foundries* (BOUNDARY PRACTICE AND EQUIPMENT)
- Arthur J. Flohn*** *Late Retired Vice President, Project Operations Division, Burns & Roe, Inc.* (COST OF ELECTRIC POWER)
- Sanford Fleeter** *McAllister Distinguished Professor, School of Mechanical Engineering, Purdue University* (JET PROPULSION AND AIRCRAFT PROPELLERS)
- Luc G. Fréchette** *Professor of Mechanical Engineering, Université de Sherbrooke, Canada* [AN INTRODUCTION TO MICROELECTROMECHANICAL SYSTEMS (MEMS)]
- William L. Gamble** *Professor Emeritus of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign* (CEMENT, MORTAR, AND CONCRETE. REINFORCED CONCRETE DESIGN AND CONSTRUCTION)
- Robert F. Gambon** *Power Plant Design and Development Consultant* (COST OF ELECTRIC POWER)
- Burt Garofab** *Senior Engineer, Pittston Corp.* (MINES, HOISTS, AND SKIPS. LOCOMOTIVE HOURLAGE, COAL MINES)
- Slamak Ghofranlian** *Senior Engineer, Rockwell Aerospace* (DOCKING OF TWO FREE-FLYING SPACECRAFT)
- Samuel V. Glorioso** *Section Chief, Metallic Materials, Johnson Space Center, NASA* (STRESS CORROSION CRACKING)
- Norman Goldberg** *Consulting Engineer, Economides and Goldberg* (AIR-CONDITIONING, HEATING, AND VENTILATING)
- Andrew Goldenberg** *Professor of Mechanical and Industrial Engineering, University of Toronto, Canada; President and CEO of Engineering Service Inc. (ESI) Toronto* (ROBOTICS, MECHANICS, AND INTELLIGENT AUTOMATION)
- David T. Goldman*** *Late Deputy Manager, U.S. Department of Energy, Chicago Operations Office* (MEASURING UNITS)
- Frank E. Goodwin** *Executive Vice President, ILZRO, Inc.* (BEARING METALS. LOW-MELTING-POINT METALS AND ALLOYS. ZINC AND ZINC ALLOYS)
- Don Graham** *Manager, Turning Products, Carboly, Inc.* (CEMENTED CARBIDES)
- David W. Green** *Supervisory Research General Engineer, Forest Products Lab., USDA* (WOOD)
- Leonard M. Grillo** *Principal, Grillo Engineering Co.* (MUNICIPAL WASTE COMBUSTION)
- Walter W. Guy** *Chief, Crew and Thermal Systems Division, Johnson Space Center, NASA* (SPACECRAFT LIFE SUPPORT AND THERMAL MANAGEMENT)
- Marsbed Hablian** *Retired Manager of Engineering and R&D, Varian Vacuum Technologies* (HIGH-VACUUM PUMPS)
- Christopher P. Hanson** *Structures and Mechanism Engineer, NASA Johnson Space Center* (PORTABLE HYPERBARIC CHAMBER)
- Harold V. Hawkins*** *Late Manager, Product Standards and Services, Columbus McKinnon Corp.* (DRAGGING, PULLING, AND PUSHING. PIPELINE FLEXURE STRESSES)
- Keith L. Hawthorne** *Vice President—Technology, Transportation Technology Center, Inc.* (RAILWAY ENGINEERING)
- V. Terrey Hawthorne** *Late Senior Engineer, LTK Engineering Services* (RAILWAY ENGINEERING)
- J. Edmund Hay** *U.S. Department of the Interior* (EXPLOSIVES)
- Terry L. Henshaw** *Consulting Engineer, Magnolia, TX* (DISPLACEMENT PUMPS, CENTRIFUGAL PUMPS)
- Roland Hernandez** *Research Engineer, Forest Products Lab., USDA* (WOOD)
- David T. Holmes** *Manager of Engineering, Lift-Tech International Div. of Columbus McKinnon Corp.* (MONORAILS, OVERHEAD TRAVELING CRANES)
- Hoyt C. Hottel** *Late Professor Emeritus, Massachusetts Institute of Technology* (RADIANT HEAT TRANSFER)
- Michael W. Hyer** *Professor of Engineering Science & Mechanics, Virginia Polytechnic Institute and State University* (MECHANICS OF COMPOSITE MATERIALS)
- Timothy J. Jacobs** *Research Fellow, Department of Mechanical Engineering, University of Michigan* (INTERNAL COMBUSTION ENGINES)
- Michael W. M. Jenkins** *Professor, Aerospace Design, Georgia Institute of Technology* (AERONAUTICS)
- Peter K. Johnson** *Consultant* (POWDERED METALS)
- Randolph T. Johnson** *Naval Surface Warfare Center* (ROCKET FUELS)
- Robert L. Johnston** *Branch Chief, Materials, Johnson Space Center, NASA* (METALLIC MATERIALS FOR AEROSPACE APPLICATIONS. MATERIALS FOR USE IN HIGH-PRESSURE OXYGEN SYSTEMS)
- Byron M. Jones*** *Retired Assistant Professor of Electrical Engineering, School of Engineering, University of Tennessee at Chattanooga* (ELECTRONICS)
- Scott K. Jones** *Professor, Department of Accounting & MIS, Alfred Lerner College of Business & Economics, University of Delaware* (COST ACCOUNTING)
- Robert Jorgensen** *Engineering Consultant* (FANS)
- Serope Kalpakjian** *Professor Emeritus of Mechanical and Materials Engineering, Illinois Institute of Technology* (MACHINING PROCESSES AND MACHINE TOOLS)
- Igor J. Karassik*** *Late Senior Consulting Engineer, Ingersoll Dresser Pump Co.* (CENTRIFUGAL AND AXIAL FLOW PUMPS)
- Jonathan D. Kemp** *Vibration Consultant, Acenotech, Inc., Cambridge, MA* (SOUND, NOISE, AND ULTRASONICS)
- J. Randolph Kissell** *President, The TCB Partnership* (ALUMINUM AND ITS ALLOYS)
- John B. Kitto, Jr.** *Babcock & Wilcox Co.* (STEAM BOILERS)
- Andrew C. Klein** *Professor of Nuclear Engineering, Oregon State University; Director of Training, Education and Research Partnership, Idaho National Laboratories* (NUCLEAR POWER. ENVIRONMENTAL CONTROL. OCCUPATIONAL SAFETY AND HEALTH. FIRE PROTECTION)
- Doyle Knight** *Professor of Mechanical and Aerospace Engineering, Rutgers University* (INTRODUCTION TO COMPUTATIONAL FLUID MECHANICS)
- Ronald M. Kohner** *President, Landmark Engineering Services, Ltd.* (DERICKS)
- Ezra S. Krendel** *Emeritus Professor of Operations Research and Statistics, University of Pennsylvania* (HUMAN FACTORS AND ERGONOMICS. MUSCLE GENERATED POWER)
- A. G. Kromis*** *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE)
- Srlrangam Kumaresan** *Biomechanics Institute, Santa Barbara, California* (HUMAN INJURY TOLERANCE AND ANTHROPOMETRIC TEST DEVICES)
- L. D. Kunsman*** *Late Fellow Engineer, Research Lab., Westinghouse, Electric Corp.* (NONFERROUS METALS AND ALLOYS. METALS AND ALLOYS FOR NUCLEAR ENERGY APPLICATIONS)
- Colin K. Larsen** *Vice President, Blue Giant U.S.A. Corp.* (SURFACE HANDLING)
- Stan Lebow** *Research Forest Products Technologist, Forest Products Lab., USDA* (WOOD)
- John H. Lewis** *Engineering Consultant; Formerly Engineering Staff, Pratt & Whitney Division, United Technologies Corp.; Adjunct Associate Professor, Hartford Graduate Center, Rensselaer Polytechnic Institute* (GAS TURBINES)
- Jackie Jie Li** *Professor of Mechanical Engineering, The City College of the City University of New York* (FERROELECTRICS/PIEZOELECTRICS AND SHAPE MEMORY ALLOYS)
- Peter E. Lilley** *Professor Emeritus of Mechanical Engineering, Purdue University* (THERMODYNAMICS, THERMODYNAMIC PROPERTIES OF SUBSTANCES)
- James P. Locke** *Flight Surgeon, NASA Johnson Space Center* (PORTABLE HYPERBARIC CHAMBER)
- Ernst K. H. Marburg** *Manager, Product Standards and Service, Columbus McKinnon Corp.* (LIFTING, HOISTING, AND ELEVATING. DRAGGING, PULLING, AND PUSHING. LOADING, CARRYING, AND EXCAVATING)
- Larry D. Means** *President, Means Engineering and Consulting* (WIRE ROPE)
- Leonard Malrovitch** *University Distinguished Professor Emeritus, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University* (VIBRATION)
- George W. Michalec** *Late Consulting Engineer* (GEARING)
- Duane K. Miller** *Manager, Engineering Services, Lincoln Electric Co.* (WELDING AND CUTTING)
- Patrick C. Mock** *Principal Electron Optical Scientist, Science and Engineering Associates, Inc.* (OPTICS)
- Thomas L. Moser** *Deputy Associate Administrator, Office of Space Flight, NASA Headquarters, NASA* (SPACE-VEHICLE STRUCTURES)
- George J. Moskos*** *Professor Emeritus of Computer and Information Science, New Jersey Institute of Technology* (COMPUTERS)
- Eduard Muljadi** *Senior Engineer, National Wind Technology Center, National Renewable Energy Laboratory* (WIND POWER)
- Otto Muller-Girard*** *Consulting Engineer* (INSTRUMENTS)
- James W. Murdock** *Late Consulting Engineer* (MECHANICS OF FLUIDS)
- Gregory V. Murphy** *Professor, Department of Electrical and Computer Engineering, College of Engineering, University of Alabama* (AUTOMATIC CONTROLS)
- Joseph F. Murphy** *Research General Engineer, Forest Products Lab., USDA* (WOOD)
- John Nagy** *Retired Supervisory Physical Scientist, U.S. Department of Labor, Mine Safety and Health Administration* (DUST EXPLOSIONS)
- B. W. Niebel*** *Professor Emeritus of Industrial Engineering, The Pennsylvania State University* (INDUSTRIAL ECONOMICS AND MANAGEMENT)
- James J. Noble** *Formerly Research Associate Professor of Chemical and Biological Engineering, Tufts University* (RADIANT HEAT TRANSFER)
- Charles Osborn** *Business Manager, Precision Cleaning Division, PTI Industries, Inc.* (PRECISION CLEANING)
- D. J. Patterson** *Professor of Mechanical Engineering, Emeritus, University of Michigan* (INTERNAL COMBUSTION ENGINES)
- Harold W. Paxton** *United States Steel Professor Emeritus, Carnegie Mellon University* (IRON AND STEEL)
- Richard W. Perkins** *Professor Emeritus of Mechanical, Aerospace, and Manufacturing Engineering, Syracuse University* (WOODCUTTING TOOLS AND MACHINES)
- W. R. Perry*** *University of Cincinnati* (ORBITAL MECHANICS. SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE)

- Kenneth A. Phair** Senior Project Engineer, Shaw Stone & Webster (GEOHERMAL POWER)
- Orvis E. Pigg** Section Head, Structural Analysis, Johnson Space Center, NASA (SPACE VEHICLE STRUCTURES)
- Henry O. Pohl** Chief, Propulsion and Power Division, Johnson Space Center, NASA (SPACE PROPULSION)
- Nicholas R. Rafferty** Retired Technical Associate, E. I. du Pont de Nemours & Co., Inc. (ELECTRICAL ENGINEERING)
- Rama Ramakumar** PSO/Albrecht Naeter Professor and Director, Engineering Energy Laboratory, Oklahoma State University (WIND POWER)
- Pascal M. Rapier*** Scientist III, Retired, Lawrence Berkeley Laboratory (ENVIRONMENTAL CONTROL, OCCUPATIONAL SAFETY AND HEALTH, FIRE PROTECTION)
- James D. Redmond** President, Technical Marketing Services, Inc. (STAINLESS STEELS)
- Darold E. Roen** Late Manager, Sales & Special Engineering & Government Products, John Deere (OFF-HIGHWAY VEHICLES)
- Ivan L. Ross*** International Manager, Chain Conveyor Division, ACCO (OVERHEAD CONVEYORS)
- Robert J. Ross** Supervisory Research General Engineer, Forest Products Lab., USDA (WOOD)
- J. W. Russell*** University of Cincinnati (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE, LUNAR- AND INTERPLANETARY FLIGHT MECHANICS)
- A. J. Rydzewski** Consultant, DuPont Engineering, E. I. du Pont de Nemours and Company (MECHANICAL REFRIGERATION)
- All M. Sadegh** Professor of Mechanical Engineering, The City College of The City University of New York (MECHANICS OF MATERIALS, NONMETALLIC MATERIALS, MECHANISM, MACHINE ELEMENTS, SURFACE TEXTURE DESIGNATION, PRODUCTION, AND QUALITY CONTROL, INTRODUCTION TO BIOMECHANICS, AIR-INFLATED FABRIC STRUCTURES, RAPID PROTOTYPING)
- Anthony Sances, Jr.** Biomechanics Institute, Santa Barbara, CA (HUMAN INJURY TOLERANCE AND ANTHROPOMETRIC TEST DEVICES)
- C. Edward Sandifer** Professor, Western Connecticut State University, Danbury, CT (MATHEMATICS)
- Erwin M. Saniga** Dana Johnson Professor of Information Technology and Professor of Operations Management, University of Delaware (OPERATIONS MANAGEMENT)
- Adel F. Sarofim** Presidential Professor of Chemical Engineering, University of Utah (RADIANT HEAT TRANSFER)
- Martin D. Schlesinger** Late Consultant, Wallingford Group, Ltd. (FUELS)
- John R. Schley** Manager, Technical Marketing, RMI Titanium Co. (TITANIUM AND ZIRCONIUM)
- Matthew S. Schmidt** Senior Engineer, Rockwell Aerospace (DOCKING OF TWO FREEBLY FLYING SPACECRAFT)
- William C. Schnelder** Retired Assistant Director Engineering/Senior Engineer, NASA Johnson Space Center; Visiting Professor, Texas A&M University (ASTRONAUTICS)
- James D. Shearouse, III** Late Senior Development Engineer, The Dow Chemical Co. (MAGNESIUM AND MAGNESIUM ALLOYS)
- David A. Shifler** Metallurgist, MERA Metallurgical Services (CORROSION)
- Rajiv Shrivastava** Professor of Industrial, Welding, and Systems Engineering, Ohio State University (PLASTIC WORKING OF METALS)
- James C. Simmons** Senior Vice President, Business Development, Core Furnace Systems Corp. (ELECTRIC FURNACES AND OVENS)
- William T. Simpson** Research Forest Products Technologist, Forest Products Lab., USDA (WOOD)
- Kenneth A. Smith** Edward R. Gilliland Professor of Chemical Engineering, Massachusetts Institute of Technology (TRANSMISSION OF HEAT BY CONDUCTION AND CONVECTION)
- Lawrence H. Sobel*** University of Cincinnati (VIBRATION OF STRUCTURES)
- James G. Spelght** Western Research Institute (FUELS)
- Robert D. Steele** Project Manager, Voith Siemens Hydro Power Generation, Inc. (HYDRAULIC TURBINES)
- Stephen R. Swanson** Professor of Mechanical Engineering, University of Utah (FIBER COMPOSITE MATERIALS)
- John Symonds*** Fellow Engineer, Retired, Oceanic Division, Westinghouse Electric Corp. (MECHANICAL PROPERTIES OF MATERIALS)
- Peter L. Tea, Jr.** Professor of Physics Emeritus, The City College of the City University of New York (MECHANICS OF SOLIDS)
- Anton Ten Wolde** Supervisory Research Physicist, Forest Products Lab., USDA (WOOD)
- W. David Teter** Retired Professor of Civil Engineering, University of Delaware (SURVEYING)
- Michael C. Tracy** Rear Admiral, U.S. Navy (MARINE ENGINEERING)
- John H. Tundermann** Former Vice President, Research and Technology, INCO Int., Inc. (METALS AND ALLOYS FOR USE AT ELEVATED TEMPERATURES, NICKEL AND NICKEL ALLOYS)
- Charles O. Velzy** Consultant (MUNICIPAL WASTE COMBUSTION)
- Harry C. Verakis** Supervisory Physical Scientist, U.S. Department of Labor, Mine Safety and Health Administration (DUST EXPLOSIONS)
- Arnold S. Vernick** Former Associate, Geraghty & Miller, Inc. (WATER)
- Robert J. Vondrasek*** Assistant Vice President of Engineering, National Fire Protection Assoc. (COST OF ELECTRIC POWER)
- Michael W. Washo** Senior Engineer, Retired, Eastman Kodak Co. (BEARINGS WITH ROLLING CONTACT)
- Larry F. Wieserman** Senior Technical Supervisor, ALCOA (ALUMINUM AND ITS ALLOYS)
- Robert H. White** Supervisory Wood Scientist, Forest Products Lab., USDA (WOOD)
- John W. Wood, Jr.** Manager, Technical Services, Garlock Klotz Corp. (PACKING, GASKETS, AND SEALS)