

UL 913

ISBN 0-7629-0129-2

Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations

ULNORM.COM : Click to view the full PDF of UL 913 1997

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

UL Standard for Safety
for

Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations, UL 913

Fifth Edition, Dated February 21, 1997

The requirements were originally published as the Fourth edition of this UL Standard. This edition also contains pages dated February 24, 1997 that were originally issued as revision pages to the fourth edition. These pages are not part of the ANSI approved text.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

UL's Standards for Safety are copyrighted by UL. Neither a printed copy of a Standard, nor the distribution diskette for a Standard-on-Diskette and the file for the Standard on the distribution diskette should be altered in any way. All of UL's Standards and all copyrights, ownerships, and rights regarding those Standards shall remain the sole and exclusive property of UL.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form by any means, electronic, mechanical photocopying, recording, or otherwise without prior permission of UL.

Revisions of UL Standards for Safety are issued from time to time. A UL Standard for Safety is current only if it incorporates the most recently adopted revisions.

UL provides this Standard "as is" without warranty of any kind, either expressed or implied, including but not limited to, the implied warranties of merchantability or fitness for any purpose.

In no event will UL be liable for any special, incidental, consequential, indirect or similar damages, including loss of profits, lost savings, loss of data, or any other damages arising out of the use of or the inability to use this Standard, even if UL or an authorized UL representative has been advised of the possibility of such damage. In no event shall UL's liability for any damage ever exceed the price paid for this Standard, regardless of the form of the claim.

UL will attempt to answer support requests concerning WordPerfect, Envoy, and Standards-on-Diskette. However, this support service is offered on a reasonable efforts basis only, and UL may not be able to resolve every support request. UL supports a Standards-on-Diskette only if it is used under the conditions and operating systems for which it is intended. UL's support policies may change from time-to-time without notification.

UL reserves the right to change the format, presentation, file types and formats, delivery methods and formats, and the like of both its printed and electronic Standards without prior notice.

Standards-on-Diskette purchasers agree to defend, indemnify, and hold UL harmless from and against any loss, expense, liability, damage, claim, or judgement (including reasonable attorney's fees) resulting from any error or deviation introduced while purchaser is storing a Standard-on-Diskette on the purchaser's computer system.

If a single-user version Standards-on-Diskette was purchased, one copy of this Standard may be stored on the hard disk of a single personal computer, or on a single LAN file-server or the permanent storage device of a multiple-user computer in such a manner that this Standard may only be accessed by one user at a time and for which there is no possibility of multiple concurrent access. The original distribution diskette should be stored in a safe place.

If a multiple-user version Standards-on-Diskette was purchased, one copy of the Standard may be stored on a single LAN file-server, or on the permanent storage device of a multiple-user computer. The number of concurrent users shall not exceed the number of users authorized for the Standards-on-Diskette version. The original distribution diskette should be stored in a safe place.

Standards-on-Diskette are intended for on-line use, such as for viewing the requirements of a Standard, conducting a word search, and the like. Only one copy of the Standard may be printed from each single-user version of a Standards-on-Diskette. Only one copy of the Standard may be printed for each authorized user of a multiple-user version of a Standards-on-Diskette. An employee of an organization purchasing a Standard-on-Diskette can make a copy of the page or pages being viewed for their own fair and/or practical internal use. Because of differences in the computer/software/printer setup used by UL and those of Standards-on-Diskette purchasers, the printed copy obtained by a purchaser may not look exactly like the on-line screen view or the printed Standard.

The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing or Classification and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

Copyright 1997 Underwriters Laboratories Inc.

This Standard consists of pages dated as shown in the following checklist:

Page	Date
tr1 - tr4	February 21, 1997
1	February 21, 1997
2, 3	February 24, 1997
4	February 21, 1997
5, 6	February 24, 1997
7 - 8	February 21, 1997
9 - 12	February 24, 1997
13 - 31	February 21, 1997
32 - 35	February 24, 1997
36 - 39	February 21, 1997
40, 41	February 24, 1997
42 - 62, A1 - A10, B1, B2	February 21, 1997

ULNORM.COM : Click to view the full PDF of UL 913-1997

No Text on This Page

ULNORM.COM : Click to view the full PDF of UL 913 1997

FEBRUARY 21, 1997



1

UL 913

Standard for

**Intrinsically Safe Apparatus and Associated Apparatus for Use in
Class I, II, III, Division 1, Hazardous (Classified) Locations**

The First edition was titled Standard for Intrinsically Safe Electrical Equipment for Use in Hazardous Locations. The Second edition was titled Standard for Intrinsically Safe Electrical Circuits and Apparatus for Use in Hazardous Locations and its Associated Apparatus.

First Edition – November, 1971
Second Edition – January, 1976
Third Edition – July, 1979
Fourth Edition – July, 1988

Fifth Edition

February 21, 1997

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated February 21, 1997. These pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Approved as ANSI/UL/NFPA 4913-1979, November 5, 1979
Approved as ANSI/UL 913-1988, May 20, 1988

Figures 18.1 – 18.4 and 18.8 are from British Approvals Service for Electrical Equipment in Flammable Atmospheres Certification Standard SFA 3012:1972 – Intrinsic Safety. Permission to use this Crown Copyright Material is gratefully acknowledged. Figures 18.5 and 18.6 are from "Some Aspects of the Design of Intrinsically Safe Circuits," Research Report 256 by D. W. Wiggenton, Safety in Mines Research Establishment, Sheffield, England, 1968.

Revisions of this standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

ISBN 0-7629-0129-2

COPYRIGHT © 1976, 1997 UNDERWRITERS LABORATORIES INC.

CONTENTS**FOREWORD****INTRODUCTION**

1 Scope	5
2 Purpose	5
3 Applicability of Other Standards	6
4 Definitions	6
5 Class I, Zone, and Group Equivalency	9
6 Control Drawing	9
7 Evaluation of Intrinsic Safety	9

CONSTRUCTION REQUIREMENTS

8 Creepage and Clearance Distances	15
9 Encapsulation	18
10 Field Wiring Connections	18
11 Internal Wiring Conductors	20
12 Protective Components	20
13 Miscellaneous Components	25
14 Portable Apparatus Enclosures	26
15 Cells and Batteries	27
16 Maximum Temperature	29

MARKING

17 General	31
------------	----

COMPARISON PROCEDURE FOR DETERMINING SPARK IGNITION CAPABILITY

18 General	34
19 Maximum voltage and current levels	43

APPARATUS FOR CLASS II AND CLASS III LOCATIONS

20 Applicability of Other Requirements in this Standard	44
21 Specific Requirements for Intrinsic Safety	44
22 Dust-Tight Enclosures	45

TEST PROCEDURES

23 Protective Transformers Tests	46
24 Current-Limiting Resistor	48
25 Shunt Diode Protective Barrier Tests	48
26 Optical Isolator Tests	49
27 Temperature Tests	50
28 Small Component Ignition Test	52
29 Dielectric Tests	52
30 Mechanical Tests	54
31 Drop Test	54
32 Dust-Tight Enclosure Test	54

33	Dust Blanketing Temperature Test	54
34	Lamp Breakage Test	55
35	Encapsulation Tests	56
36	Internal Capacitance or Inductance Test	56
37	Spark Ignition Test	57
38	Verification of Spark Test Apparatus	60

APPENDIXES

APPENDIX A

Additional Information	A1
------------------------------	----

APPENDIX B

Referenced Publications	B1
-------------------------------	----

ULNORM.COM : Click to view the full PDF of UL 913 1997

FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

NOTICE: The asterisk following the subsection number signifies that explanatory material on that paragraph appears in Appendix A.

1 Scope

1.1 This standard applies to:

- a) Apparatus or parts of apparatus in Class I, II, or III, Division 1 locations^a;
- b) Those parts of apparatus located outside of the Class I, II, or III, Division 1 location having a design and construction that may influence the intrinsic safety of an electrical circuit within the Class I, II, or III, Division 1 location;
- c) Apparatus or parts of apparatus in Class I, Zone 0 or 1, Groups IIA, IIB, and IIC locations;
- d) Those parts of apparatus located outside of the Class I, Zone 0 and 1, Groups IIA, IIB, or IIC location having a design and construction that may influence the intrinsic safety of an electrical circuit within the Class I, Zone 0 and 1, Group IIA, IIB, or IIC location.

^a Section 500-3(a) of ANSI/NFPA 70-1987, National Electrical Code, states that equipment that has been approved for a Division 1 location shall be permitted in a Division 2 location of the same class and group.

1.2* These requirements are based on consideration of ignition in locations made hazardous by the presence of flammable or combustible material under normal atmospheric conditions.

1.3 For the purposes of this standard, normal atmospheric conditions are considered to be:

- a) An ambient temperature of 40°C (104°F);
- b) An oxygen concentration not greater than 21 percent; and
- c) A pressure of one atmosphere.

1.4 This standard does not cover mechanisms of ignition from external sources, such as static electricity or lightning, which are not related to the electrical characteristics of the apparatus. This standard does not cover apparatus based on high voltage electrostatic principles, such as electrostatic paint spraying apparatus.

2 Purpose

2.1 The purpose of this standard is to provide requirements for the construction and testing of electrical apparatus, or parts of such apparatus, having circuits that are not capable of causing ignition in Division 1 hazardous locations as defined in Article 500 of the National Electrical Code, ANSI/NFPA 70-1987.

2.2 This standard is not to be considered an instruction manual for untrained persons. It is intended to promote uniformity of practice among those skilled in the field of intrinsic safety.

3 Applicability of Other Standards

3.1 Except where modified by the requirements of this standard, intrinsically safe and associated apparatus shall comply with the applicable requirements for ordinary locations.^a

^a As an example of requirements for ordinary locations, see ANSI C39.5, Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation, available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

3.2 Associated apparatus and circuits shall conform to the requirements of the location in which the apparatus and circuits are installed.^a

^a For guidance on installation, see ANSI/ISA RP12.6, Installation of Intrinsically Safe Systems for Class I Hazardous (Classified) Locations, available from the Instrument Society of America, 67 Alexander Drive, Research Triangle Park, North Carolina, 27709.

4 Definitions

4.1 Associated Apparatus - Apparatus in which the circuits are not necessarily intrinsically safe themselves, but which affect the energy in the intrinsically safe circuits and are relied upon to maintain intrinsic safety. Associated electrical apparatus may be either:

- a) Electrical apparatus that has an alternative type of protection for use in the appropriate potentially flammable atmosphere; or
- b) Electrical apparatus not so protected that shall not be used within a potentially flammable atmosphere.

4.2 Control Drawing – A drawing or other document provided by the manufacturer of the intrinsically safe or associated apparatus that details the allowed interconnections between the intrinsically safe and associated apparatus.

4.3* Entity Evaluation – A method used to determine acceptable combinations of intrinsically safe apparatus and connected associated apparatus that have not been investigated in such combinations.

4.4 External Inductance-to-Resistance Ratio – The ratio of inductance to resistance of the intrinsically safe circuit connected to the associated apparatus.

4.5 Fault – A defect or electrical breakdown of any component, spacing, or insulation that alone or in combination with other faults may adversely affect the electrical or thermal characteristics of the intrinsically safe circuit. If a defect or breakdown leads to defects or breakdowns in other components, the primary and subsequent defects and breakdowns are considered to be a single fault.

4.6 Internal Inductance-to-Resistance Ratio – The ratio of inductance to resistance of the intrinsically safe apparatus.

4.7 Internal Wiring – Wiring and electrical connections that are made within the apparatus by the manufacturer. Within racks or panels, interconnections between separate pieces of apparatus made in accordance with detailed instructions from the apparatus' manufacturer are considered to be internal wiring.

4.8 Intrinsically Safe Apparatus – Apparatus in which all the circuits are intrinsically safe.

4.9 Intrinsically Safe Circuit – A circuit in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable, under the test conditions prescribed in this standard, of causing ignition of a mixture of flammable or combustible material in air in the mixture's most easily ignitable concentration.

4.10 Linear Output Associated Apparatus – Associated apparatus in which the output current is limited by a resistor such that the output voltage-current plot is a straight line drawn between open circuit voltage and short-circuit current.

4.11 Maximum Allowed Capacitance – The maximum value of capacitance that may be connected to the intrinsically safe circuit of the associated apparatus.

4.12 Maximum Allowed Inductance – The maximum value of inductance that may be connected to the intrinsically safe circuit of the associated apparatus.

4.13 Maximum Input Current – The maximum dc or peak ac current that can be safely applied to the terminals of the intrinsically safe apparatus. The maximum input current may be different for different terminals.

4.14 Maximum Input Voltage – The maximum dc or peak ac voltage that can be safely applied to the terminals of an intrinsically safe apparatus. The maximum input voltage may be different for different terminals.

4.15 Maximum Internal Capacitance – The total equivalent internal capacitance of the intrinsically safe apparatus that must be considered as appearing across the terminals of the intrinsically safe apparatus.

4.16 Maximum Internal Inductance – The total equivalent internal inductance of the intrinsically safe apparatus that must be considered as appearing across the terminals of the intrinsically safe apparatus.

4.17 Maximum Nonhazardous Location Voltage – The maximum voltage that may be applied to each of the nonintrinsically safe terminals of associated apparatus without affecting intrinsic safety.

4.18 Maximum Output Current – The maximum dc or peak ac current that may be extracted from the intrinsically safe connections of the associated apparatus.

ULNORM.COM : Click to view the full PDF of UL 913 1997

4.19 Maximum Output Voltage – The maximum dc or peak ac open circuit voltage that can appear at the intrinsically safe connections of the associated apparatus.

4.20 Normal Operation – Intrinsically safe apparatus or associated apparatus conforming electrically and mechanically with its design specification.

4.21 Protective Component or Assembly – A component or assembly that is so unlikely to become defective in a manner that will lower the intrinsic safety of the circuit that it may be considered not subject to fault when analysis or tests for intrinsic safety are conducted.

4.22 Shunt Diode Barrier – A fuse- or resistor-protected diode barrier.

4.23 Fuse-Protected Shunt Diode Barrier – A network designed to limit current and voltage that consists of a series fuse, voltage-limiting shunt diodes, and a current-limiting resistor or other current-limiting components. The fuse is intended to protect the diodes from open-circuiting when high fault currents flow.

4.24 Resistor-Protected Shunt Diode Barrier – A network identical to a fuse-protected shunt diode barrier, except that the fuse is replaced by a resistor.

5 Class I, Zone, and Group Equivalency

5.1 Class I, zone 0 and 1, group IIA

5.1.1 Apparatus or parts of apparatus intended to be marked in accordance with 17.4 shall comply with all the requirements for apparatus for use in Class I, Group D locations.

5.2 Class I, zone 0 and 1, group IIB

5.2.1 Apparatus or parts of apparatus intended to be marked in accordance with 17.3 shall comply with all the requirements for apparatus for use in Class I, Group C locations.

5.3 Class I, zone 0 and 1, group IIC

5.3.1 Apparatus or parts of apparatus intended to be marked in accordance with 17.2 shall comply with all the requirements for apparatus for use in both Class I, Group A and Class I, Group B locations.

6 Control Drawing

6.1 A control drawing shall be provided for all intrinsically safe apparatus or associated apparatus that requires interconnection to other circuits or apparatus.

6.2 An intrinsically safe system could consist of apparatus investigated as a system or apparatus investigated under the entity concept. If the intrinsically safe and associated apparatus are investigated as a system, the control drawing shall provide information for proper connection and installation. If the intrinsically safe or associated apparatus is investigated under the entity concept, the control drawing shall include applicable electrical parameters to permit selection of apparatus for interconnection.

7 Evaluation of Intrinsic Safety

7.1 Fundamental requirements

7.1.1 Intrinsically safe apparatus and circuits shall comply with the two basic requirements specified in 7.1.2 and 7.1.3.

7.1.2 The energy available in the hazardous location shall not be capable of igniting the flammable mixture specified in 37.3.1 through 37.3.5 due to arcing or hot surfaces during normal operation.

7.1.3 For evaluation purposes, normal operation is to include all of the following:

- a) Supply voltage at maximum rated value;
- b) Environmental conditions within the ratings given for the intrinsically safe apparatus or associated apparatus;

ULNORM.COM : Click to view the full PDF of UL 913 1997

- c) Tolerances of all components in the combination that represents the most unfavorable condition;
- d) Adjustments at the most unfavorable settings;
- e) Opening of any one of the field wires, shorting of any two field wires, or grounding of any one of the field wires of the intrinsically safe circuit being evaluated.

7.1.4* For test purposes, normal operation is to include an additional test factor of 1.5 applied to energy. This factor is to be achieved according to the procedures outlined in 38.3.1 through 38.3.5.

7.1.5 The energy available in the hazardous location shall not be capable of igniting the flammable mixture specified in 37.3.1 through 37.3.5 due to arcing or hot surfaces under fault conditions. Before faults are introduced, the apparatus is to be in normal operation as specified in 7.1.3.

7.1.6 Fault conditions are to include the following:

- a) The most unfavorable single fault and any subsequent related defects and breakdowns, with an additional test factor of 1.5 applied to energy;
- b) The most unfavorable combination of two faults and any subsequent related defects and breakdowns, with no additional test factor. Such test factors are to be achieved according to the procedures outlined in 38.3.1 through 38.3.5.

7.1.7 Apparatus in which no fault or only one fault can occur shall be considered acceptable if it complies with:

- a) The test requirements for normal operation as described in 7.1.3 with an additional test factor of 1.5 applied to energy,
- b) The test requirements for any fault that can occur with an additional test factor of 1.5 applied to energy, and
- c) The requirements of this standard.

7.1.8 All intrinsically safe and associated apparatus and circuits shall comply with the requirements in Sections 8 – 17.

7.2 Evaluation procedure

7.2.1 Circuits are to be evaluated for intrinsic safety as specified in 7.2.3 through 7.2.5.

7.2.2* The circuits are to be analyzed to determine circuit parameters under the normal and fault conditions specified in 7.1.1 through 7.1.8. For intrinsically safe apparatus, each possible ignition point where circuit interruption, short circuit, or ground fault may occur is to be considered.

7.2.3 Construction details and temperatures are to be reviewed for compliance with Sections 8 and 16. The apparatus shall comply with the applicable test procedures of Section 23 – 36.

7.2.4 The possibility of arc ignition under normal and fault conditions is to be determined by either of the following two procedures:

- a) Testing the circuit according to the test requirements of Section 37; or
- b) Comparing the calculated or measured values of current, voltage, and associated inductances and capacitances to the appropriate figures in Section 18 to establish that the current and voltage levels are below the specified values in 19.1 and 19.2.

7.2.5 In evaluating circuits for intrinsic safety, ignition sources such as the following are to be considered:

- a) Sources of spark ignition:
 - 1) Discharge of a capacitive circuit;
 - 2) Interruption of an inductive circuit;
 - 3) Intermittent making and breaking of a resistive circuit;
 - 4) Hot wire fusing.
- b) Sources of thermal ignition:
 - 1) Heating of small gage wire strand;
 - 2) Glowing of a filament;
 - 3) High surface temperature of components.

7.3* Entity evaluation

7.3.1 The requirements in 7.4.1 through 7.7.4 are intended for entity evaluations. These requirements may also be used for system evaluations. Only associated apparatus with linear outputs having each output referenced to ground are presently considered in Sections 7.4 through 7.7.4.

7.4* Associated apparatus evaluation

7.4.1 Associated apparatus is to be evaluated to determine that the output is intrinsically safe. Associated apparatus shall comply with 7.1.1 through 7.2.5.

7.4.2 The maximum output voltage is to be the highest output voltage from the following:

- a) No faults and the most unfavorable normal operating condition.
- b) The most unfavorable one fault condition.
- c) The most unfavorable two fault condition.

7.4.3 The maximum output current is to be the highest short-circuit current obtainable under the conditions specified in 7.4.2.

7.4.4 The maximum allowed capacitance is determined by test or by comparison and is the lower value obtained from the following:

- a) The maximum capacitance that does not cause ignition at 1.22 times the maximum output voltage if this voltage was determined with less than two faults.
- b) The maximum capacitance that does not cause ignition at the maximum output voltage if this voltage was determined with two faults.

7.4.5 The maximum allowed inductance is determined by test or by comparison and is the lower value obtained from the following:

- a) The maximum inductance that does not cause ignition at 1.22 times the maximum output current if this current was determined with less than two faults.
- b) The maximum inductance that does not cause ignition at the maximum output current if this current was determined with two faults.

7.5* Intrinsically safe apparatus inductance and capacitance determination

7.5.1 The intrinsically safe apparatus maximum internal capacitance or inductance is to be determined considering both normal and fault conditions by one of the following methods:

- a) Inspection or analytical computation; or
- b) Confirmation of the value by testing in accordance with 36.1 through 36.6, if the apparatus manufacturer declares a maximum internal capacitance or maximum internal inductance value; or
- c) Derivation of the value of maximum internal capacitance or maximum internal inductance using the procedure specified in 36.1 through 36.6.

7.6* Intrinsically safe and associated apparatus control drawing

7.6.1 The control drawing shall specify the allowed associated apparatus that may be connected to each terminal on the intrinsically safe apparatus by a set or sets of maximum voltage and maximum current. The control drawing shall explain which associated apparatus normally provides power.

7.6.2 A countable fault is imposed for evaluations based upon the specified maximum voltage and current ratings. A maximum of one fault is counted even if all associated apparatus common to the loop are considered to be at their maximum voltages and currents.

ULNORM.COM : Click to view the full PDF of UL 913 1997

7.6.3 The shorting of any two associated apparatus outputs or the grounding of any one associated apparatus output shall not be a countable fault. The shorting of each additional associated apparatus output is a countable fault.

7.6.4 If two associated apparatus outputs are shorted and then the connection is grounded, the grounding is a countable fault.

7.6.5 The shorting and grounding specified in 7.6.4 shall not be considered if the associated apparatus are connected to separate circuits and the control drawing specifies cables in which shorting is not expected to occur. (Reference ISA RP12.6)

7.6.6 The shorting and grounding specified in 7.6.4 shall not be a countable fault if connection is considered because of inadequate spacing within the intrinsically safe apparatus.

7.6.7 The shorting and grounding specified in 7.6.4 shall not be a countable fault if connection can be considered through internal resistance within the intrinsically safe apparatus. The evaluation will be done using the most unfavorable internal resistance.

7.6.8* The control drawing shall contain notes to explain the following if applicable:

- a) The polarity requirements for associated apparatus.
- b) That associated apparatus must not be connected in parallel unless this is permitted by the associated apparatus approval.
- c) How to calculate the allowed capacitance and inductance values for field wiring used in the intrinsically safe circuit.

7.7 Intrinsically safe apparatus evaluation

7.7.1 Intrinsically safe apparatus is to be evaluated for the possibility of arc ignition or hot surface ignition using 7.1.1 through 7.2.5. The associated apparatus connected to each terminal is determined from the control drawing. The number of faults counted when connecting various allowed combinations of the associated apparatus is described in 7.6.1 through 7.6.8.

7.7.2 The determination of temperature rise of a component in an entity evaluation is to be made using a power source having parameters that are within the stated entity parameters at a voltage and current that is on the relevant ignition curve and that results in maximum power transfer.

7.7.3 Capacitive discharge evaluation of the intrinsically safe apparatus is done using the highest specified maximum output voltage from any set of parameters adjusted by the test factor described in 2.1.2.1, considering current drawn from the source during discharge.

7.7.4 Inductive discharge evaluation of the intrinsically safe apparatus is to be done using an equivalent power source that has parameters within the stated entity parameters at a voltage and current that lie on the relevant ignition curve. The source is to be chosen that causes maximum current flow in the inductor. The current is adjusted using the test factor described in 7.1.6.

CONSTRUCTION REQUIREMENTS

8* Creepage and Clearance Distances

8.1 Creepage and clearance distances between uninsulated conductive parts shall be considered not subject to fault if, taking into consideration likely movement of components, they comply with the values given in Table 8.1, except as noted in 8.2 through 8.9.

Table 8.1
Clearances, creepage distances, and distances
through casting compound and insulations^{a,b}

1. Nominal Voltage ^c	10	30	60	90	190	375	550	750	1000	1300	1575	3.3Kv	4.7Kv	9.5Kv	15.6Kv
2. Creepage Distance															
mm	1.5	2	3	4	8	10	15	18	25	36	40	67	90	160	240
(in.)	0.059	0.079	0.118	0.157	0.315	0.394	0.591	0.709	0.984	1.42	1.58	2.64	3.54	6.30	9.45
3. Creepage Distance Under Coating															
mm	0.5	0.7	1	1.3	2.6	3.3	5	6	8.3	12	13.3	23	30	53	80
(in.)	0.020	0.028	0.039	0.051	0.102	0.130	0.197	0.236	0.327	0.472	0.524	0.906	1.18	2.09	3.15
4. Minimum Comparative Tracking Index	90	90	90	90	175	175	175	175	175	175	300	—	—	—	—
5. Clearance															
mm	1.5	2	3	4	5	6	7	8	10	14	16	27	36	60	100
(in.)	0.059	0.079	0.118	0.157	0.197	0.236	0.276	0.315	0.394	0.551	0.630	0.06	1.42	2.36	3.94
6. Distance Through Casting Compound															
mm	0.5	0.7	1	1.3	1.7	2	2.4	2.7	3.3	4.6	5.3	9	12	20	33
(in.)	0.020	0.028	0.039	0.051	0.067	0.079	0.094	0.181	0.221	0.308	0.355	0.602	0.803	1.34	2.21
7. Distance Through Solid Insulation															
mm	0.5	0.5	0.5	0.7	0.8	1	1.2	1.4	1.7	2.3	2.7	4.5	6	10	16.5
(in.)	0.020	0.020	0.020	0.028	0.031	0.039	0.047	0.055	0.067	0.091	0.106	0.177	0.236	0.394	0.650
^a Creepage distance is to be assessed on the basis of the maximum continuing nominal rms voltage. Clearance is to be assessed on the basis of the maximum normal peak voltage.															
^b For circuits 1500V or greater and with high power capability the danger due to power arcing in the circuit is to be taken into account.															
^c The value of the voltage is the normal rms voltage for assessing creepage distance and nominal peak voltage for assessing clearance distance, tolerance not considered. The voltages are to be the sum of the normal operating voltages of the circuits being considered, except if the normal operating voltage of one circuit is less than 20 percent of the voltage of the other circuit, the voltage is to be the greater.															
^d See Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials, ASTM D3638-85.															

8.2 Clearances, creepage distances, and distances through casting compound and insulations that are at least one third of the relevant values but less than the relevant values specified in Table 8.1 are to be considered connected if connection results in the most severe condition. Each such connection is to be counted as a fault subject to the requirements in 7.2.1 through 7.2.5.

8.3 If the separation between two conductors is less than one third of that specified in Table 8.1, the conductors are to be considered connected if connection results in the most severe condition.

8.4* If more than two conductors are involved and the spacing between adjacent conductors is less than one third the applicable value in Table 8.1, the sum of the individual spacings is to be added until the total spacing equals or exceeds one third the applicable value. Only that number of conductors is to be considered connected. A single fault is to be counted. Within a total dimension equal to the applicable table value, only one such group of conductors is to be considered connected.

8.5* The requirements in 8.1 also apply where breakdown between intrinsically safe circuits could increase the energy in the circuit so that it is no longer intrinsically safe.

8.6 The requirements in 8.2 do not apply where grounded metal (e.g., printed wiring or a partition) separates an intrinsically safe circuit from other circuits and other parts of the same circuit, provided breakdown to ground does not adversely affect intrinsic safety and the grounded conductor can carry the maximum current which would flow under fault conditions.

8.7 A grounded metal partition shall have strength and rigidity so that it is unlikely to be damaged and shall be of sufficient thickness and shall have current-carrying capacity to prevent burn-through or loss of ground under fault conditions. A partition at least 0.25 mm (0.01 in.)^a thick, attached to a rigid, grounded metal portion of the apparatus and complying with the test requirements in 30.1 is presumed to comply with the requirements of this subsection.

^a The 0.25 mm (0.01 in.) minimum thickness complies from the standpoint of current-carrying capacity

8.8 The clearance between two terminals for connection of field wiring of different intrinsically safe circuits shall be at least 6 millimeters (1/4 in.) unless no hazard results from connection.

8.9 Printed wiring boards shall comply with the creepage distances specified in Table 8.1. The creepage distances under coating apply to printed wiring boards that are protected by an adherent insulating coating that is:

- a) At least two layers thick of materials (such as solder resist and varnish, or two coats of varnish) that have a minimum dielectric voltage rating of 200 volts per 0.025 mm (0.001 in.) of thickness; or
- b) A single layer not less than 0.7 mm (0.028 in.) thick; or
- c) A single layer, and the printed wiring board complies with the dielectric voltage-withstand test in 29.3.

9* Encapsulation

9.1 If encapsulation is used to separate conductors and components of an intrinsically safe circuit from nonintrinsically safe circuits, other intrinsically safe circuits; other parts of the same circuit; or grounded metal, the encapsulant shall:

- a) Comply with the Distance Through Casting Compound values in line 6 of Table 8.1.
- b) Be adherent to any emerging conductors or components, including printed wiring board substrates,
- c) Have sufficient rigidity to comply with the test requirements specified in 35.1.1 through 35.3.1 if the encapsulated enclosure is intended for use without additional enclosure, such as a partition device.
- e) Have a temperature rating at least equal to the maximum temperature of any encapsulated component or conductor achieved under fault conditions after encapsulation, and
- f) Have the comparative tracking index as required in Table 8.1 if any uninsulated conductors or components exit the encapsulant.

9.2 If encapsulation is used to reduce the risk of ignition of a potentially flammable atmosphere by the following types of components, then the minimum thickness of the encapsulant between such components and the free surface shall be one half of the Distance Through Casting Compound values in line 6 of Table 8.1, but no less than 1 mm.

- a) Piezoelectric devices and their connection to any suppression devices.
- b) Energy storage devices and their suppression components where breakage of the connection could occur.

9.3 If the surface of the encapsulant is in contact with an enclosure of electrical insulating material, then the thickness requirement need not be applied.

9.4 If encapsulation is used to reduce surface temperatures, the volume of encapsulant and its minimum thickness over the hot component or conductor shall be at least that necessary to reduce the encapsulant surface temperature to the desired level. The rated operating temperature of the encapsulant shall be at least equal to the hottest surface that it contacts.

9.5 The free surface of the encapsulant shall comply with the test requirements in 35.1.1. If the encapsulant is not protected from shock by another enclosure or partition it shall comply with 35.2.1.

9.6 The encapsulant is to be identified by generic name, specific type designation, and maximum temperature rating for reporting purposes.

10 Field Wiring Connections

10.1 Terminals for intrinsically safe circuits shall be adequately separated from terminals for nonintrinsically safe circuits by one or more of the methods described in 10.2 through 10.8.

10.2 Separation may be accomplished by distance. The distance between adjacent terminals shall be at least 50 mm (2 in.). Care shall be exercised in the layout of terminals so as to reduce the risk of unintended contact between different circuits if a field wire becomes dislodged.^a

^a Additional precautions, such as wiring tie downs or special wiring methods, may be necessary to provide adequate separation. This is especially true when terminals are arranged one above the other. In such cases, spacing alone will not usually provide adequate separation.

10.3 Separation may be accomplished by locating intrinsically safe and nonintrinsically safe terminals in separate enclosures or by use of either an insulating partition or a grounded metal partition between terminals.

ULNORM.COM : Click to view the full PDF of UL 913 1997

10.4 Separate enclosures or partitions within common enclosures shall be arranged to prevent wiring of an intrinsically safe circuit from contacting the wiring of a nonintrinsically safe circuit, taking into consideration stowage of excess wire in each compartment.

10.5 Partitions used to separate terminals shall extend to within 1.5 mm (0.06 in.) of enclosure walls to provide adequate separation.

10.6 Metal partitions shall be grounded and shall possess sufficient strength and rigidity that they are not likely to be damaged during field wiring. (See 8.7)

10.7 Nonmetallic insulating partitions shall possess sufficient thickness and shall be so supported that they cannot be readily deformed to defeat their purpose. See 30.1.

10.8 If plugs and receptacles are used for external connections, the plugs and receptacles used to connect intrinsically safe circuits shall be noninterchangeable with other plugs and receptacles.

Exception: This requirement does not apply to circuits other than branch circuits, if interchange does not affect intrinsic safety, or to plugs and receptacles that are identified so that interchange is unlikely.

11 Internal Wiring Conductors

11.1 Internal wiring conductors that are not rigidly supported so as to maintain the spacings specified in Table 8.1 shall be insulated according to 11.2 and 11.3, and separated according to 11.4.

11.2 Where breakdown may adversely affect intrinsic safety of the same or separate intrinsically safe circuits, each circuit shall be wired with insulated conductors having a grade of insulation capable of withstanding an ac test voltage of 500 volts rms or twice the normal working voltage of the intrinsically safe circuit, whichever is the greater.

Exception: A dc test voltage may be used as described in 29.1 (a).

11.3 Nonintrinsically safe circuits in the same enclosure with intrinsically safe circuits shall be wired with insulated conductors having a grade of insulation capable of withstanding an ac test voltage of $2U + 1000$ volts, with a minimum of 1500 volts rms, where U is the sum of the rms values of the voltages of the intrinsically safe circuit and the nonintrinsically safe circuit. (See 29.1 through 29.3 for dielectric voltage test procedure.)

Exception: A dc test voltage may be used as described in 29.1 (a).

11.4* Separation of the intrinsically safe and nonintrinsically safe wiring shall be accomplished by enclosing either type of wiring in a grounded shield capable of carrying the fault current which would flow if the nonintrinsically safe circuit were to become connected to the shield.

Exception: If the wiring of a nonintrinsically safe circuit is rated as a National Electrical Code Class 2 or 3 power-limited circuit, a shield is not required. But, the wiring shall be insulated and sized so that overload, including consideration of faults and overcurrent protection, will not damage insulation to the extent that the nonintrinsically safe circuit becomes connected to the intrinsically safe circuit.

12* Protective Components

12.1 General

12.1.1 In evaluating intrinsically safe and associated apparatus, components complying with the requirements of the following subsections are to be considered not subject to fault.

12.2 Transformers

12.2.1 Transformers used as protective components for supplying intrinsically safe circuits shall comply with the following construction requirements and the test requirements in 23.1.1 through 23.5.

12.2.2* The winding supplying the intrinsically safe circuit shall be electrically separated from all other windings by one of the following types of construction:

- a) Type 1(a) – The windings are side by side on one leg of the core and separated by an insulating partition not less than 0.71 mm (0.028 in.) thick.
- b) Type 1(b) – The windings are on different legs of the core.
- c) Type 2(a) – The windings are wound one over another, with high temperature insulation such as mica, glass fiber, layers of polyamide film, or aromatic polyamide paper between the winding supplying the intrinsically safe circuit and all other windings.
- d) Type 2(b) – The input and output windings are wound one over another with a grounded shield of copper foil or an equivalent wire winding between the input winding and all other windings.^a (See 12.2.3.)
- e) Type 3 – The transformer is either Type 1(a), Type 1(b), or Type 2(b) construction, except that the shield of a Type 2(b) construction may be provided with a single lead to the ground connection. No primary fuse is required. (See Appendix A5.4 and A5.5)

^a No type test is normally required for Type 2(b) construction.

12.2.3 A Type 2(b) construction shall comply with the following:

- a) The thickness of the copper foil shield or the diameter of the wire shield shall be such that in the event of a short circuit between any winding and the shield, the shield will be able to withstand without breakdown the current which flows until the fuse or circuit breaker functions. A shield made of copper foil at least 0.13 mm (0.005 in.) thick is considered to comply with this requirement without test.
- b) The shield shall be provided with two independently connected leads to the ground connection, each of which is capable of withstanding without damage the current which flows before the fuse or circuit breaker operates. The shield grounding leads are considered to comply without testing if each lead is at least equal in size to the primary leads of the transformer but not less than No. 24 AWG (0.21 mm²).
- c) A wire-wound shield shall consist of at least two layers of windings.

12.2.4 If a fuse is used to prevent transformer burnout, its prospective current rating shall be specified by the apparatus manufacturer.

12.2.5 The core of a power supply transformer shall be provided with a ground connection, unless grounding is not practicable, as with insulated toroidal core transformers used in dc-to-dc converters.

12.2.6 All transformers shall be impregnated or encapsulated in order to consolidate the windings.

12.3 Damping windings

12.3.1 Damping windings are to be considered not subject to fault if they are of reliable mechanical construction, such as seamless metal tubes, windings of bare wire continuously short circuited by soldering, or the equivalent.

12.4 Current-limiting resistors

12.4.1 Current-limiting resistors are to be considered not subject to short-circuit faults if:

- a) They are a film type, a wire-wound type with protection to prevent unwinding of the wire in the event of breakage, or similar construction in which the resistance normally increases during failure and
- b) If they comply with the requirements in 24.1 and 24.2.

ULNORM.COM : Click to view the full PDF of UL 913 1997

12.5 Blocking capacitors

12.5.1 Blocking capacitors connected between an intrinsically safe circuit and a nonintrinsically safe circuit are to be considered not subject to fault if two capacitors are connected in series and each capacitor is rated to withstand an ac test voltage of twice the fault voltage across the capacitors plus 1000 volts rms. They shall be high-reliability types such as hermetically sealed or ceramic capacitors. Electrolytic or tantalum capacitors shall not be used for this purpose. Failure of a single capacitor is a countable fault. When analyzing or testing, the capacitance value to be used is the capacitance of one capacitor.

Exception: If the capacitors are connected in a secondary circuit, they need not withstand the test voltage specified if they are each rated for three times the fault voltage across the assembly.

12.6 Shunt protective components

12.6.1 Shunt protective components, such as diodes and voltage-limiting resistors fitted to inductive elements, are not considered subject to fault if they are redundant. Bridge connected diodes are accepted as redundant shunt diodes. There shall be no unacceptable increase in energy in the intrinsically safe circuit if one of the components becomes defective. They shall be connected close to the protected component in such a manner that both cannot become disconnected due to a single fault, unless the disconnection of either of the shunt components results in disconnection of the protected component. Breakdown of the protected component to ground is to be considered.

12.7 Shunt diode barriers

12.7.1 Shunt diode barriers are to be considered protective assemblies, as defined in 4.23 and 4.24, if they comply with the requirements of 12.7.2 through 12.7.8.

12.7.2 Barrier component failures shall not increase the energy of the intrinsically safe circuit to an unacceptable level upon the application of up to the maximum nonhazardous location voltage to the assembly. This maximum voltage is assumed to be less than or equal to 250 volts rms, unless a higher value is specified. Application of this voltage is considered a fault.

12.7.3 Construction of the shunt diode barrier shall be such that:

- a) Resistor-protected barrier diodes comply with the requirements in 25.1 and 25.2.
- b) The fuse of a fuse-protected barrier operates at least 10 times faster than the open circuit time of the diode, as specified in 25.4; or the fuse time-current characteristic shall not permit the steady state or surge current ratings of the protected diode to be exceeded, or each diode used shall be routinely tested with a series of rectangular 50 μ S current pulses at 60 hertz for 5 seconds. The current shall be that which will flow upon application of 250 volts rms or the specified maximum voltage taking into account all resistance in series with the diode.
- c) Barrier shunt diodes are duplicated so that the assembly remains effective if one of the diodes open circuits.

12.7.4 The design of shunt diode barriers shall be such that the assembly can readily be seen to be mounted correctly.

12.7.5 At least one terminal or connection shall be provided on each barrier or barrier assembly for connecting the barrier circuit to ground. The grounding terminal or connection shall be sized to accommodate a No. 12 AWG (3.3 mm^2) minimum grounding conductor. The following constructions or their equivalents comply:

- a) A No. 8 (4.8 mm diameter) wire binding screw that engages the terminal plate by at least two full threads. The terminal plate shall be no less than 1.25 mm (0.049 in.) thick, and shall be provided with upturned lugs or the equivalent to hold the conductor in place.
- b) A pressure-type wire connector complying with the requirements for such connectors. (Soldering lugs, push-in connectors, quick-connects, or similar friction fit connectors are unacceptable.)
- c) Bolting the barrier to a grounding bus.

ULNORM.COM : Click to view the full PDF of UL 913 1997

12.7.6 The barrier components shall be so mounted and physically arranged as to prevent occurrence of a fault which could impair the effective operation of the barrier (for example, a short circuit of a resistor or fuse or open circuit of a diode).

12.7.7 If components are not encapsulated, the enclosure shall be constructed so as to prevent access to components other than fuses and to protect components.

12.7.8 If it is accessible for replacement, the fuse on a fuse-protected shunt diode barrier shall not be replaceable by one of higher rating.

12.8 Optical Isolators

12.8.1 Optical isolators are to be considered not subject to a short-circuit fault between the input and output circuits if they comply with the requirements in 26.1 through 26.3.

13 Miscellaneous Components

13.1 Derating of components

13.1.1* During normal operation conditions as defined in 7.1.3, all components affecting intrinsic safety shall operate at not more than two thirds of their rated current, voltage, or power, as appropriate.

Exception: Transformers need not comply with this requirement.

13.1.2 Semiconductor devices used as shunt energy-limiting components shall not fail in the open condition when subjected to the current which would flow if the semiconductor device short-circuits and the fault conditions in 7.1.5 and 7.1.6 are assumed, taking into account overcurrent protection devices.

13.2 Plug-In boards and components

13.2.1 Plug-in boards and components shall not be interchangeable with nonidentical boards or components in the same apparatus.

Exception: If intrinsic safety is not affected from interchange or if plug-in boards and components are identified so that interchange is unlikely, noninterchangeable plug-in boards and components are not required.

13.3* Relays

13.3.1 Where intrinsically safe and nonintrinsically safe circuits are connected to the same relay, the creepage and clearance distances shall comply with 8.1. Except as specified in 13.3.2, the currents and voltages switched by the contacts in the nonintrinsically safe circuits shall not exceed 5 amperes and 250 volts, dc or rms, respectively, and the product of the current and voltage shall not exceed 100 volt-amperes. If the voltage exceeds 250 volts and the current and volt-amperes do not exceed 10 amperes and 500 volt-amperes, respectively, the creepage and clearance distances shall be twice the applicable values in Table 8.1.

13.3.2 With respect to the requirement in 13.3.1, for higher values of current and voltage, the circuits shall be connected to the same relay only if they are separated by a grounded metal partition or an insulating partition. A grounded metal partition shall not be used where breakdown to ground would affect intrinsic safety. A metal partition at least 0.25 mm (0.01 in.) thick, attached to a grounded metal part of the device, or an insulating partition at least 0.7 mm (0.03 in.) thick complies with this requirement. However, a thicker insulating partition may be required to take into account ionization due to operation of the relay.

14 Portable Apparatus Enclosures

14.1 Exposed external surfaces of the external enclosure and parts shall be made of a nonsparking material, such as plastic or brass, unless the part is protected by a recess or a guard.

Exception: Such a surface may be of a sparking material if an investigation indicates that percussion sparks capable of igniting a flammable atmosphere are unlikely.

ULNORM.COM : Click to view the full PDF of UL 913 1997

15 Cells and Batteries

15.1 These requirements apply to both portable and stationary battery-operated apparatus in which the entire apparatus, including batteries, is intended to be used in a Division 1 hazardous location and is not provided with other means of protection, such as an explosionproof or dust-ignitionproof enclosure. These requirements apply to both primary (nonrechargeable) and secondary (rechargeable) cells and batteries.

15.2 Battery cells shall be of a type from which there can be no spilling of electrolyte or shall be enclosed to prevent contact between the electrolyte and circuits which affect intrinsic safety. Compartments containing batteries which emit flammable gas shall be ventilated to prevent accumulations of ignitable concentrations.

15.3 The battery shall be constructed to prevent shorting between internal cells, unless the shorting does not result in an ignition source.

15.4 For the purpose of evaluation and test, the battery voltage is to be the maximum open circuit voltage attainable under normal conditions, such as that voltage measured on a fresh primary battery or a secondary battery just after full charge.

15.5 For the purpose of evaluation and test, the battery short-circuit current is to be the maximum initial current under short-circuit conditions.

15.6* When conducting tests which require applying a factor of 1.5 applied to energy, in accordance with 38.3.1 through 38.3.5, one of the following methods, or its equivalent, is to be used:

- a) Additional individual cells identical to the cells used in a multi-cell battery pack are to be added in series or parallel, as appropriate, to yield a simulated battery with at least 1.5 times the energy capacity of the battery used in the apparatus.
- b) The battery voltage or current value, as appropriate, is to be simulated with a suitable power supply, and the value increased so that the energy level is increased by a factor of 1.5.
- c) The intended batteries are to be used, either two in series for double voltage or two in parallel for double current, as appropriate, yielding an energy factor greater than 1.5.

15.7 If batteries are used for spark ignition tests, four trials with fresh or fully charged batteries, two for each polarity, are to be conducted.

15.8 Battery-operated apparatus in which the battery requires energy-limiting components for intrinsic safety shall either have the energy-limiting components as an integral part of the battery assembly, or use replaceable batteries with the energy-limiting components contained separately within the apparatus.

15.9 If the energy-limiting components are contained separately within the apparatus, the apparatus shall be constructed as follows:

- a) The energy limiting components shall be located as close to the battery terminals as practical. All live parts of the nonintrinsically safe circuit except for connection points shall be insulated and spaced by a minimum clearance distance specified in Table 8.1.
- b) The battery housing or attachment shall be arranged so that batteries can be installed and replaced without short-circuiting the battery output and without applying the battery output to the load side of the energy-limiting components.

- c) For hand-held portable apparatus, such as radio receivers and transceivers, the construction shall prevent the ejection or separation of the batteries from the apparatus even under rough-use conditions, as represented by the drop test described in 31.1.
- d) The apparatus shall be marked to warn against replacement of the batteries in a hazardous location, as described in 17.9.

ULNORM.COM :: Click to view the full PDF of UL 913 1997

15.10 If an energy-limiting component is necessary and is provided as an integral part of the battery assembly, it shall form a complete replaceable unit with the battery assembly. The assembly shall be constructed so that the energy-limiting component is unlikely to be bypassed. The assembly shall be intrinsically safe under the rough-use conditions, as represented by the drop test described in 31.1.

15.11* Apparatus or battery packs that are provided with external contacts for recharging the batteries shall be provided with means to prevent the batteries from delivering ignition-capable energy to the contacts when any pair of the contacts is accidentally short-circuited. This may be accomplished by one or more of the following:

- a) Providing blocking diodes or series resistors in the charging circuit. Unless these blocking diodes or resistors are protective components, they are to be considered subject to fault.
- b) Recessing at least one contact of a pair of contacts so that a circular disc probe 1.2 mm (3/64 in.) thick and 18 mm (45/64 in.) in diameter will not touch the contact. In this case, short-circuiting of the pair of charging contacts is to be counted as one fault.
- c) Separately recessing each contact of a pair of contacts so that a circular disc probe as defined in (b) above cannot touch either contact. In this case, short-circuiting of the pair of charging contacts is to be counted as two faults.
- d) Separately recessing each contact of a pair of contacts at least 0.5 mm (0.02 in.) below the plane of the surrounding surface and separating the two contacts such that two circular disc probes as defined in (b) above may touch the contacts but cannot be arranged in any way to simultaneously touch and complete a short circuit between the two contacts. In this case, short-circuiting of the pair of charging contacts is to be counted as one fault.

15.12 If the charging contacts are not arranged in accordance with 15.11 (b), (c) or (d), short-circuiting of the charging contacts is to be considered a condition of normal operation.

15.13 If the charging contacts are not separated in accordance with the minimum distances required in 8.1, short-circuiting of the charging contacts is to be considered a condition of normal operation.

16* Maximum Temperature

16.1 Intrinsically safe apparatus in the hazardous location shall not have, under normal or fault conditions, any surface exposed to flammable or combustible materials that operates at a temperature exceeding the temperature rating marked on the apparatus. If the apparatus is not marked with a temperature rating, the surface temperature shall not exceed 100°C (212°F).

Exception: Rather than measuring temperatures, the apparatus may be subjected to the test specified in 28.1 through 28.6.

16.2* If wiring other than wound coils or transformer wiring of intrinsically safe apparatus is copper and its current is in accordance with the requirements in Table 16.1, or the following equation, temperature tests to determine its maximum surface temperature are not necessary.

$$I = \frac{\sqrt{I_M^2 t [1 + 0.00393(T - t)]}}{T}$$

In which:

I is the current, amperes,

I_M is the current at which the wire melts, amperes,

T is the temperature at which copper melts, 1083°C, and

t is the maximum acceptable wire temperature, °C.

ULNORM.COM : Click to view the full PDF of UL 913 1997

Table 16.1
Currents in copper wire^a

Minimum conductor size ^b					Maximum conductor current, amperes, for apparatus Rated T4, T5, or T6		
Diameter		Area		(Wire size AWG)			
mm	(Mils)	mm ² x10 ⁵	In. 2 x10 ⁵			T4	T5
0.035	1.4	0.962	0.14	—	0.53	0.48	0.43
0.050	2.0	1.96	0.30	44	1.04	0.93	0.84
0.100	3.9	7.85	1.21	38	2.1	1.9	1.7
0.200	7.9	31.4	4.86	32	3.7	3.3	3.0
0.350	13.8	96.2	14.9	27	6.4	5.6	5.0
0.500	19.7	196	30.4	24	7.7	6.9	6.7

^a For conductors on printed wiring boards, the current is 250 percent of that listed in the table. For flexible flat conductors, such as ribbon cable, the tabulated values apply.

^b For stranded conductors, the cross sectional area is the sum of the cross sectional areas of each strand of the conductor.

16.3* Temperatures higher than that of the marked operating temperature per 17.1 (c) shall be permitted for small components, for example, transistors or resistors, if it is shown by the test procedures described in 28.1 through 28.6 and 33.1 through 33.4 that the temperature is insufficient to cause ignition or charring.

MARKING

17 General

17.1 The minimum marking shall include the following:

- Identification of the apparatus, including manufacturer's name or trademark and type or model designation;
- Hazardous location class and group;
- Maximum surface temperature or temperature identification number based on operation at 40°C (104°F) ambient temperature (See Table 500-2(b) of NFPA 70-1987, National Electrical Code);

Exception: Apparatus having a maximum surface temperature no greater than 100°C (212°F) need not have a marked maximum surface temperature or temperature identification number.

d) For shunt diode and similar protective barrier assemblies which are intended for field or panel installation, the maximum nonhazardous location voltage. (See 12.7.1)

e) Control drawing number, except for apparatus not intended to be connected to other apparatus or circuits.

17.2 In addition to, or as an alternative to, the marking requirement in 17.1 (b), apparatus or parts of apparatus that have been investigated and found to comply with the requirements for Class I, Group D locations may additionally or alternatively be marked as follows:

- a) Class I, Zone 0, Group IIA; or
- b) Class I, Zone 0 and 1, Group IIA.

17.3 In addition to, or as an alternative to, the marking requirement in 17.1 (b), apparatus or parts of apparatus that have been investigated and found to comply with the requirements for Class I, Group C locations may additionally or alternatively be marked as follows:

- a) Class I, Zone 0, Group IIB; or
- b) Class I, Zone 0 and 1, Group IIB.

17.4 In addition to, or as an alternative to, the marking requirement in 17.1 (b), apparatus or parts of apparatus that have been investigated and found to comply with the requirements for both Class I, Group A, and Class I, Group B locations may additionally or alternatively be marked as follows:

- a) Class I, Zone 0, Group IIC; or
- b) Class I, Zone 0 and 1, Group IIC.

17.5 Apparatus or parts of apparatus marked Group IIB may also be marked Group IIA.

17.6 Apparatus or parts of apparatus marked Group IIC may also be marked Group IIA, Group IIB, or both Group IIA and Group IIB.

17.7* In addition to the minimum marking specified in 17.1, the marking shall include the following. As much information as possible shall be provided on the apparatus label. It is recognized, however, that it is impractical to mark small pieces of apparatus with all the required information. If this information is not on the apparatus, it shall be included in the accompanying literature.

a) For intrinsically safe apparatus:

- 1) An indication that the apparatus is intrinsically safe;
- 2) If investigated using the entity evaluation, the maximum input voltage, maximum input current, maximum internal capacitance and maximum internal inductance;
- 3) If repair is possible, a warning label worded "Warning – Substitution of Components May Impair Intrinsic Safety;" and
- 4) A reference to accompanying literature, that provides special installation, maintenance, or operating instructions. If this information is not on the apparatus, it shall be included or referenced on the control drawing.

b) For associated apparatus:

- 1) If investigated using the entity evaluation, the maximum output voltage, maximum output current, maximum allowed capacitance, and maximum allowed inductance;

- 2) If repair is possible, a warning worded "Warning – Substitution of Components May Impair Intrinsic Safety;"
- 3) Any other necessary information, in particular, an indication of any other type of protection and its characteristics; and
- 4) A reference to accompanying literature, that provides special installation, maintenance, or operating instructions. If this information is not on the apparatus, it shall be included or referenced on the control drawing.

ULNORM.COM : Click to view the full PDF of UL 913 1997

17.8 Terminals, terminal boxes, and plugs and receptacles for connection to intrinsically safe circuits shall be clearly identified and clearly distinguishable. If color only is used to comply with this requirement, the color shall be light blue.

17.9 Battery-powered apparatus shall be marked with a caution statement to:

- a) Indicate the type, size, and voltage of batteries to be used or
- b) Indicate the specific battery by manufacturer and model number or equivalent to be used.

If the batteries used are not intrinsically safe, the apparatus shall be marked with the following warning or equivalent: "Warning – to reduce the risk of ignition of a flammable atmosphere, batteries must only be changed in an area known to be nonflammable."

COMPARISON PROCEDURE FOR DETERMINING SPARK IGNITION CAPABILITY

18* General

18.1 General

18.1.1 Apparatus may be considered intrinsically safe without spark ignition testing if the circuits can be readily assessed. To be considered intrinsically safe by the comparison procedure, circuits and apparatus shall comply with 19.1 through 19.4.

18.1.2 Circuits that cannot be readily assessed in terms of elementary circuits represented by the ignition curves shown in the figures in this chapter, circuits in which the current or voltage values exceed those indicated on the curves, and circuits that do not comply with 19.1 through 19.4 are to be evaluated by the test procedures in Section 37.

18.2 Resistance circuits

18.2.1 Figures 18.1 and 18.2^a apply to resistance circuits only and show combinations of voltage and current that will ignite gas and vapors in air for Groups A, B, C, D and for methane. These figures apply only to circuits having an output voltage-current plot that is a straight line drawn between open circuit voltage and short-circuit current.

^a All figures, except Figures 18.5 and 18.6, are reprinted from Certification Standard SFA 3012, 1972 edition, with permission of the Department of Trade and Industry, British Approvals Service for Electrical Equipment in Flammable Atmospheres. Figures 18.5 and 18.6 are from "Some Aspects of the Design of Intrinsically Safe Circuits," Research Report 256, 1968, by D. W. Widgeon, Safety in Mines Research Establishment, Sheffield, England.

18.2.2 Resistance-inductance circuits, Figures 18.3 and 18.4 apply to resistance-inductance circuits and show the combinations of inductance and current at 24 volts which will ignite gases or vapors in air for Groups A, B, C, D and for methane. Figures 18.5 and 18.6 apply to resistance-inductance circuits and show combinations of inductance and current at specific voltages which will ignite gases or vapors in Group B and methane, respectively.

18.3 Resistance-capacitance circuits

18.3.1 Figures 18.7 and 18.8 apply to resistance-capacitance circuits and show combinations of capacitance, voltage, and resistance which will ignite gases or vapors in air for Groups A and B and for methane. These curves represent capacitor discharge only. They do not include the additional current which may be available from the associated apparatus.

Figure 18.1
Resistance circuits

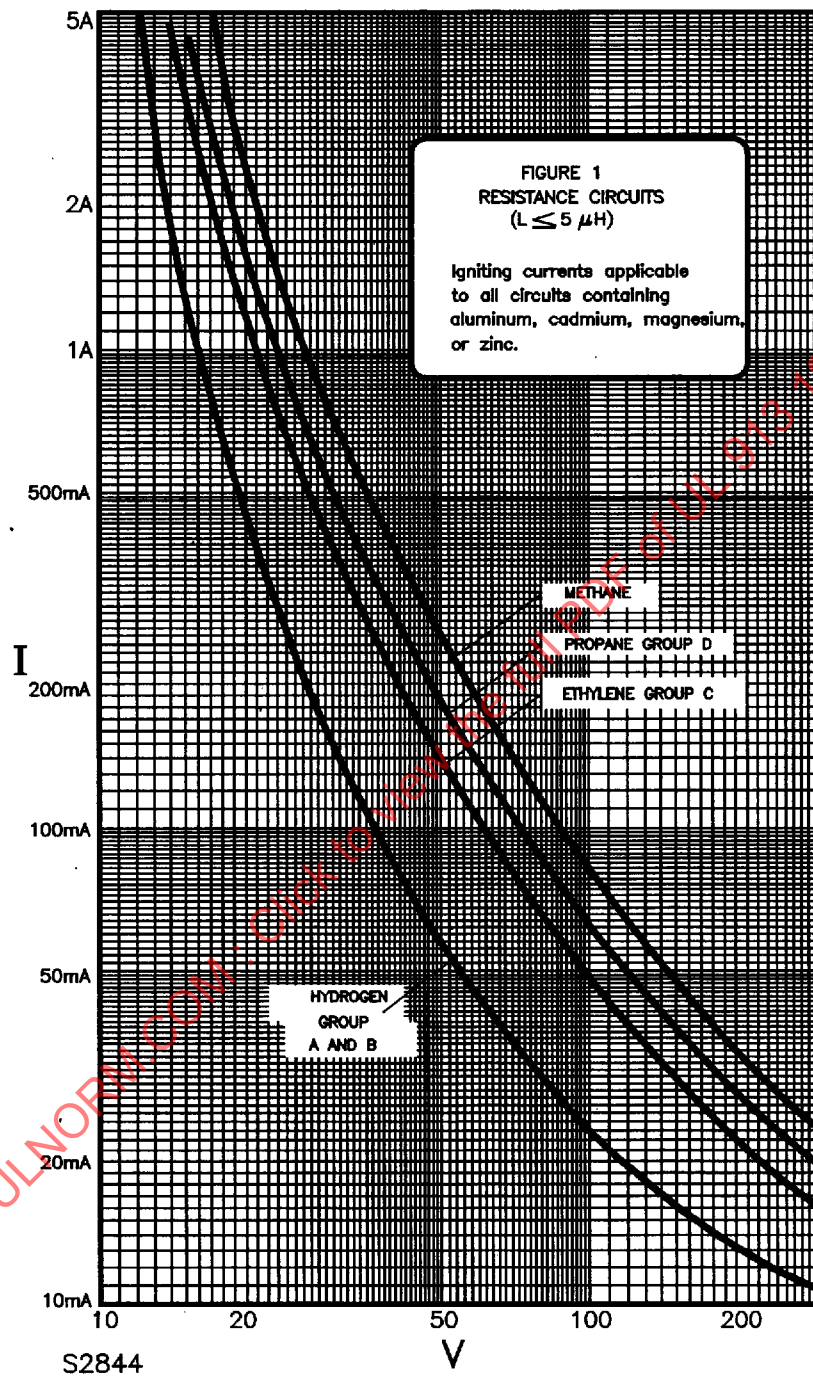


Figure 18.2
Resistance circuits

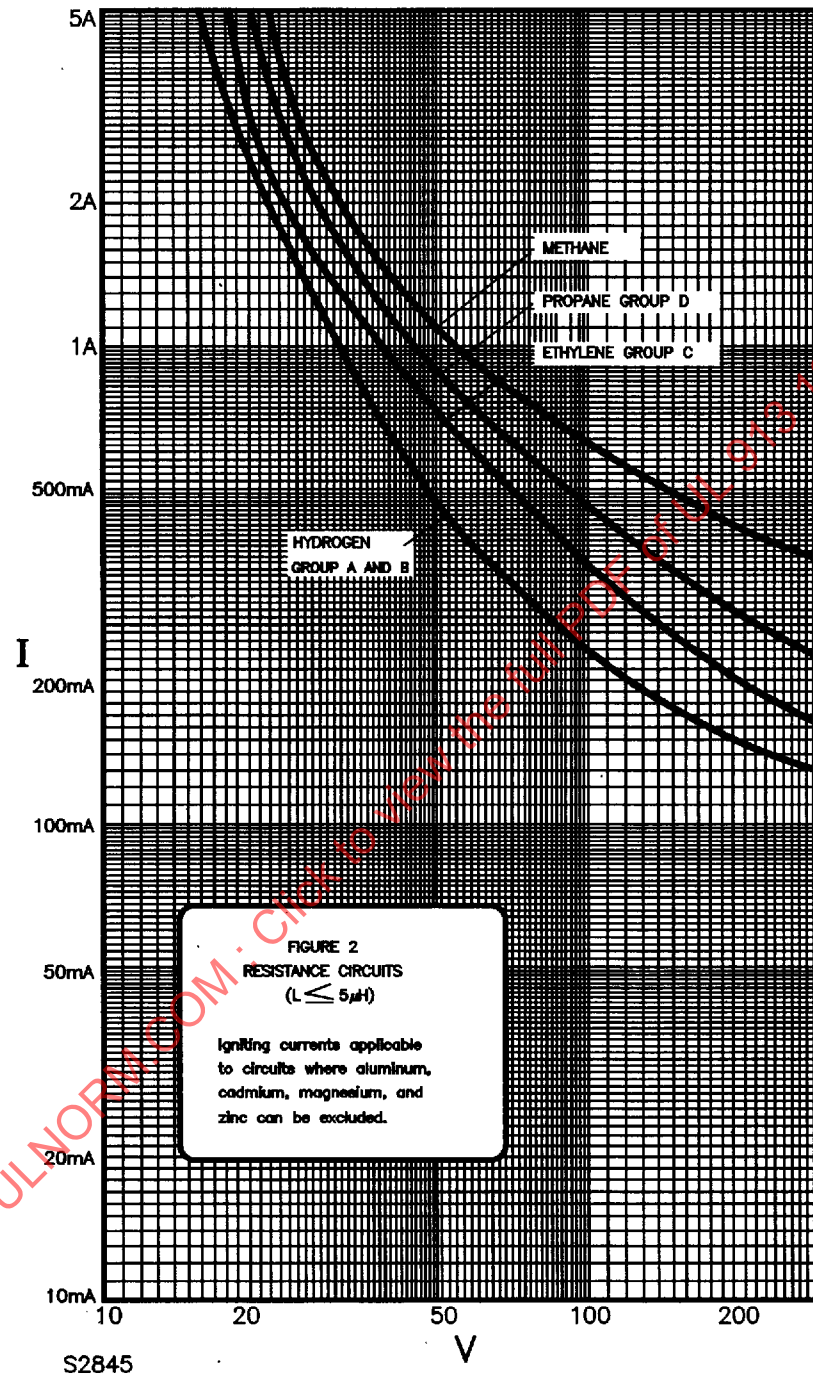
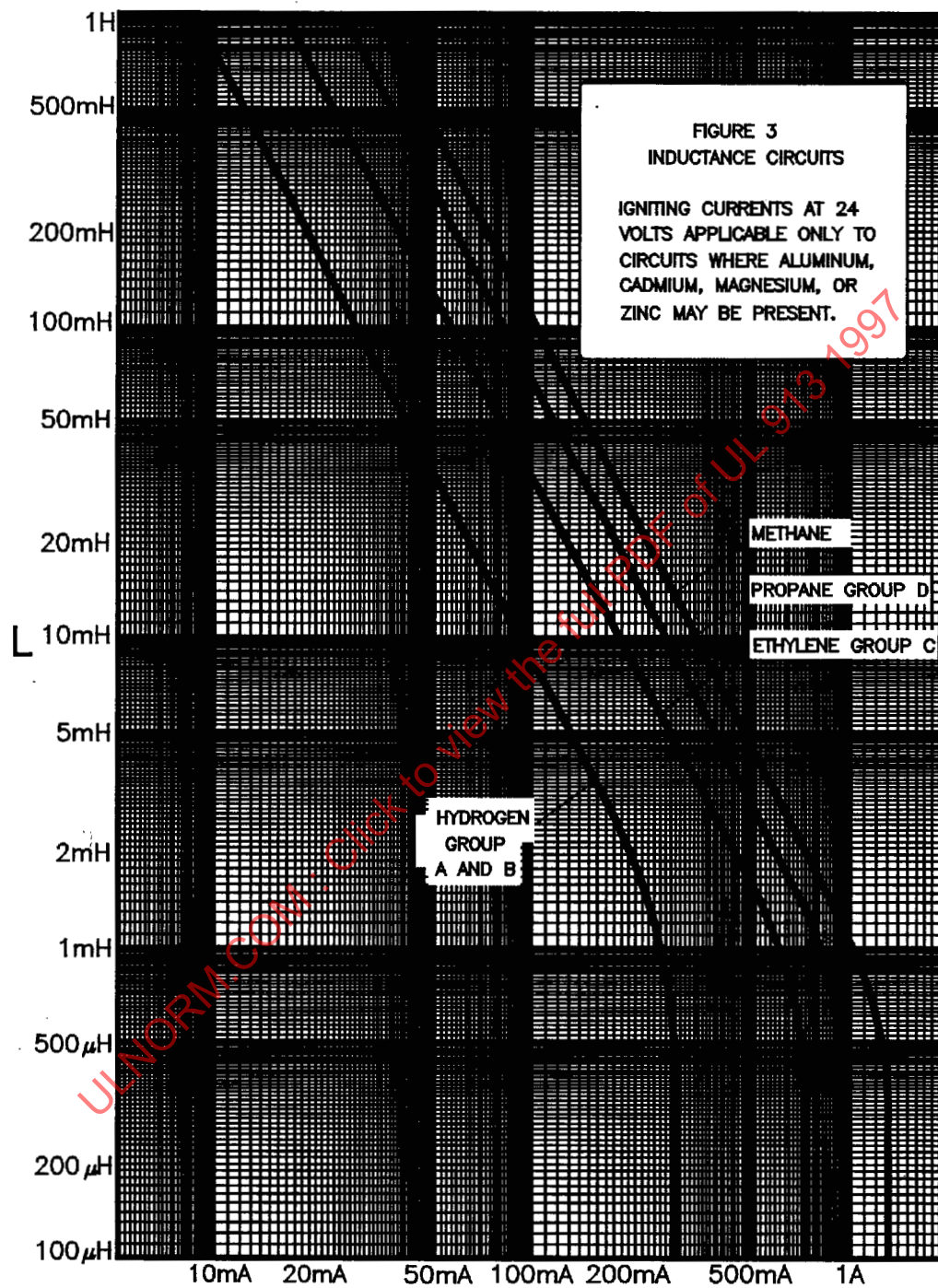


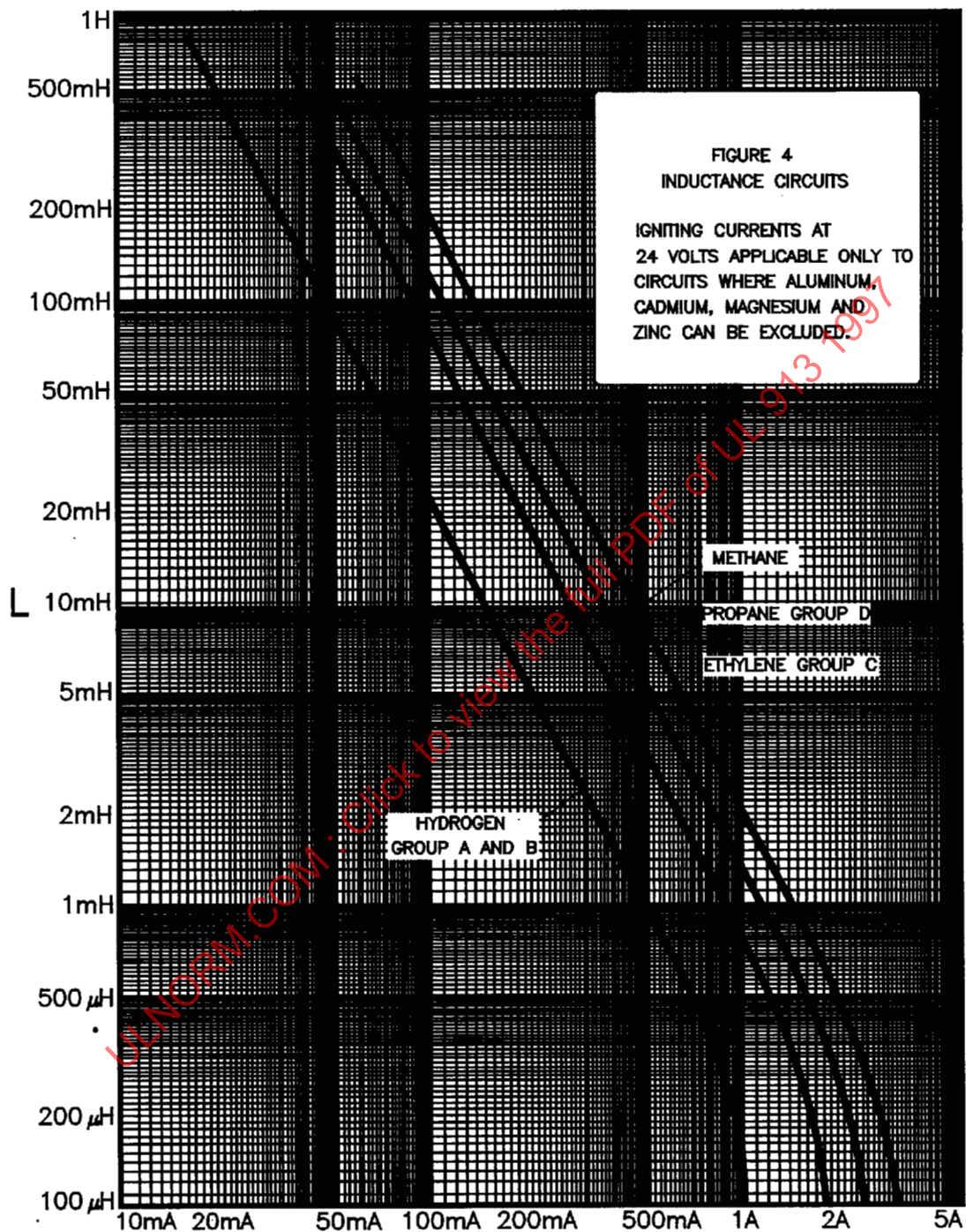
Figure 18.3
Inductance circuits



S2846

I

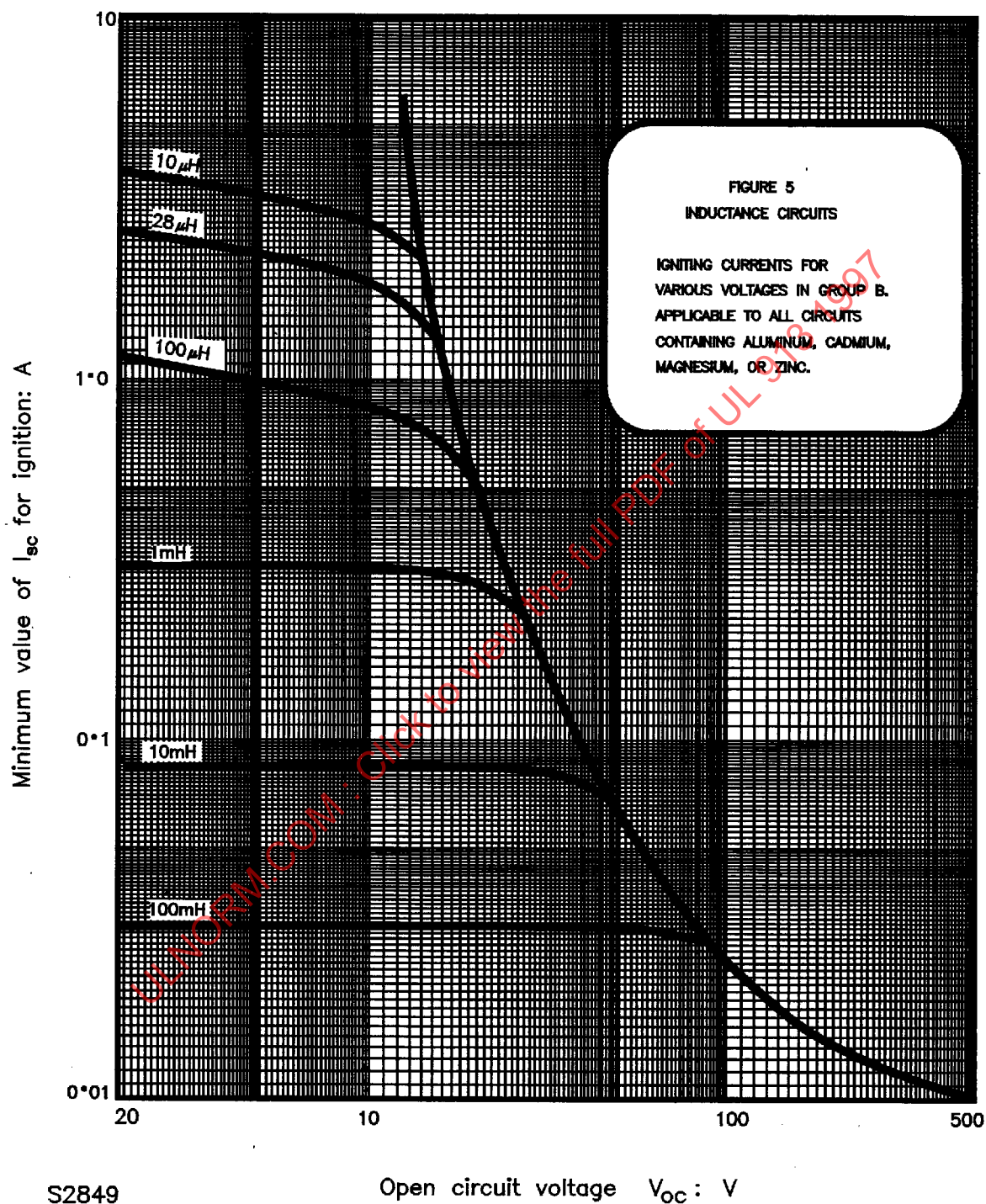
Figure 18.4
Inductance circuits



S2847

I

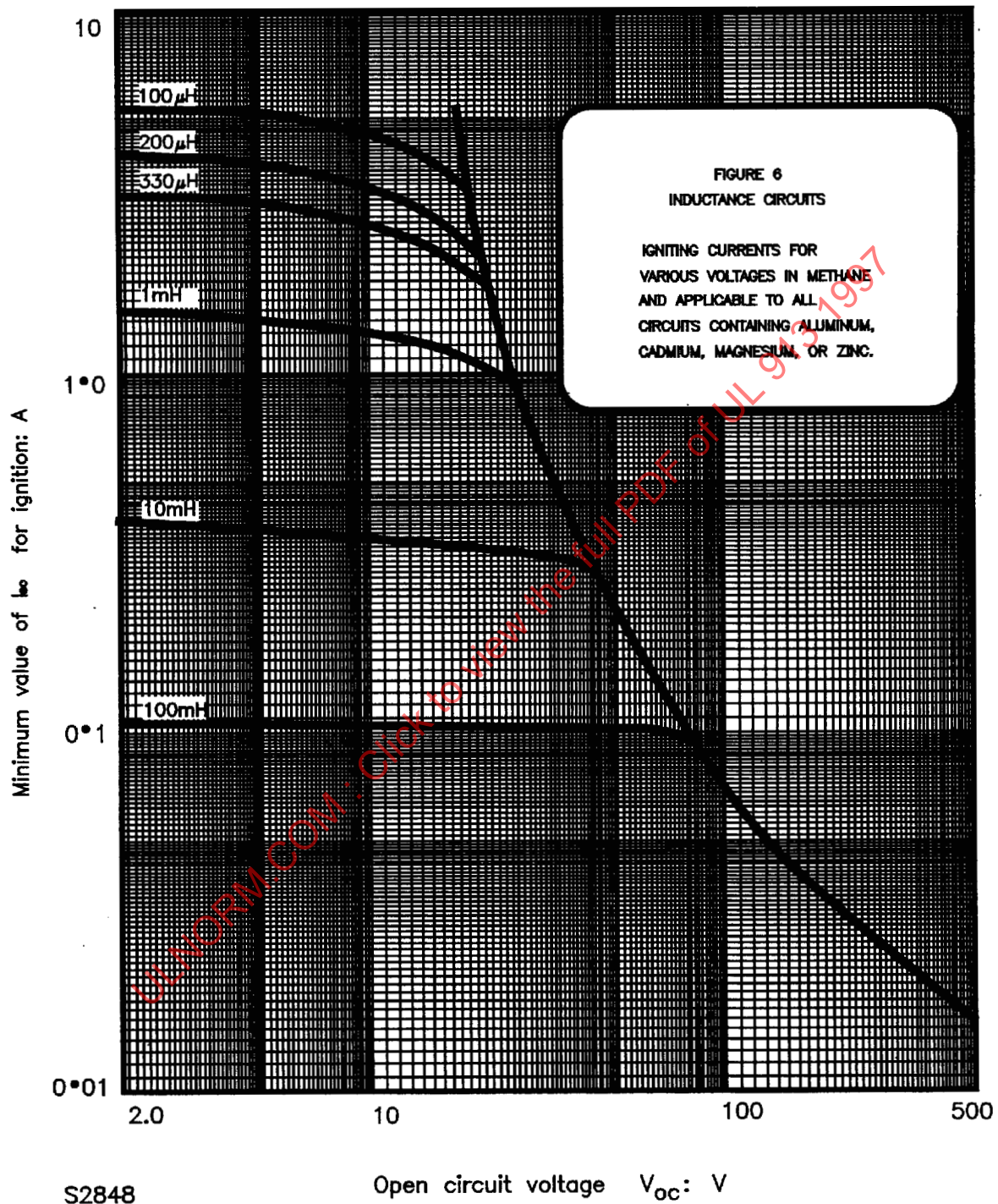
Figure 18.5
Inductance circuits



S2849

Open circuit voltage V_{oc} : V

Figure 18.6
Inductance circuits



S2848

Figure 18.7
Capacitance circuits

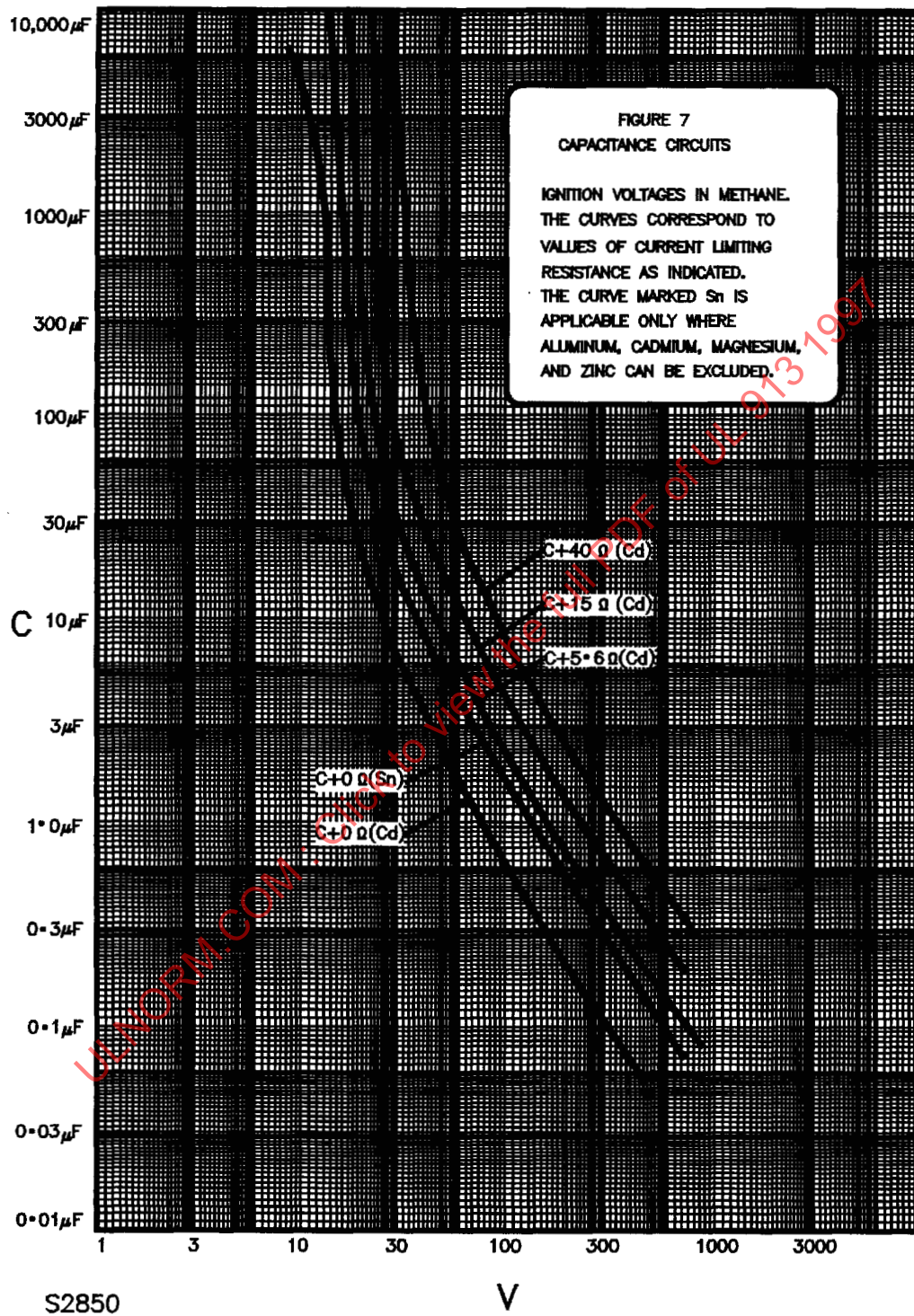
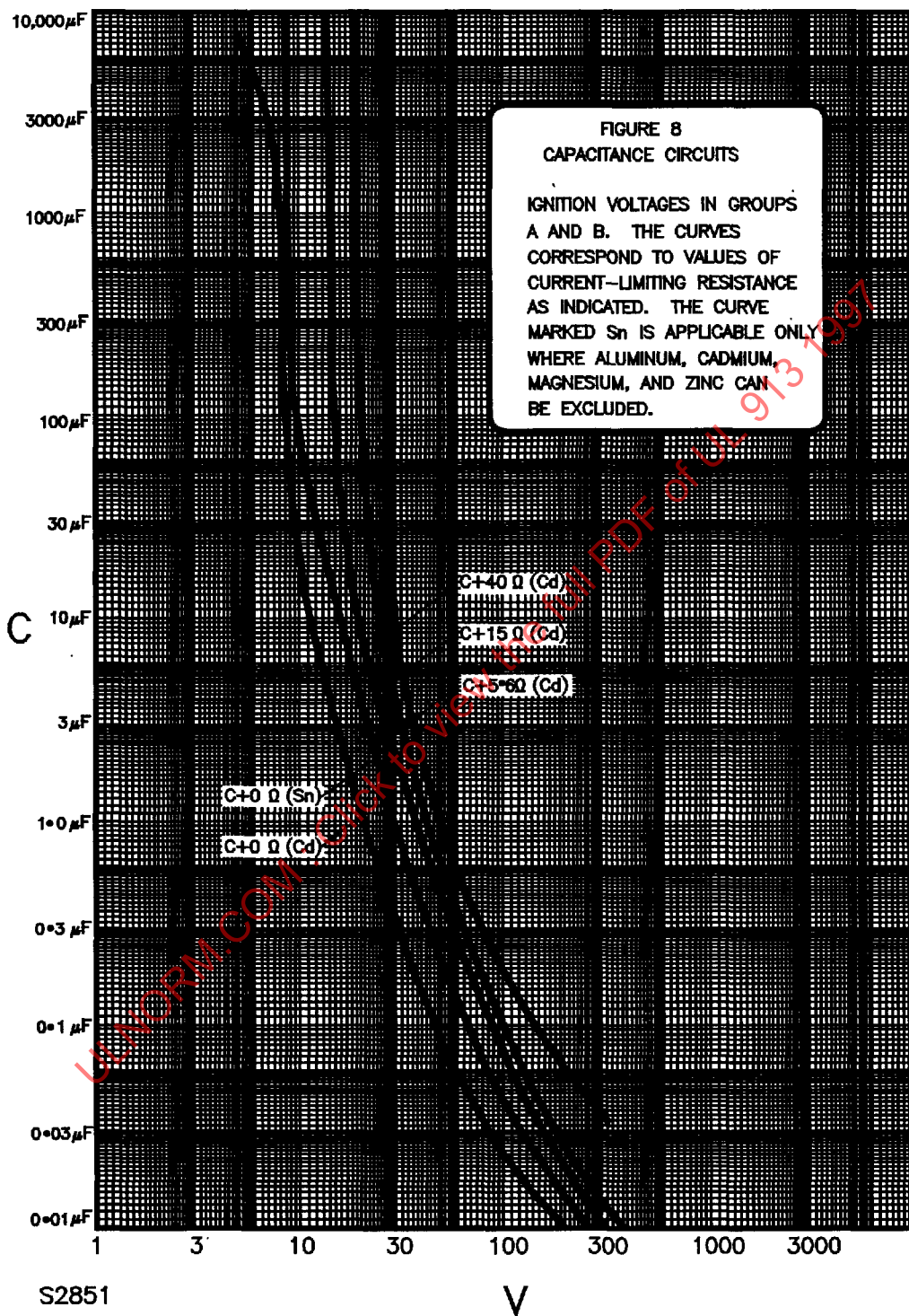


Figure 18.8
Capacitance circuits



19 Maximum voltage and current levels

19.1 The circuit conditions are to include all normal and fault conditions described in this standard, excluding the 1.5 test factor.

19.2 Maximum voltage and current levels (dc or peak ac) in circuits determined to be intrinsically safe by the comparison procedure shall not exceed the values in 19.3 and 19.4, for given circuit constants.

19.3 For normal or single-fault operation, the current shall not exceed 80 percent of the value determined from Figures 18.1 through 18.6. The voltage shall not exceed 80 percent of the value determined from Figures 18.7 and 18.8.

19.4 For two-fault condition, the current shall not exceed 90 percent of the value determined from Figures 18.1 through 18.6. The voltage shall not exceed 90 percent of the value determined from Figures 18.7 and 18.8.

ULNORM.COM : Click to view the full PDF of UL 913 1997

APPARATUS FOR CLASS II AND CLASS III LOCATIONS

20 Applicability of Other Requirements in this Standard

20.1 Intrinsically safe and associated apparatus intended for use in Class II and Class III, Division 1 hazardous locations shall comply with all requirements in Sections 1 through 19 in this standard.

21 Specific Requirements for Intrinsic Safety

21.1 Apparatus and associated wiring that complies with the requirements in Sections 1 through 19 in this standard, as applicable, shall also be considered to comply with the requirements for Class II and Class III locations if they comply with 21.2 and either 21.3 or 21.4.

21.2 The temperature of exposed surfaces of apparatus shall not exceed the following values when tested according to the procedures described in 33.1 through 33.4. For this requirement, "exposed" means exposed to the flammable or combustible material or atmospheres. Parts within a dust-tight enclosure are not considered exposed; the outside surfaces of the enclosure are exposed.

Class II, Group E – 200°C (392°F);

Class II, Group G and Class III – 165°C (329°F);

Class II, Carbonaceous Dusts (Group E or G) – 200°C (392°F)

Exception: Temperature excursions of small components under fault conditions may exceed these limits if it is shown by test that such higher temperatures will not result in ignition or charring. See 33.1 through 33.4.

21.3 Except as specified in 21.4, intrinsically safe apparatus shall be enclosed in a dust-tight enclosure that complies with the requirements in 22.1 through 22.3. The apparatus shall also comply with the spark ignition requirements for Class I locations as follows:

Hazardous Location	Applicable Limits
Class II, Groups E and G; Class III	Class I, Group D or Methane

21.4* Intrinsically safe apparatus not enclosed in a dust-tight enclosure complying with the requirements in 22.1 through 22.3 shall comply with the spark ignition requirements specified in 21.3. In this case, it is to be assumed that all spacings do not comply with the creepage and clearance distance requirements specified in 8.1 and that all connections between live or grounded parts and conductors are in the most unfavorable condition. The number of such connections is unlimited.

22* Dust-Tight Enclosures

22.1 For the purposes of this standard, an enclosure is considered suitable if it:

- a) complies with the requirements in 22.2 or 22.3, or
- b) complies with the requirements in 32.1, or
- c) is dust-ignitionproof.

In addition, a portable apparatus shall be dust-tight after the drop test described in 31.1.

22.2 An enclosure is considered suitable if:

- a) It conforms to applicable requirements for enclosures for ordinary locations,
- b) It has no openings, and
- c) All joints are either threaded with a three full-thread minimum engagement or sealed by continuous welding, brazing, soldering or fusion of glass.

22.3 Parts of apparatus within an enclosure suitable for ordinary locations that are encapsulated to a depth of at least 1 mm (0.04 in.) are to be considered dust-tight.

ULNORM.COM : Click to view the full PDF of UL 913-1997

TEST PROCEDURES

23 Protective Transformers Tests

23.1 Routine tests

23.1.1 Transformers for direct connection to an external supply shall be capable of withstanding the following test voltages. (See 29.1 through 29.3.)

Where applied	Rms test voltages
Between input and output windings.	(U_n = highest rated voltage of any winding) $4U_n$ or 2500 V, whichever is the greater.
Between all the output windings and the core or shield.	$2U_n$ or 1000 V, whichever is the greater.
Between each winding supplying an intrinsically safe circuit and every other output winding.	$2U_n + 1000$ V or 1500 V, whichever is the greater.

23.1.2 For transformers not intended for direct connection to an external supply system, the test voltage between input and output windings shall be reduced to $2U_n + 1000$ volts rms or 1500 volts, whichever is greater.

23.2 Type tests

23.2.1 The transformer is to be subjected to the appropriate type tests described below, followed by a voltage test of twice the highest rated voltage of any winding plus 1000 volts rms or 1500 volts, whichever is greater, between any windings used to supply the intrinsically safe system and all other windings. (See 29.1 through 29.3.)

23.3 Type 1(a) and type 1(b) transformers

23.3.1 The transformer's secondary winding or windings are to be short-circuited or loaded in such a way so that the highest primary winding current does not exceed 1.5 times the fuse or circuit breaker rating. If 1.5 times the rating of the overcurrent device is not reached, then the transformer's secondary winding or windings are to be short-circuited or loaded to draw maximum primary current with the primary winding subjected to its worst case rated input voltage. The protective fuse or circuit breaker in the primary circuit is to be bypassed for this test.

23.3.2 The temperature rise of the transformer shall at no point exceed the permissible value for the class of insulation used during continuous operation for at least 6 hours or up to the moment when the imbedded thermal trip device, if any, functions.

23.3.3 If an output winding has a current-limiting resistor arranged so that a short circuit is unlikely to occur directly across the winding, the test is to be conducted with the resistor in the circuit.

23.4 Type 2(a) transformer

23.4.1 The test is to be conducted by loading the secondary winding(s) so that maximum primary current is drawn while the primary winding is connected to its rated input voltage. The primary winding current is not to be limited.

23.4.2 The transformer is to be tested for 6 hours or until failure, whichever occurs first. Either the primary winding or the secondary winding(s) may short-circuit to the core during this test, if shorting of the secondary winding(s) to the core does not result in unacceptable energies in the hazardous location.

23.4.3 The transformer shall not burst into flames during the test. An imbedded one-time thermal fuse may be used to reduce the likelihood that a transformer will burst into flames.

23.5 Type 3 transformer

23.5.1 The transformer is to be operated with any or all secondary windings short-circuited, depending on which represents the more severe condition of heating, and with rated voltage applied to the primary winding until thermal equilibrium is established. All thermal fuses or other current- or temperature-sensitive protective devices are to be shortcircuited during this test. The temperature rise of the transformer shall at no point exceed the permissible value for the class of insulation employed.

ULNORM.COM : Click to view the full PDF of UL 913-1997

24 Current-Limiting Resistor

24.1 As a result of being subjected to 1.5 times the maximum fault voltage appearing across a current-limiting resistor, it shall:

- a) Open circuit,
- b) Increase in resistance, or
- c) Decrease in resistance no more than 33 percent during the test and no more than 10 percent after the test.

Exception No. 1: If the resistor is protected by a fuse, it is to be tested at:

- a) A current of 1.7 times the current rating of the fuse without the fuse in the circuit, and*
- b) A voltage of 1.5 times the maximum fault voltage with the fuse connected in series with the resistor.*

Exception No. 2: This requirement does not apply to resistors that are operated at no more than two thirds of their power rating during both normal and fault conditions.

24.2 The test voltage is to be raised from zero to the required value in approximately one minute. The test is to continue until the resistor temperature becomes stable or until it is evident that no further deterioration will occur.

25 Shunt Diode Protective Barrier Tests

25.1 Resistor-protected barrier diodes shall either:

- a) Withstand without damage or
- b) Fail without rendering the barrier ineffective, as a result of being subjected to 1.5 times the maximum current that will flow continuously through the resistor when up to the maximum nonhazardous location voltage is applied to the barrier.

25.2 The test is to continue until the temperatures become stable or until it is evident that no further deterioration will occur.

25.3 Zener diode maximum voltage is to be the summation of the nominal Zener voltage, plus maximum tolerance of the Zener.

25.4 The adequacy of a fuse in preventing an open circuit of a Zener diode is to be determined by one of the following methods:

- a) The barrier assembly fuse is to be substituted by a similar type fuse having a current rating 10 times greater. The substituted fuse shall operate prior to diode failure, upon application of up to the maximum nonhazardous location voltage.
- b) A current flow of 200 percent of the fuse current rating is to be applied to the barrier assembly, without the fuse, for 10 times longer than the operating time of the fuse. There shall be no diode failure that will render the barrier ineffective. The operating time of the fuse is to be determined by test or taken from the manufacturer's operating time versus current curve at 200 percent of its current rating.

26 Optical Isolator Tests

26.1 An optical isolator in a secondary circuit shall withstand the test voltage specified in 23.1.2.

26.2 An optical isolator in a primary circuit shall be capable of withstanding a 4000 volt rms test voltage initially and 1000 volts plus twice the highest rated voltage of the circuit or 1500 volts, whichever is greater, after the limited short circuit test procedure described in 26.3. The test voltage is to be applied between the intrinsically safe circuit and the nonintrinsically safe circuit. Three samples are to be used for each test. See 29.1 (a) through 29.1 (c) and 29.2.

26.3 With regard to 26.2, the open circuit voltage of the test circuit is to be the nominal maximum rated nonhazardous location voltage, for example, 120 or 240 volts. The available instantaneous short-circuit current capacity of the test circuit is to be at least 200 amperes. The test circuit is to be connected to the optical isolator so that the test current flows through the nonintrinsically safe circuit terminals of the optical isolator. Protective components or fuses are to be permitted in the circuit for the test.

ULNORM.COM : Click to view the full PDF of UL 913 1997

27 Temperature Tests

27.1 All temperature data are to be referred to a base ambient temperature of 40°C (104°F). Tests to be based on an ambient temperature of 40°C (104°F) may be conducted at any ambient temperature within the range of 15 – 40°C (59 – 104°F). The difference between the ambient temperature at which the test was conducted and 40°C (104°F) is to then be added to the temperature measured.

Exception: Temperatures other than those for determining temperature marking on components of associated apparatus, such as protective transformers, shall be referred to a base ambient temperature of 25°C (77°F) or the maximum rated ambient temperature of the apparatus, whichever is higher.

27.2 Temperatures are to be measured either by thermocouples consisting of wires not larger than No. 24 AWG (0.21 mm²) or by equivalent means.

Exception: Coil temperatures may be determined by the method described in 27.8.

27.3 A thermocouple is to be used for determining the temperature of a coil or winding of a protective transformer if the thermocouple can be mounted without removal of encapsulating compound or similar material:

- a) On the integrally applied insulation of a coil without a wrap, or
- b) On the outer surface of a wrap that is not more than 0.8 mm (1/32 in.) thick and consists of cotton, paper, rayon, or similar material (but not thermal insulation).

The change-of-resistance method is to be used if the thermocouple measurement cannot be conducted in accordance with the foregoing considerations.

27.4 Tests are to be continued until constant temperatures are attained, or until the maximum temperature has been attained, whichever occurs first.

27.5 A temperature is to be considered constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test (but no less than 5-minute intervals) indicate no change.

27.6 The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements for special thermocouples as listed in the table of limits of error of thermocouples in ANSI C96.1, Temperature Measurement Thermocouples.^a

^a Available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

27.7 A thermocouple junction and adjacent thermocouple lead wires are to be securely held in good thermal contact with the surface of the material being measured. In most cases, good thermal contact will result from securely taping or cementing the thermocouple in place; but if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

27.8 The formula for obtaining the temperature rise of a protective transformer winding by the resistance method is as follows. The windings are to be at room ambient temperature at the start of the test:

$$\Delta T = \frac{R}{r} (k + t_1) - (K + t_2)$$

in where:

Δt is the temperature rise, °C

R is the resistance of the coil at the end of the test, ohms

r is the resistance of the coil at the beginning of the test, ohms

t_1 is the room temperature, °C, at the beginning of the test

t_2 is the room temperature, °C, at the end of the test

k is the 234.5 for copper, 225.0 for aluminum electrical conductor (EC grade).

ULNORM.COM :: Click to view the full PDF of UL 913 1997

28 Small Component Ignition Test

28.1 Small components and small gage wire that either exceed the marked operating temperature of apparatus intended for use in Class I locations or exceed 100°C (212°F) for apparatus not required to be marked with an operating temperature shall not cause ignition of the flammable mixture used when tested as described in 28.2 through 28.5.

28.2 The flammable mixture used is to be diethyl ether for apparatus marked T4.

28.3 The test is to be conducted under the fault condition that produces the maximum surface temperatures on the component.

28.4 The component may be mounted in the apparatus as intended or the component may be tested in the mixture to determine the temperature at which ignition occurs. The temperature of the component in the apparatus being assessed may then be determined. The flammable mixture is to be introduced into the apparatus enclosure so as to assure contact between the mixture and the surface of the component being tested. If this is impractical, such a condition is to be simulated so as to assure representative test results, taking into consideration other parts of the apparatus in the vicinity of the component being tested that could affect the temperature of the mixture and the flow of the mixture around the component due to ventilation and thermal effects.

28.5* The test is to also be conducted under the normal or fault condition that produces the maximum release of thermal energy whenever such condition produces maximum surface temperature that both exceeds the marked operating temperature and is lower than that produced in 28.3, that is, the temperature rise of more than one component exceeds the marked operating temperature.

28.6 The tests are to continue until thermal equilibrium of the component under test and surrounding parts is attained or until the temperature of the component under test drops to a value equal to the marked operating temperature as a result of failure of the component, whichever occurs first. If failure of the component terminates the test, five additional samples are to be tested; none of these shall ignite the mixture. If no ignition occurs, the mixture is to be ignited by other means to verify presence of a flammable mixture.

29 Dielectric Tests

29.1 The following test method is to be used:

- a) The test is to be conducted using alternating voltage of substantially sinusoidal wave form at a frequency between 48 Hz and 62 Hz. Alternatively, the test is to be conducted using a dc voltage having no more than 3 percent peak-to-peak ripple and at a level of 1.414 times the specified ac voltage.
- b) The supply is to have sufficient volt-ampere capacity to maintain the test voltage, taking into account any leakage current that may occur.
- c) The voltage is to be increased steadily to the specified value in a period not less than 10 seconds and then maintained for at least 60 seconds.
- d) For routine tests, the test voltage may be increased 20 percent and applied for not less than 1 second.

29.2 There shall be no breakdown of the apparatus between the test points.

29.3 Representative circuits on printed wiring boards coated with a single layer of adherent insulating coating that is less than 0.7 mm thick (0.028 inch) are to be subjected to a dielectric withstand test. See 29.1 and 29.2 for the test method. The test voltage is to be based on the operating voltages of the circuits being considered in accordance with note c to Table 8.1 and the values specified in Table 29.1.

ULNORM.COM : Click to view the full PDF of UL 913 1997

Table 29.1
Coated board withstand test values

Circuit operating voltage, volts		Withstand test, kV, rms
Peak	rms	
10	7.07	1.39
30	21.2	1.68
60	42.4	2.21
90	63.6	2.68
190	134.4	3.11
375	265.2	3.51
550	388.9	3.89
750	530.3	4.26
1000	707.1	4.95
1300	919.2	6.59

30 Mechanical Tests

30.1 Partitions shall withstand a force of 30 newtons (6.75 lbs-force), applied by a 6 mm (0.25 in.) diameter rigid test rod. The force is to be applied at the approximate center of the partition for 10 seconds. There shall be no deformation of the partition that would defeat its purpose.

31 Drop Test

31.1 Portable apparatus is to be subjected to the following drop test. Intrinsic safety shall not be affected.

a) A sample of the apparatus is to be dropped six times, not more than once on any one surface, edge, or corner, from a height of 1.00 meter (39.4 in.) onto a smooth horizontal concrete floor.

b) If appropriate, a nonrestrictive guide is to be used to obtain free-fall dropping on the surface to be tested.

32 Dust-Tight Enclosure Test

32.1 A dust-tight enclosure shall comply with the requirements for the Dust Test as specified in NEMA Publication No. 250-1985, Enclosures for Electrical Equipment (1000 Volts Maximum).^a

^a Available from National Electrical Manufacturers Association., 2101 "L" Street, N.W., Washington, DC 20037.

33 Dust Blanketing Temperature Test

33.1 The apparatus is to be mounted in its normal position and covered with the dust mixture specified in 33.2 until no more will stay on the enclosure or component (see 21.2) or to a depth of 12 mm (0.48 in.), whichever is less.

33.2 The dust used is to be one of the following:

- a) Wheat or corn dust (or a mixture of both);
- b) Type 1, General Purpose Portland Cement; or
- c) Aluminum oxide.

The dust is to be fine enough to pass through a 100-mesh screen. Alternatively, magnesium dust may be used for Group E.

33.3 The apparatus is to be operated under fault conditions appropriate to the apparatus until all temperatures become constant. See 21.1 through 21.4.

33.4 The temperature of surfaces exposed to dust shall not exceed the values in 21.2. Temperatures are to be based on temperature rise above ambient in the test chamber and 40°C (104°F).

Exception: Higher temperatures are permitted for tests using grain dust if the dust does not char or ignite.

34 Lamp Breakage Test

34.1 The heated filament of a tungsten-filament lamp shall not ignite a surrounding explosive mixture when the glass envelope is broken.

34.2 The lamp is to be mounted in a test chamber connected to a normal (no fault) power supply. The chamber is to be filled with an explosive mixture specified in 37.3.1 through 37.3.5 in accordance with applicable fault procedures in 7.1.6. The lamp envelope is to be broken quickly and completely (not just cracked) while the lamp is immersed in the mixture to expose the glowing filament to the explosive mixture. The filament is not to be broken by the breakage of the envelope. Six samples are to be tested.

35 Encapsulation Tests

35.1 Force test

35.1.1 An encapsulant shall withstand a force of 30 newtons (6.74 lb) applied using the flat end of a 6 mm (0.24 in.) diameter solid test rod. The force is to be applied for at least 10 seconds in a direction perpendicular to the surface of the encapsulant. The encapsulant may transiently move during the test, but shall not permanently deform or be damaged in a way that impairs the protection provided.

35.2 Impact test

35.2.1 Encapsulant that is not protected from shock by another enclosure or partition is also to be subjected to an impact test of 2 joules (1.48 ft·lbf). The encapsulant may transiently move during the test, but shall not permanently deform or be damaged in a way that impairs the protection provided.

35.2.2 The impact is to be applied by a 0.25 kg (0.55 lb) test mass having a hardened steel impact head 25 mm (0.98 in.) diameter falling through a vertical distance of 0.8 meters (2.62 ft).

35.2.3 The apparatus is to be mounted on a steel base having a mass of at least 20 kg (44 lb) or is to be mounted on a steel base rigidly fixed to or inserted in the floor. The direction of the impact is to be normal to flat surfaces being tested, or normal to a tangent to the surface if the surface is not flat.

35.3 Solvent vapor exposure

35.3.1 An encapsulant shall be constructed of materials suitable for the intended environment including consideration for atmospheric contaminants and for corrosive compounds. There shall be no deterioration that impairs the protection provided.

36 Internal Capacitance or Inductance Test

36.1 These requirements apply to apparatus to be investigated in accordance with 7.5.1 (b) or 7.5.1 (c). The effective capacitance or inductance of the intrinsically safe apparatus is to be determined by the change in capacitance or inductance required to just prevent ignition using the spark ignition test apparatus and methods described in Section 37.

36.2 A variable capacitor is to be tested in accordance with 38.2.1 through 38.2.4. The capacitor is to be adjusted until ignition just does not occur. The test source voltage is to be 1.22 times the maximum input voltage. The value of the capacitor (C_1 in 36.5) is to be recorded.

36.3 The intrinsically safe apparatus is then to be connected in parallel with the variable capacitor using whatever terminals on the intrinsically safe apparatus are relevant. In some cases, the test may have to be repeated using a different set of terminals.

36.4 The variable capacitor and intrinsically safe apparatus combination is to be tested in accordance with 38.2.1 through 38.2.4. The variable capacitor is again to be adjusted until ignition just does not occur. The value of the variable capacitor (C_2 in 36.5) is again recorded.

36.5 The maximum internal intrinsically safe apparatus capacitance, C_1 , for those terminals is the difference between the two recorded capacitance values as follows: $C_i = C_1 - C_2$. A negative number is assumed to be zero.

36.6 The procedure described in 36.2 through 36.5 is also used to determine the effective inductance. In this case, the terminals of the intrinsically safe apparatus are placed in series with a 95 millihenry inductor. The power source is to be 24 volts dc open circuit. However, the source voltage and inductance may be altered to improve sensitivity for circuits that operate on currents higher than 100 milliamperes. The current is to be varied with noninductive series resistance until ignition just does not occur. The difference in currents can then be related to the effective inductance utilizing the appropriate curve in Figure 18.3.

37 Spark Ignition Test

37.1 General Requirements

37.1.1 All circuits requiring spark ignition testing are to be tested to ensure that they are incapable of causing ignition under the conditions specified in Section 7, taking into account the appropriate gas group or groups specified in 37.3.1 through 37.3.5. See also 21.3.

37.1.2 Normal and fault conditions are to be simulated during the tests. Factors shall be added as described in 38.3.1 through 38.3.5. Specialized test apparatus as described in 37.2.1 and 37.2.2 is to be used rather than the contacts used in the field. The test apparatus contacts are to be operated in a chamber filled with the most readily ignited mixture of the test gas with air as determined by verification in accordance with 38.1.1 and 38.1.2.

37.2* Test apparatus

37.2.1 The spark test apparatus is to consist of an explosion chamber of about 250 cubic centimeters (15.25 cu. in.) volume, in which circuit-making-and-breaking sparks can be produced in the presence of the prescribed test gas.

37.2.2 Components of the contact arrangement are a cadmium disc with 2 slots and 4 tungsten wires of 0.2 mm (0.008 in.) diameter, which slide over the disc. The free length of the tungsten wires is to be 11 mm (0.44 in.). The driving spindle, to which the tungsten wires are attached, is to make 80 revolutions a minute. The spindle on which the cadmium disc is mounted is to revolve in the opposite direction. The ratio of the speeds of the driving spindle to the disc spindle is to be 50 to 12. The spindles are to be insulated from one another and from the housing. See Figure 37.1. The explosion chamber is to withstand pressures up to 1470 kPa (213.2 lbf/in.²) or be provided with suitable pressure relief. When cadmium, zinc, or magnesium will not be present, the cadmium disc may be replaced by a tin disc.

37.3 Gas mixtures^a

^a The purity of commercially available gases and vapors is normally adequate for these tests, but those of purity less than 95 percent should not be used. The effect of normal variations in laboratory temperature and pressure and of the humidity of the air in the gas mixture is also likely to be small. Any significant effects of these variables will become apparent during the routine verification of the spark test apparatus.

37.3.1 For Group D, the test mixture is to be 5.25 ± 0.25 percent propane in air.

37.3.2 For Group C, the test mixture is to be 7.8 ± 0.5 percent ethylene in air.

37.3.3 For Groups A and B, the test mixture is to be 21 ± 2 percent hydrogen in air.

37.3.4 For Class II, Groups E, F, and G, the test mixture is to be 5.25 ± 0.25 percent propane in air or 8.3 ± 0.3 percent methane in air.

37.3.5 Intrinsically safe apparatus that is intended for use in a particular gas or vapor and that will be marked accordingly is to be tested in the most easily ignited concentration of that gas or vapor in air.

ULNORM.COM : Click to view the full PDF of UL 913 1997