

- EXAMINES THE DIFFERENT TYPES OF BATTERIES AND THEIR CAPABILITIES
- COVERS SCIENCE, APPLICATIONS, RELIABILITY, AND SAFETY
- EXPLORES NEW AND FUTURE TECHNOLOGIES, INCLUDING LITHIUM ION AND NANOTECHNOLOGY



THE **TAB**™



BATTERY BOOK

AN IN-DEPTH
GUIDE TO
CONSTRUCTION,
DESIGN, AND
USE

MICHAEL ROOT

Foreword by Dr. Ralph J. Brodd

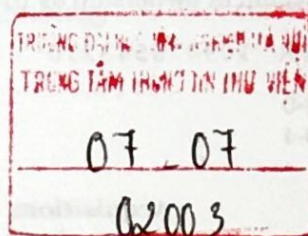


Contents at a Glance

The TABTM Battery Book

An In-Depth Guide to Construction, Design, and Use

Michael Root



**Mc
Graw
Hill**

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

McGraw-Hill books are available at special quantity discounts to use as premiums and sales promotions, or for use in corporate training programs. To contact a representative, please e-mail us at bulksales@mcgraw-hill.com.

The TAB™ Battery Book: An In-Depth Guide to Construction, Design, and Use

Copyright © 2011 by The McGraw-Hill Companies. All rights reserved. Printed in the United States of America. Except as permitted under the 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 database or retrieval system, without the prior written permission of publisher.

Trademarks: McGraw-Hill, the McGraw-Hill Publishing logo, TAB™, and related trade dress are trademarks or registered trademarks of The McGraw-Hill Companies and/or its affiliates in the United States and other countries and may not be used without written permission. All other trademarks are the property of their respective owners. The McGraw-Hill Companies is not associated with any product or vendor mentioned in this book.

All trademarks or copyrights mentioned herein are the possession of their respective owners and McGraw-Hill makes no claim of ownership by the mention of products that contain these marks.

1234567890 QFR QFR 109876543210

ISBN 978-0-07-173990-0

MHID 0-07-173990-4

Sponsoring Editor

Roger Stewart

Editorial Supervisor

Patty Mon

Project Manager

Shruti Vasishta,
Glyph International

Acquisitions Coordinator

Joya Anthony

Copy Editor

Bob Campbell

Proofreader

Carol Shields

Indexer

Jack Lewis

Production Supervisor

Jean Bodeaux

Composition

Glyph International

Illustration

Glyph International

Art Director, Cover

Jeff Weeks

Information has been obtained by McGraw-Hill from sources believed to be reliable. However, because of the possibility of human or mechanical error by our sources, McGraw-Hill, or others, McGraw-Hill does not guarantee the accuracy, adequacy, or completeness of any information and is not responsible for any errors or omissions or the results obtained from the use of such information.

Contents at a Glance

Part I	Battery Basics	
1	Why We Need Batteries	3
2	The Many Uses of Batteries	7
3	The History of Batteries	13
4	Basic Physics and Chemistry	35
5	The Science of Batteries	49
6	Battery Engineering Designs	71
7	Battery Performance	83
8	Battery Reliability and Safety	105
Part II	Battery Technologies	
9	Primary Batteries	123
10	Rechargeable or Secondary Batteries	157
11	Charging Rechargeable Batteries	183
12	Selecting the Right Battery	195
13	The Future of Battery Technology	207
A	Battery Resources	219
	Glossary	227
	Index	235

Contents

Foreword	xi
Introduction	xiii

Part I Battery Basics

CHAPTER 1 Why We Need Batteries	3
Getting Unplugged: Portable Energy and Long-Term Energy Storage	3
Chemical Energy Storage Compared	5
CHAPTER 2 The Many Uses of Batteries	7
Portable Consumer Devices	7
Medical Devices	8
Electric Vehicles	9
Large-Scale Electrical Energy Storage	9
Space	10
Military	10
CHAPTER 3 The History of Batteries	13
Electrostatic Energy	14
Electrochemical Energy	16
Improvements in Battery Technology	19
Engineering Improvements to Volta's Battery	19
Further Improvements to Volta's Battery	22
Oxidizing Cathode Materials	23
Continued Development of New Active Electrode Materials	26
Primary Batteries	26
Solid Cathode Materials	26
The Dry Cell	28
Alkaline Batteries	29
Lithium Batteries	31
Secondary Batteries	31
Battery Time Lines	34

CHAPTER 4 Basic Physics and Chemistry	35
Writing Large and Small Numbers	36
Units	37
Electrons	38
Atoms	39
Matter, Substances, and Their Properties	42
Molecules and Bonding	44
Ions	44
Chemical Reactions	45
Energy	47
CHAPTER 5 The Science of Batteries	49
Battery or Cell	50
The Basic Cell	50
Battery Electrochemistry: Thermodynamics	52
The Electrochemical Cell	53
Energy from Electrochemistry	56
Potentials of Electrochemical Reactions: Standard Conditions	58
Potentials of Electrochemical Reactions: Nonstandard Conditions	64
Battery Electrochemistry: Kinetics	66
Capacity	68
CHAPTER 6 Battery Engineering Designs	71
Battery Shapes and Sizes	72
Battery Components	74
Electrode Design	76
Seal Design	79
Vent Design	79
Other Safety Features	79
Batteries	80
CHAPTER 7 Battery Performance	83
Terms and Units	83
Potential or Voltage	83
Current	85
Resistance	85
Capacity	87
Power	91
Energy	91
Practical Battery Performance	92
Other Battery Performance Behaviors	99
Discharge Voltage	99
Self-Discharge	101
Measuring Battery Performance	102

CHAPTER 8 Battery Reliability and Safety	105
Reliability	105
Measuring Variability	106
Assessing Reliability	110
Accelerated Testing	116
Safety	118

Part II Battery Technologies

CHAPTER 9 Primary Batteries	123
Batteries with Aqueous Electrolytes	124
Leclanché Zinc-Carbon and Zinc-Chloride	126
Alkaline Zinc-Manganese Dioxide	129
Zinc-Air	131
Zinc-Silver Oxide	135
Zinc-Mercuric Oxide	138
Reserve Batteries	140
Batteries with Nonaqueous Electrolytes	141
Lithium-Thionyl Chloride, Lithium-Sulfuryl Chloride and Lithium-Sulfur Dioxide	143
Lithium-Manganese Dioxide	146
Lithium-Carbon Monofluoride	146
Lithium-Iron Disulfide	150
Lithium-Iodine	150
Lithium-Silver Vanadium Oxide	152
Lithium-Copper Oxide	155
CHAPTER 10 Rechargeable or Secondary Batteries	157
Batteries with Aqueous Electrolytes	159
Lead Acid	161
Nickel-Cadmium	166
Nickel-Metal Hydride	170
Alkaline Zinc-Manganese Dioxide	173
Batteries with Nonaqueous Electrolytes	174
Lithium Ion	175
Lithium Metal	179
Comparing Rechargeable Batteries	182
CHAPTER 11 Charging Rechargeable Batteries	183
Safe Charging	184
The Charging Process	185
Charging Considerations	186
Charge Rate	187
Charging Methods	188

x Contents

Constant Potential or Constant Voltage Charging	188
Constant Current Charging	190
Constant Current-Constant Potential Or Voltage Charging	191
Other Charging Modes	191
Battery Monitoring and Charge Termination	193
CHAPTER 12 Selecting the Right Battery	195
Battery Standards	195
Battery Identification Codes	197
Battery Chemistry Codes	197
Battery Shape Codes	197
Battery Size Codes	197
Manufacturer Data Sheets	203
Putting It All Together	205
CHAPTER 13 The Future of Battery Technology	207
Small Batteries	207
Thin-Film Batteries	209
Nanotechnology	209
Large Energy Storage Batteries	213
Flow Batteries	213
High-Temperature Batteries	215
High-Energy Density Batteries	216
Going Forward	217
APPENDIX Battery Resources	219
Standards Organizations	219
Governmental Agencies and Nongovernmental Organizations	220
Industry Organizations	222
Scientific and Technical Societies	225
GLOSSARY	227
Index	235

Foreword

The TAB Battery Book enables the reader to understand in simple layperson terms the complex operations that occur inside a battery in order to generate electrical power on demand. The author offers simple, easily understandable explanations of the complex chemical processes that occur inside a battery. The book is written to provide the typical reader with a working relationship with the batteries he or she uses in everyday life.

The author starts at the very beginning with fundamental descriptions of the Volta pile and continues with the Leclanché 1.5-volt primary battery for flashlights and early portable radios. He goes on to describe the rechargeable lead acid 2.0-volt battery that is now common to most automobile operations. Today, new high-energy systems find wide application, especially the lithium-ion battery with the very high energy density needed to power mobile phones and portable computers, and readers will find that these systems are well covered.

Batteries are capable of very efficient direct energy conversion and can deliver about 95 percent of the contained energy to useful work, compared to an internal combustion car engine, which converts in the range of 25 percent of the energy stored in gasoline to useful energy in propelling the car. An electrical generation plant that converts coal to electricity operates at about 40 percent efficiency.

Batteries are an integral component of our daily lives, whether in mobile phones, portable computers, starting your car engine, or powering the satellite that brings radio communication signals down to earth. The various battery systems are discussed and explained in language that everyone can easily understand.

The reader should find this book to be a valuable resource.

Ralph J. Brodd
President of Broddarp of Nevada, Inc.