IEEE STANDARDS ASSOCIATION

IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications

IEEE Power & Energy Society

Sponsored by the
Stationary Batteries Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

25 February 2011

IEEE Std 450™-2010
(Revision of
IEEE Std 450-2002)

IEEE Std 450™-2010
(Revision of
IEEE Std 450-2002)

IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications

Sponsor

Stationary Batteries Committee
of the
IEEE Power & Energy Society

Approved 9 December 2010

IEEE-SA Standards Board

Abstract: Maintenance, test schedules, and testing procedures that can be used to optimize the life and performance of permanently installed, vented lead-acid storage batteries used for standby service are provided. This recommended practice also provides guidance to determine when batteries should be replaced. This recommended practice is applicable to standby service stationary applications where a charger maintains the battery fully charged and supplies the dc loads.
Keywords: acceptance test, battery capacity, battery installation, battery maintenance, battery replacement criteria, battery service test, battery terminal voltage, connection resistance measurements, electrolyte level, equalize charge, float voltage, IEEE 450, modified performance test, performance test, service test, specific gravity, standby power applications, state of charge, test-discharge rate, vented lead-acid battery

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

PDF: ISBN 978-0-7381-6521-9 STD97063
Print: ISBN 978-0-7381-6522-6 STDPD97063

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied "**AS IS**."

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation, or every ten years for stabilization. When a document is more than five years old and has not been reaffirmed, or more than ten years old and has not been stabilized, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon his or her independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal interpretation of the IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Recommendations to change the status of a stabilized standard should include a rationale as to why a revision or withdrawal is required. Comments and recommendations on standards, and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Introduction

This introduction is not part of IEEE Std 450-2010, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.

Stationary lead-acid batteries play an ever-increasing role in industry today by providing normal control and instrumentation power and back-up energy for emergencies. This recommended practice fulfills the need within the industry to provide common or standard practices for battery maintenance, testing, and replacement. The installations considered herein are designed for standby service with a battery charger serving to maintain the battery in a charged condition as well as to supply power to the normal dc loads. However, specific applications, such as emergency lighting units and semi-portable equipment, may have other appropriate practices that are beyond the scope of this recommended practice.

This recommended practice may be used separately, and, when combined with IEEE Std 484™, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications and IEEE Std 485™, IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications, will provide the user with a general guide to sizing, designing, placing in service, maintaining, and testing a vented lead-acid storage battery installation. IEEE Std 535 provides a standard for qualification of Class 1E lead storage batteries for nuclear power generating stations.

Notice to users

Laws and regulations

Users of these documents should consult all applicable laws and regulations. Compliance with the provisions of this standard does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

Updating of IEEE documents

Users of IEEE standards should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Standards Association web site at http://ieeexplore.ieee.org/xpl/standards.jsp, or contact the IEEE at the address listed previously.

For more information about the IEEE Standards Association or the IEEE standards development process, visit the IEEE-SA web site at http://standards.ieee.org.

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: http://standards.ieee.org/reading/ieee/updates/errata/index.html. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: http://standards.ieee.org/reading/ieee/interp/index.html.

Patents

Attention is called to the possibility that implementation of this recommended practice may require use of subject matter covered by patent rights. By publication of this recommended practice, no position is taken with respect to the existence or validity of any patent rights in connection therewith. A patent holder or patent applicant has filed a statement of assurance that it will grant licenses under these rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses. Other Essential Patent Claims may exist for which a statement of assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this recommended practice are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this recommended practice was submitted to the IEEE-SA Standards Board for approval, the Vented Lead Acid Maintenance and Testing Working Group had the following membership:

M. S. (Steve) Clark, *Chair*
José Marrero, *Vice Chair*
Thomas Carpenter, *Secretary*

Phyllis Archer
Curtis Ashton
Robert Beavers
William Cantor
Leonard Casella
Terry Chapman
Thomas Croda
Peter Demar
Robert Fletcher
Kyle Floyd
John Gagge, Jr.
Wayne Johnson
Michael Jump
Jeffrey LaMarca
Daniel Lambert
Stephen McCluer
Matthew McConnell
Russell Miller
Tania Martinez Navedo
Michael Nispel
Howard Nudi
Rudy Ortega
John Polenz
Edward Rafter
Jan Reber
Christopher Searles
Joseph Stevens
H. F. Taylor
Richard Tressler
Kurt Uhlir
Lesley Varga
Allan Williamson

The following members of the individual balloting committee voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

William J. Ackerman
Michael Adams
S. Aggarwal
Samuel Aguirre
Steven Alexanderson
Edward Amato
Phyllis Archer
Stan Arnot
Curtis Ashton
Ali Al Awazi
Adam Bagby
Gary Balash
Farouk Baxter
Robert Beavers
Steven Bezner
Richard Bolgeo
Mark Bowman
Steven Brockschink
William Cantor
Thomas Carpenter
Larry Carlson
Jay Chamberlin
Suresh Channarasappa
Terry Chapman
Charles Chilton
John Coyle
Peter Demar
Gary Donner
Randall Dotson
Neal Dowling
Donald Dunn
Gary Engmann
Charles Finin
John Gagge, Jr.
James Gleason
James Graham
Randall Groves
Paul Anthonius Cornelis Hectors
Scott Hietpas
Werner Hoelzl
Gary Houston
David Horvath
James Houston
David Ittner
Randy Jamison
James Jones
Gael Kennedy
James Kinney
David Krause
Jim Kulchisky
Thomas Ladson
Chung-Yiu Lam
Daniel Lambert
Thomas La Rose
Daniel Levin
Debra Longtin
Thomas Lundquist
Greg Luri
Stephen McCluer
James McDowall
Peter McNutt
John Merando
T. David Mills
Daleep Mohla
Kimberly Mosley
Haissam Nasrat
Dennis Neitzel
Arthur Neubauer
Michael S. Newman
Gary Nissen
Howard Nudi
James Parello
Bansi Patel
Anthony Picagli
Percy Pool
Harold Priestley
Edward Rafter
Robert Rallo
Jan Reber
Michael Roberts
Charles Rogers
Bartien Sayogo
Robert Seitz
Gil Shultz
David Smith
Joseph Stevens
Gary Stoedter
S. Thamilarasan
Wayne Timm
Richard Tressler
Michael Tucker
Joe Uchiyama
Eric Udren
Lesley Varga
John Vergis
Kenneth White
Allan Williamson
Ahmed Zobaa

When the IEEE-SA Standards Board approved this recommended practice on 9 December 2010, it had the following membership:

Robert M. Grow, *Chair*
Richard H. Hulett, *Vice Chair*
Steve M. Mills, *Past Chair*
Judith Gorman, *Secretary*

Karen Bartleson
Victor Berman
Ted Burse
Clint Chaplin
Andy Drozd
Alexander Gelman
Jim Hughes
Young Kyun Kim
Joseph L. Koepfinger*
John Kulick
David J. Law
Hung Ling
Oleg Logvinov
Ted Olsen
Ronald C. Petersen
Thomas Prevost
Jon Walter Rosdahl
Sam Sciacca
Mike Seavey
Curtis Siller
Don Wright

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Julie Alessi
IEEE Standards Program Manager, Document Development

Soo H. Kim
IEEE Standards Program Manager, Technical Program Development

Contents

1. Overview 1
1.1 Scope 1
1.2 Purpose 2
1.3 Exclusions 2
1.4 Document Organization 2

2. Normative references 2

3. Definitions, acronyms, and abbreviations 3
3.1 Definitions 3
3.2 Abbreviations 4

4. Safety 4
4.1 Protective equipment 4
4.2 Precautions 5
4.3 Methods 5

5. Maintenance 5
5.1 General 5
5.2 Inspections 6
5.3 Corrective actions 7
5.4 State of charge 9

6. Test schedule 10
6.1 General 10
6.2 Acceptance 10
6.3 Performance 11
6.4 Service 11
6.5 Modified performance test 11

7. Procedure for battery tests 12
7.1 General 12
7.2 Initial conditions 13
7.3 Test length and discharge rate 13
7.4 Capacity test methods 14
7.5 Acceptance, modified performance, and performance tests 17
7.6 Service test 18
7.7 Restoration 19

8. Battery replacement criteria 19

9. Records 19

10. Trending 20

11. Recycling and disposal 20
11.1 General 20
11.2 Recycling 20
11.3 Disposal 20

12. Spill containment and management methodologies 21

Annex A (informative) State of charge 22
A.1 Battery discharge/charge cycle parameters 22
A.2 Stabilized charging current used to determine a fully charged condition 22
A.3 Electrolyte specific gravity used to determine a fully charged condition 23
A.4 Float current, specific gravity and float voltage 23

Annex B (normative) Specific gravity 25
B.1 Effect of charging 25
B.2 Effect of temperature 25
B.3 Effect of electrolyte level 25
B.4 Effect of water additions 25

Annex C (informative) Float voltage 26
C.1 Introduction 26
C.2 Battery float voltage 26
C.3 Individual cell float voltage 26
C.4 Effect of temperature 27

Annex D (informative) Urgency of corrective actions 28
D.1 Adding water 28
D.2 Connection resistance 28
D.3 Cell temperature 29
D.4 Equalizing charge 29
D.5 Cell/battery failure and replacement 29

Annex E (informative) Visual inspection of battery installations 31

Annex F (informative) 33
F.1 Examples of methods for performing connection resistance measurements 33
F.2 Recommended method for performing connection resistance measurements using a micro-ohmmeter 33
F.3 Recommended method for single intercell connections and parallel-post connections 34
F.4 Recommended method for double-post intercell connections 35
F.5 Recommended method for triple-post intercell connections 35
F.6 Recommended method for flag-post intercell connections 36
F.7 Recommended method for single connections 37
F.8 Recommended method for multiple terminal connections 38
F.9 Recommended method for cable-plate-post connections 39

Annex G (informative) Alternate applications 41

Annex H (informative) Effects of elevated electrolyte temperatures on vented lead-acid batteries 42

Annex I (normative) Modified performance testing methods and examples 44
I.1 Objectives 44
I.2 Rules for modified performance tests 44
I.3 Type 1 modified performance test 44
I.4 Type 2 modified performance test 45
I.5 Type 3 modified performance test 47

Annex J (informative) Alternate inspection methods 49
J.1 Introduction 49
J.2 Comparison of measurement technologies 49
J.3 Limitations 49
J.4 Precautions or discussion 50

J.5 Interpretation 50
J.6 Theory 51

Annex K (informative) Calculation of battery capacity 53
K.1 Comparison of time- and rate-adjusted performance test methods 53
K.2 Capacity calculation examples 54

Annex L (informative) Temperature-correction factors 57

Annex M (informative) Bibliography 59

IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications

1. Overview

1.1 Scope

This document provides recommended maintenance, test schedules, and testing procedures that can be used to optimize the life and performance of permanently-installed, vented lead-acid storage batteries used in standby service. It also provides guidance to determine when batteries should be replaced. This recommended practice is applicable to standby service stationary applications where a battery charger normally maintains the battery fully charged and provides the dc loads.

The maintenance and testing programs described in this recommended practice represent "the best program" based on the information available at the time this document was developed. The user should evaluate these practices against their operating experience, operating conditions, manufacturer's recommendations, resources, and needs in developing a maintenance program for a given application. These maintenance and testing recommendations were developed without consideration of economics, availability of testing equipment and personnel, or relative importance of the application. Development of a maintenance and testing program for a specific application requires consideration of all issues, not just the technical issues considered in this document.