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UL 913

STANDARD for SAFETY

INTRINSICALLY SAFE APPARATUS AND ASSOCIATED APPARATUS

FOR USE IN CLASS I, II, AND III, DIVISION I, HAZARDOUS (CLASSIFIED) LOCATIONS

UNDERWRITERS LABORATORIES INC.®

UNDERWRITERS LABORATORIES INC.®

an independent, not-for-profit organization testing for public safety

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July 29, 1988

STANDARD FOR

INTRINSICALLY SAFE APPARATUS AND ASSOCIATED APPARATUS FOR USE IN CLASS I, II, AND III, DIVISION 1, HAZARDOUS (CLASSIFIED) LOCATIONS

UL 913, FOURTH EDITION

Accompanying this transmittal notice is a copy of the fourth edition of UL 913.

THIS EDITION OF THE STANDARD IS NOW IN EFFECT EXCEPT FOR PARAGRAPHS, ITEMS, AND FIGURE, WHICH BECOME EFFECTIVE SEPTEMBER 13, 1991 AS INDICATED IN THE SMALL PRINT NOTE FOLLOWING THE AFFECTED ITEMS.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this standard unless the applicant specifically requests that the product be judged under the current requirements. However, should the applicant elect 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 Recognition and Follow-Up Services after the effective date and understanding of this should be signified in writing.

As indicated on the title page, this UL Standard for Safety is an American National Standard.

Revised and/or additional pages may be issued from time to time.

Subscribers to UL's services in the area covered by this standard will receive these revised and/or additional pages automatically. Others may receive such pages by subscribing to UL's subscription service for revisions. See UL's CATALOG OF STANDARDS FOR SAFETY for a description of the revisions subscription service, the cost of the service for this standard, and ordering information.

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A STANDARDS GLOSSARY is also available. The glossary is a compilation of terms and their definitions taken from the glossaries of over 500 UL Standards for Safety.

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UL 913

STANDARD FOR

INTRINSICALLY SAFE APPARATUS AND ASSOCIATED APPARATUS FOR USE IN CLASS I, II, AND III, DIVISION 1, HAZARDOUS (CLASSIFIED) LOCATIONS

First Edition — November, 1971
(First Edition titled Standard for Intrinsically Safe Electrical Equipment for Use in Hazardous Locations)
Second Edition — January, 1976
(Second Edition titled Standard for Intrinsically Safe Electrical Circuits and Apparatus for Use in Hazardous Locations and its associated Apparatus)
Third Edition — July, 1979

FOURTH EDITION

July 29, 1988

Approval as an American National Standard covers the numbered paragraphs on pages dated July 29, 1988. These pages should not be discarded when revised or additional pages are issued if it is desired to retain the approved text. Revisions of this standard will be made by issuing revised or additional pages bearing their dates of issue.

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

Approved as ANSI/UL/NFPA 49-13-1979, November 5, 1979
Approved as ANSI/UL 913-1988, May 20, 1988

Figures 2 — 4 and 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 5 and 6 are from "Some Aspects of the Design of Intrinsically Safe Circuits," Research Report 256 by D. W. Widgenton, Safety in Mines Research Establishment, Sheffield, England, 1968.

CONTENTS

SECTION

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.

1. General

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

1.1 Scope.

1.1.1 This standard applies to:

(1) Apparatus or parts of apparatus in Class I, II, or III, Division 1 locations[1];

(2) 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.

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

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

(1) An ambient temperature of 40°C (104°F);

(2) An oxygen concentration not greater than 21 percent; and

(3) A pressure of one atmosphere.

1.1.3 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.

[1]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 Purpose.

1.2.1 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.

1.2.2 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.

1.3 Applicability of Other Standards.

1.3.1 Except where modified by the requirements of this standard, intrinsically safe and associated apparatus shall comply with the applicable requirements for ordinary locations.[1]

1.3.2 Associated apparatus and circuits shall conform to the requirements of the location in which the apparatus and circuits are installed.[2]

1.4 Definitions.

1.4.1 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:

(1) Electrical apparatus that has an alternative type of protection for use in the appropriate potentially flammable atmosphere; or

(2) Electrical apparatus not so protected that shall not be used within a potentially flammable atmosphere.

[1]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.

[2]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.

1.4.2 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.

1.4.3* 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.

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

1.4.5 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.

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

1.4.7 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.

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

1.4.9 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.

1.4.10 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.

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

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

1.4.13 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.

1.4.14 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.

1.4.15 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.

1.4.16 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.

1.4.17 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.

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

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

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

1.4.21 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.

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

1.4.22.1 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.

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

1.5 Control Drawing.

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

Paragraph 1.5.1 effective September 13, 1991

1.5.2 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.

Paragraph 1.5.2 effective September 13, 1991

2. Evaluation of Intrinsic Safety

2.1 Fundamental Requirements. Intrinsically safe apparatus and circuits shall comply with the two basic requirements specified in 2.1.1 and 2.1.2.

2.1.1 The energy available in the hazardous location shall not be capable of igniting the flammable mixture specified in 8.3.1 through 8.3.5 due to arcing or hot surfaces during normal operation.

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

(1) Supply voltage at maximum rated value;

(2) Environmental conditions within the ratings given for the intrinsically safe apparatus or associated apparatus;

(3) Tolerances of all components in the combination that represents the most unfavorable condition;

(4) Adjustments at the most unfavorable settings;

(5) 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.

2.1.1.2* 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 8.6 through 8.6.4.

2.1.2 The energy available in the hazardous location shall not be capable of igniting the flammable mixture specified in 8.3.1 through 8.3.5 due to arcing or hot surfaces under fault conditions. Before faults are introduced, the apparatus is to be in normal operation as specified in 2.1.1.1.

2.1.2.1 Fault conditions are to include the following:

(1) The most unfavorable single fault and any subsequent related defects and breakdowns, with an additional test factor of 1.5 applied to energy;

(2) 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 8.6 through 8.6.4.

2.1.3 Apparatus in which no fault or only one fault can occur shall be considered acceptable if it complies with (1) the test requirements for normal operation as described in 2.1.1.1 with an additional test factor of 1.5 applied to energy, (2) the test requirements for any fault that can occur with an additional test factor of 1.5 applied to energy, and (3) the requirements of this standard.

2.1.4 All intrinsically safe and associated apparatus and circuits shall comply with the requirements in Sections 3 and 4.

2.2 Evaluation Procedure. Circuits are to be evaluated for intrinsic safety as specified in 2.2.1 through 2.2.4.

2.2.1* The circuits are to be analyzed to determine circuit parameters under the normal and fault conditions specified in 2.1 through 2.1.4. For intrinsically safe apparatus, each possible ignition point where circuit interruption, short circuit, or ground fault may occur is to be considered.

2.2.2 Construction details and temperatures are to be reviewed for compliance with Sections 3 and 4. The apparatus shall comply with the applicable test procedures of Section 7.

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

(1) Testing the circuit according to the test requirements of Section 8; or

(2) Comparing the calculated or measured values of current, voltage, and associated inductances and capacitances to the appropriate figures in Section 5 to establish that the current and voltage levels are below the specified values in 5.2.1 through 5.2.2.

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

(1) Sources of spark ignition:

(a) Discharge of a capacitive circuit;

(b) Interruption of an inductive circuit;

(c) Intermittent making and breaking of a resistive circuit;

(d) Hot wire fusing.

(2) Sources of thermal ignition:

(a) Heating of small gage wire strand;

(b) Glowing of a filament;

(c) High surface temperature of components.

2.3* Entity Evaluation. The requirements in 2.4 through 2.7.3 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 2.4 through 2.7.3.

Paragraph 2.3 effective September 13, 1991

2.4* Associated Apparatus Evaluation. Associated apparatus is to be evaluated to determine that the output is intrinsically safe. Associated apparatus shall comply with 2.1 through 2.2.4.

Paragraph 2.4 effective September 13, 1991

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

(1) No faults and the most unfavorable normal operating condition.

(2) The most unfavorable one fault condition.

(3) The most unfavorable two fault condition.

Paragraph 2.4.1 effective September 13, 1991

2.4.2 The maximum output current is to be the highest short-circuit current obtainable under the conditions specified in 2.4.1.

Paragraph 2.4.2 effective September 13, 1991

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

(1) 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.

(2) The maximum capacitance that does not cause ignition at the maximum output voltage if this voltage was determined with two faults.

Paragraph 2.4.3 effective September 13, 1991

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

(1) 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.

(2) The maximum inductance that does not cause ignition at the maximum output current if this current was determined with two faults.

Paragraph 2.4.4 effective September 13, 1991

2.5* Intrinsically Safe Apparatus Inductance and Capacitance Determination. 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:

(1) Inspection or analytical computation; or

(2) Confirmation of the value by testing in accordance with 7.14.1 through 7.14.6, if the apparatus manufacturer declares a maximum internal capacitance or maximum internal inductance value; or

(3) Derivation of the value of maximum internal capacitance or maximum internal inductance using the procedure specified in 7.14.1 through 7.14.6.

Paragraph 2.5 effective September 13, 1991

2.6* Intrinsically Safe and Associated Apparatus Control Drawing. 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.

Paragraph 2.6 effective September 13, 1991

2.6.1 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.

Paragraph 2.6.1 effective September 13, 1991

2.6.2 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.

Paragraph 2.6.2 effective September 13, 1991

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

Paragraph 2.6.3 effective September 13, 1991

2.6.4 The shorting and grounding specified in 2.6.3 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)

Paragraph 2.6.4 effective September 13, 1991

2.6.5 The shorting and grounding specified in 2.6.3 shall not be a countable fault if connection is considered because of inadequate spacing within the intrinsically safe apparatus.

Paragraph 2.6.5 effective September 13, 1991

2.6.6 The shorting and grounding specified in 2.6.3 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.

Paragraph 2.6.6 effective September 13, 1991

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

(1) The polarity requirements for associated apparatus.

(2) That associated apparatus must not be connected in parallel unless this is permitted by the associated apparatus approval.

(3) How to calculate the allowed capacitance and inductance values for field wiring used in the intrinsically safe circuit.

Paragraph 2.6.7 effective September 13, 1991

2.7 Intrinsically Safe Apparatus Evaluation. Intrinsically safe apparatus is to be evaluated for the possibility of arc ignition or hot surface ignition using 2.1 through 2.2.4. 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 2.6 through 2.6.7.

Paragraph 2.7 effective September 13, 1991

2.7.1 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.

Paragraph 2.7.1 effective September 13, 1991

2.7.2 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.

Paragraph 2.7.2 effective September 13, 1991

2.7.3 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 2.1.2.1.

Paragraph 2.7.3 effective September 13, 1991

3. Construction Requirements

3.1* Creepage and Clearance Distances. 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 1, except as noted in 3.1.1 through 3.1.7.

Paragraph 3.1 effective September 13, 1991

TABLE 1
CLEARANCES, CREEPAGE DISTANCES, AND DISTANCES THROUGH CASTING COMPOUND AND INSULATIONS[a,b]

(TS-410)

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[d]															
	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	2.236	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 nominal 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.

Table 1 effective September 13, 1991

3.1.1 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 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 2.2 through 2.2.4.

3.1.2 If the separation between two conductors is less than one third of that specified in Table 1, the conductors are to be considered connected if connection results in the most severe condition.

3.1.3* If more than two conductors are involved and the spacing between adjacent conductors is less than one third the applicable value in Table 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.

3.1.4* The requirements in 3.1 also apply where breakdown between intrinsically safe circuits could increase the energy in the circuit so that it is no longer intrinsically safe.

3.1.5 The requirements in 3.1.1 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.

3.1.5.1 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.)[1] thick, attached to a rigid, grounded metal portion of the apparatus and complying with the test requirements in 7.8.1 is presumed to comply with the requirements of this subsection.

3.1.6 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.

Paragraph 3.1.6 effective September 13, 1991

3.1.7 Printed Wiring Boards. Printed wiring boards shall comply with the creepage distances specified in Table 1. The creepage distances under coating apply to printed wiring boards that are protected by an adherent insulating coating that is:

(1) 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

(2) A single layer not less than 0.7 mm (0.028 in.) thick; or

(3) A single layer, and the printed wiring board complies with the dielectric voltage-withstand test in 7.7.3.

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

3.2* Encapsulation. If encapsulation is used to separate conductors and components of an intrinsically safe circuit from (1) nonintrinsically safe circuits, (2) other intrinsically safe circuits, (3) other parts of the same circuit, or (4) grounded metal, the encapsulant shall:

(1) Comply with the Distance Through Casting Compound values in line 6 of Table 1.

(2) Be adherent to any emerging conductors or components, including printed wiring board substrates,

(3) Have sufficient rigidity to comply with the test requirements specified in 7.13.1 through 7.13.3 if the encapsulated enclosure is intended for use without additional enclosure, such as a partition device.

(4) Have a temperature rating at least equal to the maximum temperature of any encapsulated component or conductor achieved under fault conditions after encapsulation, and

(5) Have the comparative tracking index as required in Table 1 if any uninsulated conductors or components exit the encapsulant.

Paragraph 3.2 effective September 13, 1991

3.2.1 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 1, but no less than 1 mm.

(1) Piezoelectric devices and their connection to any suppression devices.

(2) Energy storage devices and their suppression components where breakage of the connection could occur.

Paragraph 3.2.1 effective September 13, 1991

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

Paragraph 3.2.2 effective September 13, 1991

3.2.3 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.

Paragraph 3.2.3 effective September 13, 1991

3.2.4 The free surface of the encapsulant shall comply with the test requirements in 7.13.1. If the encapsulant is not protected from shock by another enclosure or partition it shall comply with 7.13.2.

Paragraph 3.2.4 effective September 13, 1991

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

Paragraph 3.2.5 effective September 13, 1991

3.3 Field Wiring Connections. Terminals for intrinsically safe circuits shall be adequately separated from terminals for nonintrinsically safe circuits by one or more of the methods described in 3.3.1 through 3.3.3.

3.3.1 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.[1]

3.3.2 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.

1 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.

3.3.2.1 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.

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

Paragraph 3.3.2.2 effective September 13, 1991

3.3.2.3 Metal partitions shall be grounded and shall possess sufficient strength and rigidity that they are not likely to be damaged during field wiring. (See 3.1.5.1.)

Paragraph 3.3.2.3 effective September 13, 1991

3.3.2.4 Nonmetallic insulating partitions shall possess sufficient thickness and shall be so supported that they cannot be readily deformed to defeat their purpose. See 7.8.1.

3.3.3 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.

3.4 Internal Wiring Conductors. Internal wiring conductors that are not rigidly supported so as to maintain the spacings specified in Table 1 shall be insulated according to 3.4.1 and 3.4.2, and separated according to 3.4.3.

3.4.1 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 7.7.1(1).

3.4.2 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 2 U + 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 7.7.1 through 7.7.3 for dielectric voltage test procedure.)

Exception: A dc test voltage may be used as described in 7.7.1(1).

3.4.3* 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.

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

3.5.1 Transformers. Transformers used as protective components for supplying intrinsically safe circuits shall comply with the following construction requirements and the test requirements in 7.1.1.1 through 7.1.2.3.

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

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.

Type 1(b) — The windings are on different legs of the core.

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.

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.[1] (See 3.5.1.2.)

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 A3.4.1 and A3.4.1.1.)

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

(1) 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.

(2) 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 mm^2).

(3) A wire-wound shield shall consist of at least two layers of windings.

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

3.5.1.4 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.

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

3.5.2 Damping Windings. 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.

3.5.3 Current-Limiting Resistors. Current-limiting resistors are to be considered not subject to short-circuit faults, if (1) 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 (2) if they comply with the requirements in 7.2 and 7.2.1.

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

3.5.4 Blocking Capacitors. 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.

3.5.5 Shunt Protective Components. 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.

3.5.6 Shunt Diode Barriers. Shunt diode barriers are to be considered protective assemblies, as defined in 1.4.22.1 and 1.4.22.2, if they comply with the requirements of 3.5.6.1 through 3.5.6.7.

3.5.6.1 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.

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

(1) Resistor-protected barrier diodes comply with the requirements in 7.3.1 and 7.3.1.1.

(2) The fuse of a fuse-protected barrier operates at least 10 times faster than the open circuit time of the diode, as specified in 7.3.3; 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 50uS 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.

(3) Barrier shunt diodes are duplicated so that the assembly remains effective if one of the diodes open circuits.

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

3.5.6.4 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:

(1) 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.

(2) 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.)

(3) Bolting the barrier to a grounding bus.

3.5.6.5 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).

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

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

3.5.7 Optical Isolators. 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 7.4.1 through 7.4.3.

3.6 Miscellaneous Components.

3.6.1 Derating of Components.

3.6.1.1* During normal operation conditions as defined in 2.1.1.1, 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.

3.6.1.2 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 2.1.2 and 2.1.2.1 are assumed, taking into account overcurrent protection devices.

3.6.2 Plug-In Boards and Components. 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.

3.6.3* Relays. Where intrinsically safe and nonintrinsically safe circuits are connected to the same relay, the creepage and clearance distances shall comply with 3.1. Except as specified in 3.6.3.1, 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 1.

3.6.3.1 With respect to the requirement in 3.6.3, 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.

3.7 Portable Apparatus Enclosures.

3.7.1 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.

Paragraph 3.7.1 effective September 13, 1991

3.8 Cells and Batteries. 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.

3.8.1 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 ignitible concentrations.

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

3.8.3 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.

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

3.8.5* When conducting tests which require applying a factor of 1.5 applied to energy, in accordance with 8.6 through 8.6.4, one of the following methods, or its equivalent, is to be used:

(1) 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.

(2) 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.

(3) 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.

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

3.8.6 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.

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

(1) 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 1.

(2) 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.

(3) 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 7.9.1.

(4) The apparatus shall be marked to warn against replacement of the batteries in a hazardous location, as described in 4.2.4.

Item (1) of paragraph 3.8.7 effective September 13, 1991

3.8.8 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 7.9.1.

3.8.9* 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:

(1) 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.

(2) 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.

(3) Separately recessing each contact of a pair of contacts so that a circular disc probe as defined in (2) above cannot touch either contact. In this case, short-circuiting of the pair of charging contacts is to be counted as two faults.

(4) 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 (2) 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.

3.8.9.1 If the charging contacts are not arranged in accordance with 3.8.9(2), 3.8.9(3), or 3.8.9(4), short-circuiting of the charging contacts is to be considered a condition of normal operation.

3.8.9.2 If the charging contacts are not separated in accordance with the minimum distances required in 3.1, short-circuiting of the charging contacts is to be considered a condition of normal operation.

4. Additional Requirements

4.1* Maximum Temperature.

4.1.1 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°0 (212°F).

Exception: Rather than measuring temperatures, the apparatus may be subjected to the test specified in 7.6 through 7.6.5.

4.1.2* 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 2, or the following equation, temperature tests to determine its maximum surface temperature are not necessary.

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

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,

t is the maximum acceptable wire temperature, °C.

TABLE 2
CURRENTS IN COPPER WIRE[a]

(TC-720)

Minimum Conductor Size[b]					Maximum Conductor Current, Amperes, for Apparatus Rated T4, T5, or T6		
Diameter		Area		(Wire Size, AWG)			
mm	(Mils)	mm^2 $x10^{-3}$	In. 2 $x10^{-5}$		T4	T5	T6
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.

4.1.3* Temperatures higher than that of the marked operating temperature per 4.2.1(3) shall be permitted for small components, for example, transistors or resistors, if it is shown by the test procedures described in 7.6 through 7.6.5 and 7.11.1 through 7.11.3 that the temperature is insufficient to cause ignition or charring.

4.2 Marking.

4.2.1 The minimum marking shall include the following:

(1) Identification of the apparatus, including manufacturer's name or trademark and type or model designation;

(2) Hazardous location class and group;

(3) 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.

(4) For shunt diode and similar protective barrier assemblies which are intended for field or panel installation, the maximum nonhazardous location voltage. (See 3.5.6.1.)

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

Item (5) of paragraph 4.2.1 effective September 13, 1991

4.2.2* In addition to the minimum marking specified in 4.2.1, 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.

(1) For intrinsically safe apparatus:

(a) An indication that the apparatus is intrinsically safe;

(b) If investigated using the entity evaluation, the maximum input voltage, maximum input current, maximum internal capacitance and maximum internal inductance;

(c) If repair is possible, a warning label worded "Warning — Substitution of Components May Impair Intrinsic Safety;" and

(d) 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.

(2) For associated apparatus:

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

(b) If repair is possible, a warning worded "Warning — Substitution of Components May Impair Intrinsic Safety;"

(c) Any other necessary information, in particular, an indication of any other type of protection and its characteristics; and

(d) 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.

Subitem (b) in item (1) and Subitem (a) in item (2) of paragraph 4.2.2 effective September 13, 1991

4.2.3 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.

4.2.4 Battery-powered apparatus shall be marked with a caution statement to (1) indicate the type, size, and voltage of batteries to be used or (2) 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."

5. Comparison Procedure for Determining Spark Ignition Capability

5.1* General.[1]

5.1.1 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 5.2.1 through 5.2.2.2.

1 All figures, except Figures 5 and 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 5 and 6 are from "Some Aspects of the Design of Intrinsically Safe Circuits," Research Report 256, 1968, by D. W. Widgenton, Safety in Mines Research Establishment, Sheffield, England.

5.1.2 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 5.2.1 through 5.2.2.2 are to be evaluated by the test procedures in Section 8.

5.1.3 Resistance Circuits. Figures 1 and 2 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.

5.1.4 Resistance-Inductance Circuits. Figures 3 and 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 5 and 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.

5.1.5 Resistance-Capacitance Circuits. Figures 7 and 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.

5.2 Maximum Voltage and Current Levels.

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

5.2.2 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 5.2.2.1 and 5.2.2.2, for given circuit constants.

5.2.2.1 For normal or single-fault operation, the current shall not exceed 80 percent of the value determined from Figures 1 through 6. The voltage shall not exceed 80 percent of the value determined from Figures 7 and 8.

5.2.2.2 For two-fault condition, the current shall not exceed 90 percent of the value determined from Figures 1 through 6. The voltage shall not exceed 90 percent of the value determined from Figures 7 and 8.

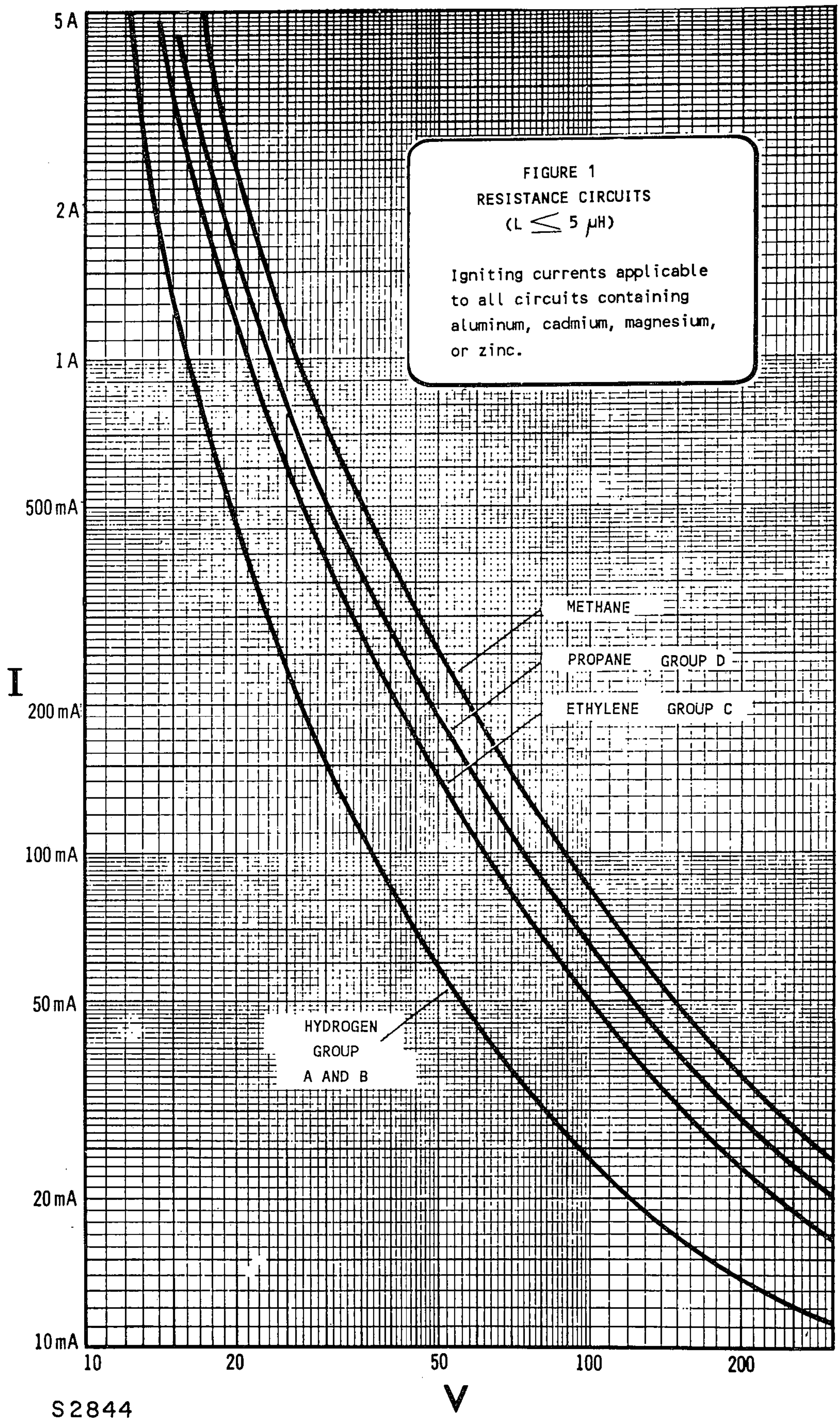


FIGURE 1
RESISTANCE CIRCUITS
(L ≤ 5 μH)
Igniting currents applicable to all circuits containing aluminum, cadmium, magnesium, or zinc.
METHANE
PROPANE GROUP D
ETHYLENE GROUP C
HYDROGEN GROUP A AND B
5 A
2 A
1 A
500 mA
200 mA
100 mA
50 mA
20 mA
10 mA
I
10
20
50
100
200
V
S2844

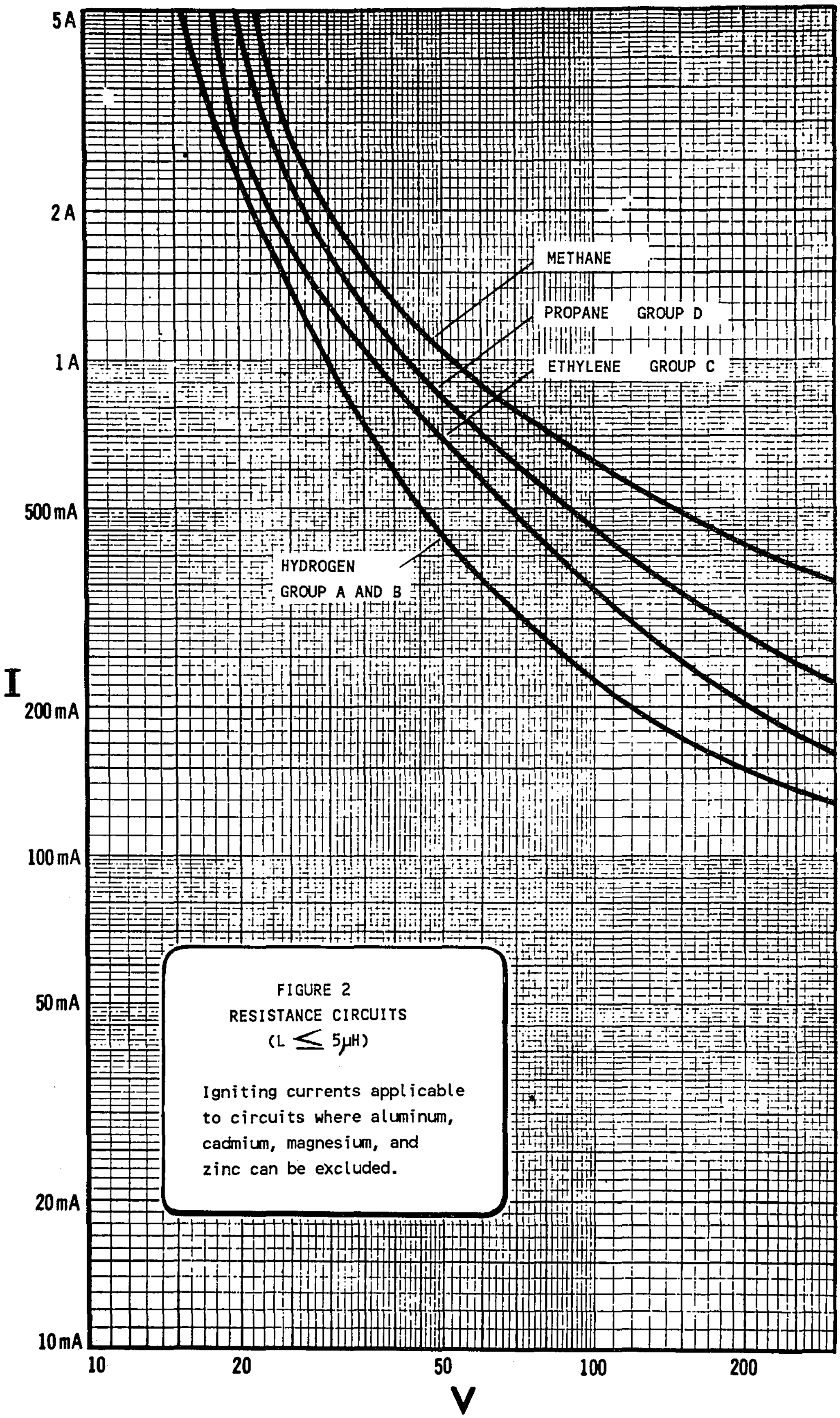


FIGURE 2
RESISTANCE CIRCUITS
(L ≤ 5μH)

Igniting currents applicable to circuits where aluminum, cadmium, magnesium, and zinc can be excluded.

S2845

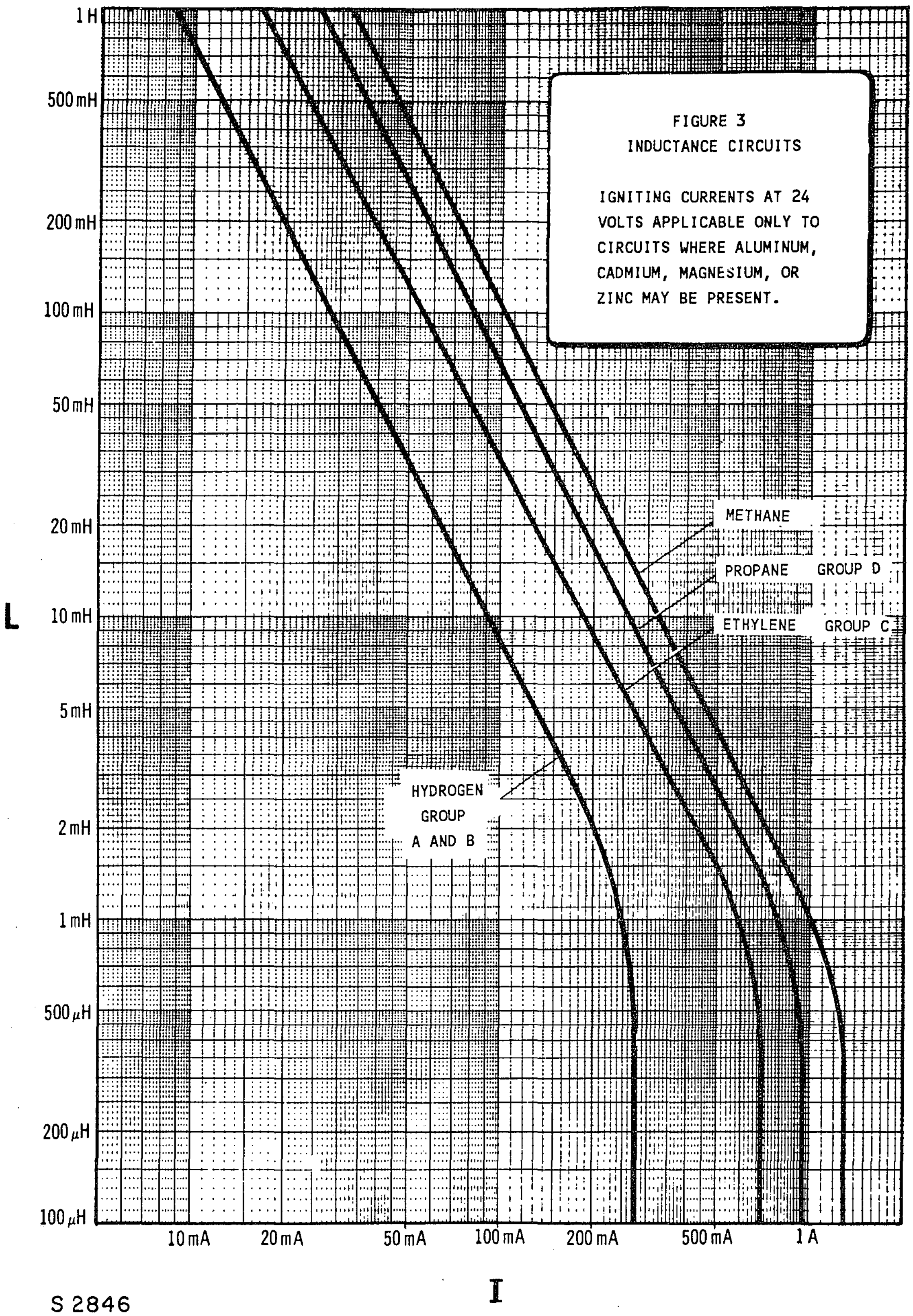


FIGURE 3
INDUCTANCE CIRCUITS
IGNITING CURRENTS AT 24 VOLTS APPLICABLE ONLY TO CIRCUITS WHERE ALUMINUM, CADMIUM, MAGNESIUM, OR ZINC MAY BE PRESENT.
1 H
500 mH
200 mH
100 mH
50 mH
20 mH
10 mH
5 mH
2 mH
1 mH
500 µH
200 µH
100 µH
L
METHANE
PROPANE
GROUP D
ETHYLENE
GROUP C
HYDROGEN
GROUP
A AND B
10 mA
20 mA
50 mA
100 mA
200 mA
500 mA
1 A
I

S 2846

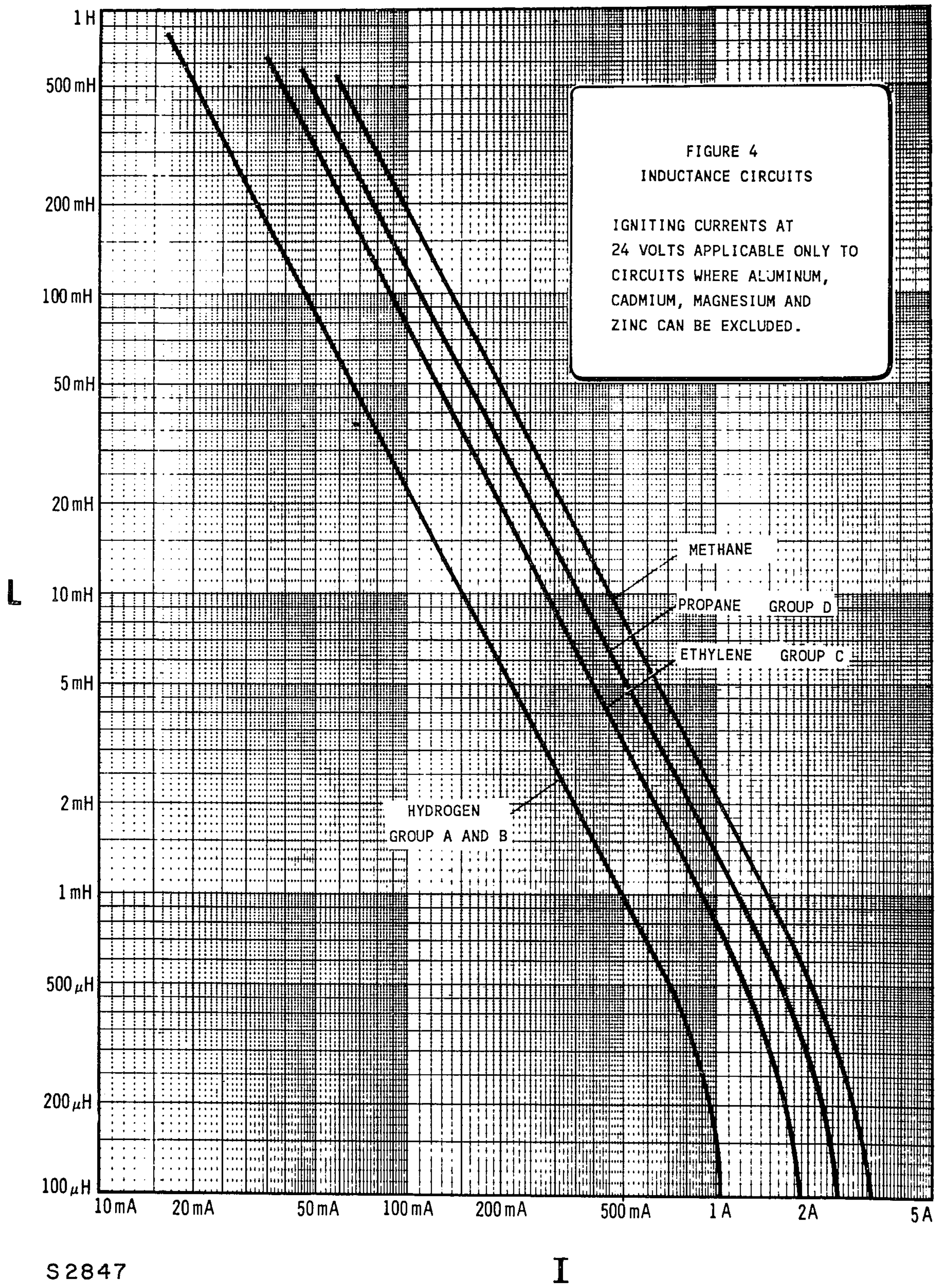
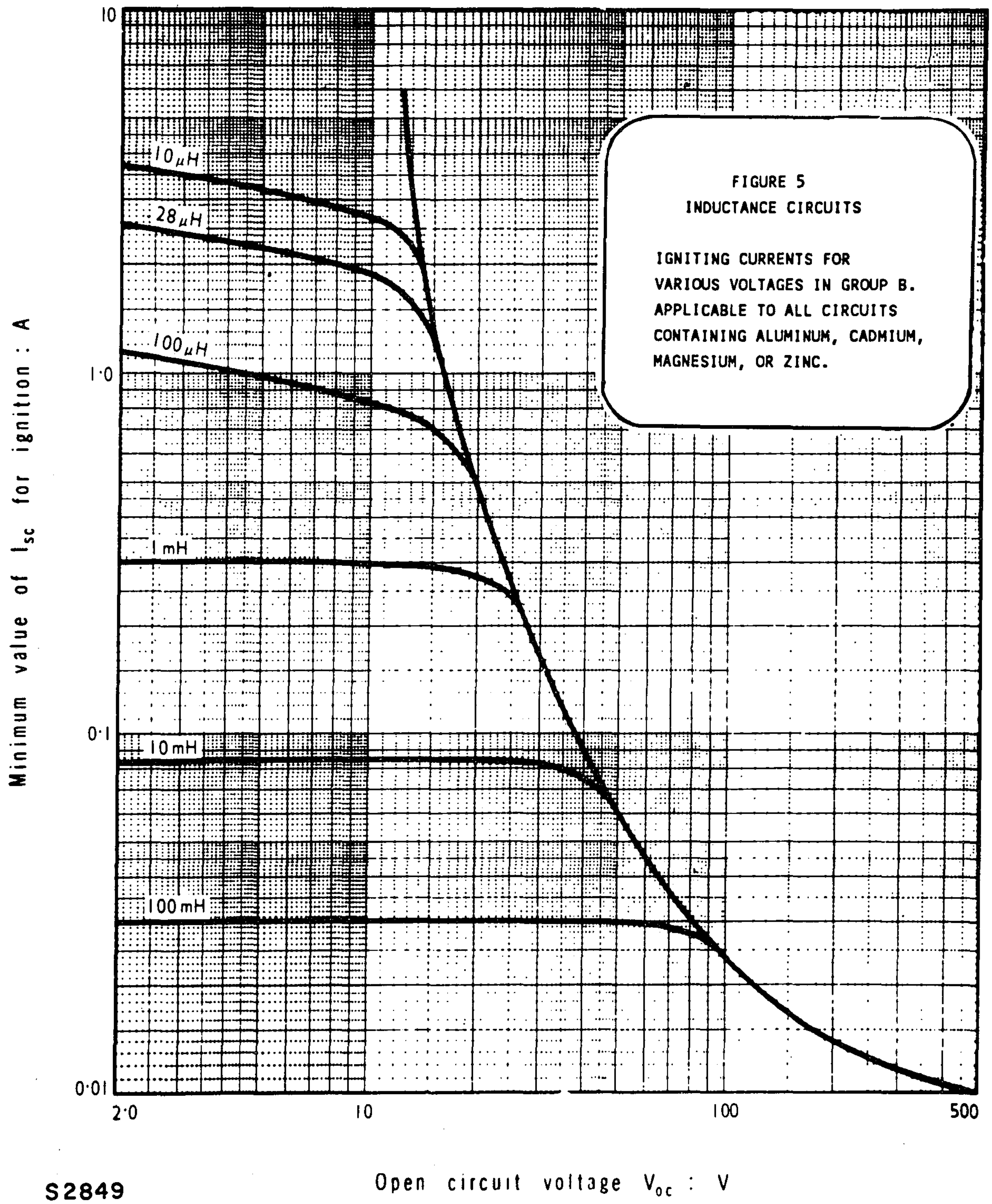


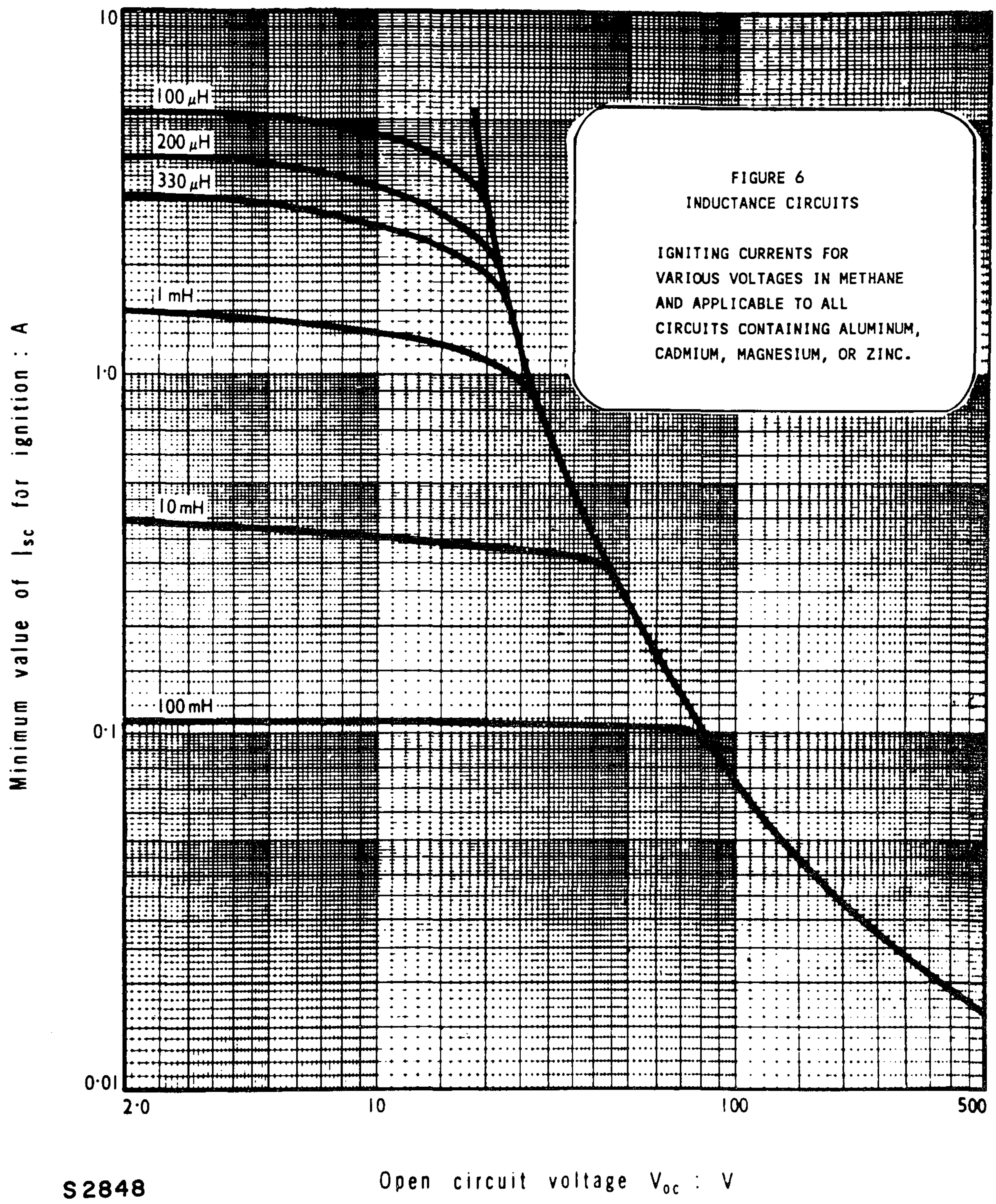
FIGURE 4
INDUCTANCE CIRCUITS
IGNITING CURRENTS AT
24 VOLTS APPLICABLE ONLY TO
CIRCUITS WHERE ALUMINUM,
CADMIUM, MAGNESIUM AND
ZINC CAN BE EXCLUDED.
METHANE
PROPANE GROUP D
ETHYLENE GROUP C
HYDROGEN
GROUP A AND B
L
1 H
500 mH
200 mH
100 mH
50 mH
20 mH
10 mH
5 mH
2 mH
1 mH
500 μH
200 μH
100 μH
10 mA
20 mA
50 mA
100 mA
200 mA
500 mA
1 A
2A
5 A
I

S2847



S2849

*Replaces page 27 dated July 29, 1988



**Replaces page 28 dated July 29, 1988*

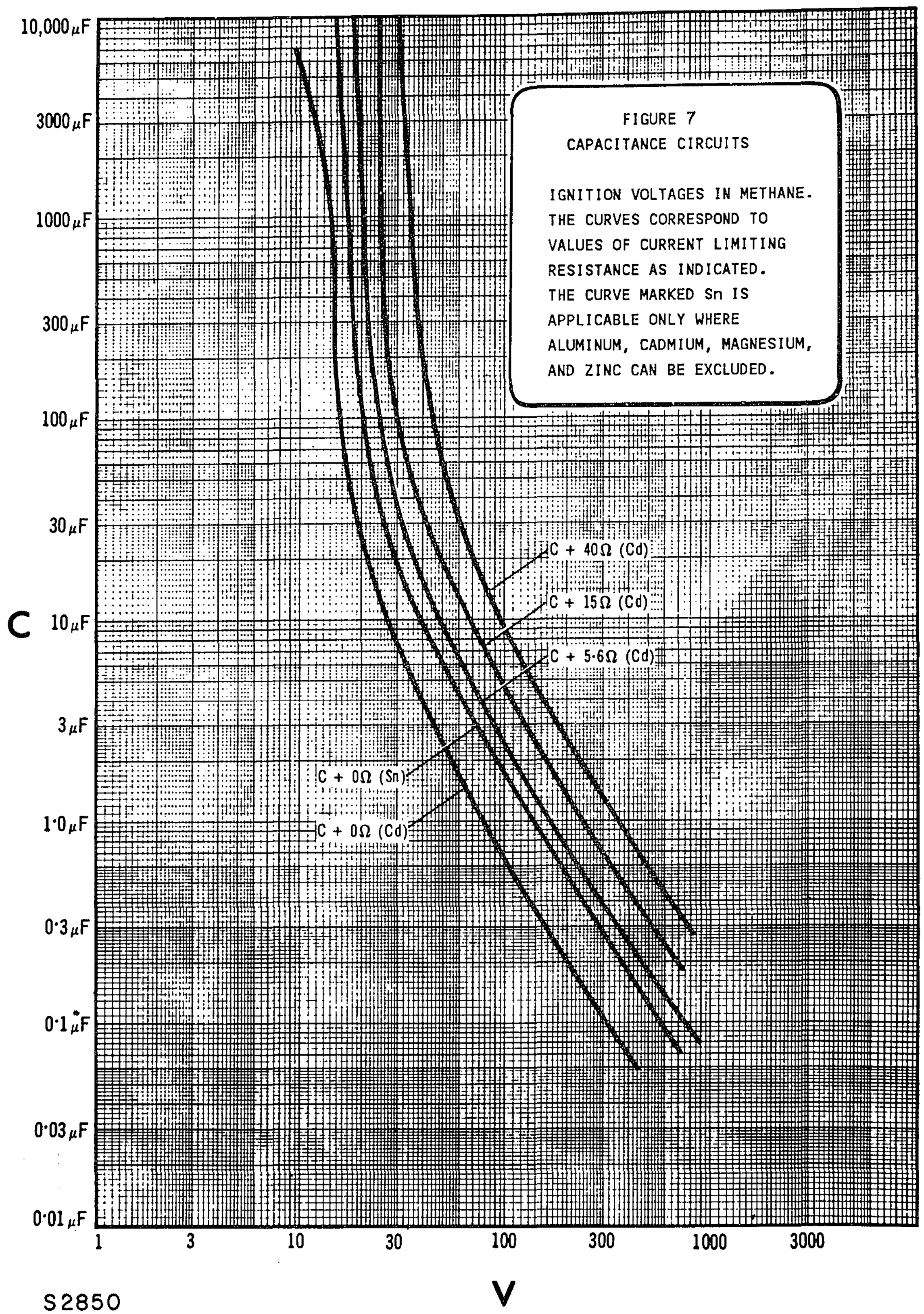


FIGURE 7
CAPACITANCE CIRCUITS
IGNITION VOLTAGES IN METHANE. THE CURVES CORRESPOND TO VALUES OF CURRENT LIMITING RESISTANCE AS INDICATED. THE CURVE MARKED Sn IS APPLICABLE ONLY WHERE ALUMINUM, CADMIUM, MAGNESIUM, AND ZINC CAN BE EXCLUDED.
C + 40Ω (Cd)
C + 15Ω (Cd)
C + 5·6Ω (Cd)
C + 0Ω (Sn)
C + 0Ω (Cd)
C
10,000 μF
3000 μF
1000 μF
300 μF
100 μF
30 μF
10 μF
3 μF
1·0 μF
0·3 μF
0·1 μF
0·03 μF
0·01 μF
1
3
10
30
100
300
1000
3000
V

S2850

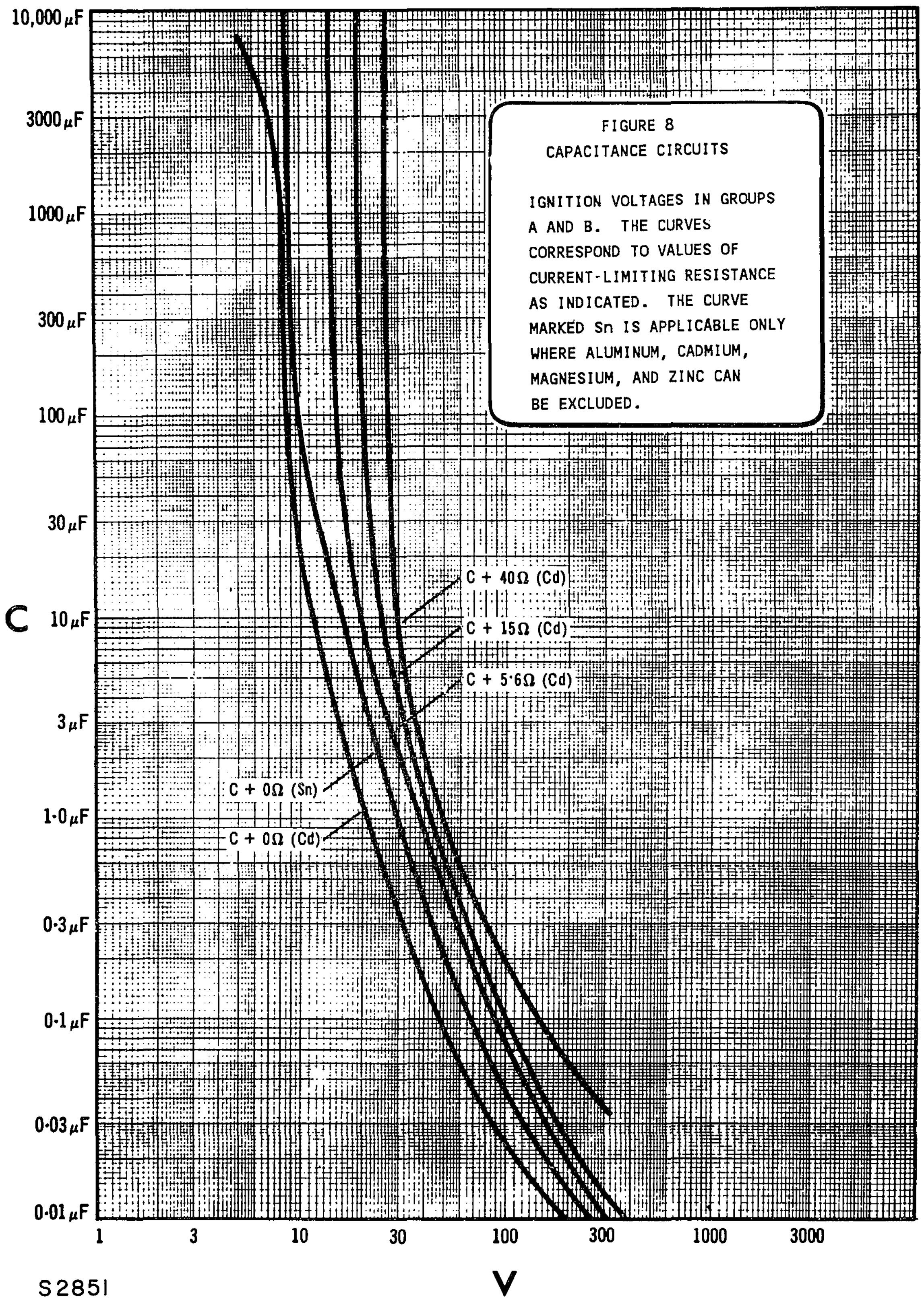


FIGURE 8
CAPACITANCE CIRCUITS
IGNITION VOLTAGES IN GROUPS A AND B. THE CURVES CORRESPOND TO VALUES OF CURRENT-LIMITING RESISTANCE AS INDICATED. THE CURVE MARKED Sn IS APPLICABLE ONLY WHERE ALUMINUM, CADMIUM, MAGNESIUM, AND ZINC CAN BE EXCLUDED.
C + 40Ω (Cd)
C + 15Ω (Cd)
C + 5·6Ω (Cd)
C + 0Ω (Sn)
C + 0Ω (Cd)
10,000 μF
3000 μF
1000 μF
300 μF
100 μF
30 μF
10 μF
3 μF
1·0 μF
0·3 μF
0·1 μF
0·03 μF
0·01 μF
C
1
3
10
30
100
300
1000
3000
V
S2851

6. Apparatus for Class II and Class III Locations

6.1 Applicability of Other Requirements in this Standard.

6.1.1 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 5 in this standard.

6.2 Specific Requirements for Intrinsic Safety.

6.2.1 Apparatus and associated wiring that complies with the requirements in Sections 1 through 5 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 6.2.2 and either 6.2.3 or 6.2.4.

6.2.2 The temperature of exposed surfaces of apparatus shall not exceed the following values when tested according to the procedures described in 7.11.1 through 7.11.3. 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 7.11.1 through 7.11.3.

6.2.3 Except as specified in 6.2.4, intrinsically safe apparatus shall be enclosed in a dust-tight enclosure that complies with the requirements in 6.3.1 through 6.3.1.2. 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

6.2.4* Intrinsically safe apparatus not enclosed in a dust-tight enclosure complying with the requirements in 6.3.1 through 6.3.1.2 shall comply with the spark ignition requirements specified in 6.2.3. In this case, it is to be assumed that all spacings do not comply with the creepage and clearance distance requirements specified in 3.1 and that all connections between live or grounded parts and conductors are in the most unfavorable condition. The number of such connections is unlimited.

6.3* Dust-Tight Enclosures.

6.3.1 For the purposes of this standard, an enclosure is considered suitable if it (1) complies with the requirements in 6.3.1.1 or 6.3.1.2, or (2) complies with the requirements in 7.10, or (3) is dust-ignitionproof. In addition, a portable apparatus shall be dust-tight after the drop test described in 7.9.1.

6.3.1.1 An enclosure is considered suitable if (1) it conforms to applicable requirements for enclosures for ordinary locations, (2) it has no openings, and (3) all joints are either threaded with a three full-thread minimum engagement or sealed by continuous welding, brazing, soldering or fusion of glass.

6.3.1.2 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.

7. Test Procedures

7.1 Protective Transformers Tests.

7.1.1 Routine Tests.

7.1.1.1 Transformers for direct connection to an external supply shall be capable of withstanding the following test voltages. (See 7.7.1 through 7.7.3.)

Where Applied	rms Test Voltages
	(U_n = highest rated voltage of any winding)
Between input and output windings.	$4U_n$ 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.

7.1.1.2 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.

7.1.2 Type Tests. 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 7.7.1 through 7.7.3.)

7.1.2.1 Type 1(a) and Type 1(b) Transformers.

(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.

(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.

(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.

7.1.2.2 Type 2(a) Transformer.

(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.

(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.

(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.

7.1.2.3 Type 3 Transformer. 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.

7.2 Current-Limiting Resistor. As a result of being subjected to 1.5 times the maximum fault voltage appearing across a current-limiting resistor, it shall (1) open circuit, (2) increase in resistance, or (3) 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 (1) a current of 1.7 times the current rating of the fuse without the fuse in the circuit, and (2) 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.

7.2.1 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.

7.3 Shunt Diode Protective Barrier Tests.

7.3.1 Resistor-protected barrier diodes shall either (1) withstand without damage or (2) 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.

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

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

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

(1) 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.

(2) 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.

7.4. Optical Isolator Tests.

7.4.1 An optical isolator in a secondary circuit shall withstand the test voltage specified in 7.1.1.2.

7.4.2 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 7.4.3. 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 7.7.1(1) through 7.7.1(3) and 7.7.2.

7.4.3 With regard to 7.4.2, 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.

7.5. Temperature Tests.

7.5.1 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.

7.5.1.1 Temperatures are to be measured either by thermocouples consisting of wires not larger than No. 24 AWG (0.21 mm^2) or by equivalent means.

Exception: Coil temperatures may be determined by the method described in 7.5.1.7.

7.5.1.2 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: (1) on the integrally applied insulation of a coil without a wrap, or (2) 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.

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

7.5.1.4 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.

7.5.1.5 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.[1]

7.5.1.6 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.

7.5.1.7 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:

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

where

Δt = the temperature rise, °C

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

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

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

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

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

[1] Available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

7.6 Small Component Ignition Test. 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 7.6.1 through 7.6.4.

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

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

7.6.3 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.

7.6.4* 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 7.6.2, that is, the temperature rise of more than one component exceeds the marked operating temperature.

7.6.5 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.

7.7 Dielectric Tests.

7.7.1 The following test method is to be used:

(1) 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.

(2) The supply is to have sufficient volt-ampere capacity to maintain the test voltage, taking into account any leakage current that may occur.

(3) 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.

(4) For routine tests, the test voltage may be increased 20 percent and applied for not less than 1 second.

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

7.7.3 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 7.7.1 and 7.7.2 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 1 and the values specified in Table 3.

TABLE 3
COATED BOARD WITHSTAND TEST VALUES
(TV-110)

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

7.8 Mechanical Tests.

7.8.1 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.

7.9 Drop Test.

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

(1) 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.

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

7.10 Dust-Tight Enclosure Test. 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).[1]

[1] Available from National Electrical Manufacturers Association., 2101 "L" Street, N.W., Washington, DC 20037.

7.11 Dust Blanketing Temperature Test.

7.11.1 The apparatus is to be mounted in its normal position and covered with the dust mixture specified in 7.11.1.1 until no more will stay on the enclosure or component (see 6.2.2) or to a depth of 12 mm (0.48 in.), whichever is less.

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

(1) Wheat or corn dust (or a mixture of both);

(2) Type 1, General Purpose Portland Cement; or

(3) 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.

7.11.2 The apparatus is to be operated under fault conditions appropriate to the apparatus until all temperatures become constant. See 6.2.1 through 6.2.4.

7.11.3 The temperature of surfaces exposed to dust shall not exceed the values in 6.2.2. 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.

7.12 Lamp Breakage Test.

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

Paragraph 7.12.1 effective September 13, 1991

7.12.2 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 8.3.1 through 8.3.5 in accordance with applicable fault procedures in 2.1.2.1. 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.

Paragraph 7.12.2 effective September 13, 1991

7.13 Encapsulation Tests.

7.13.1 Force Test. 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.

Paragraph 7.13.1 effective September 13, 1991

7.13.2 Impact Test. 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.

Paragraph 7.13.2 effective September 13, 1991

7.13.2.1 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).

Paragraph 7.13.2.1 effective September 13, 1991

7.13.2.2 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.

Paragraph 7.13.2.2 effective September 13, 1991

7.13.3 Solvent Vapor Exposure. 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.

Paragraph 7.13.3 effective September 13, 1991

7.14 Internal Capacitance or Inductance Test.

7.14.1 These requirements apply to apparatus to be investigated in accordance with 2.5(2) or 2.5(3). 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 8.

7.14.2 A variable capacitor is to be tested in accordance with 8.5.1 through 8.5.4. 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 7.14.5) is to be recorded.

7.14.3 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.

7.14.4 The variable capacitor and intrinsically safe apparatus combination is to be tested in accordance with 8.5.1 through 8.5.4. The variable capacitor is again to be adjusted until ignition just does not occur. The value of the variable capacitor (C_2 in 7.14.5) is again recorded.

7.14.5 The maximum internal intrinsically safe apparatus capacitance, C_i, 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.

7.14.6 The procedure described in 7.14.2 through 7.14.5 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 3.

8. Spark Ignition Test

8.1 General Requirements.

8.1.1 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 2, taking into account the appropriate gas group or groups specified in 8.3.1 through 8.3.5. See also 6.2.3.

8.1.2 Normal and fault conditions are to be simulated during the tests. Factors shall be added as described in 8.6 through 8.6.4. Specialized test apparatus as described in 8.2.1 and 8.2.2 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 8.4.1 and 8.4.2.

8.2* Test Apparatus.

8.2.1 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.

8.2.2 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 9. 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.

8.3 Gas Mixtures.[1]

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

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

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

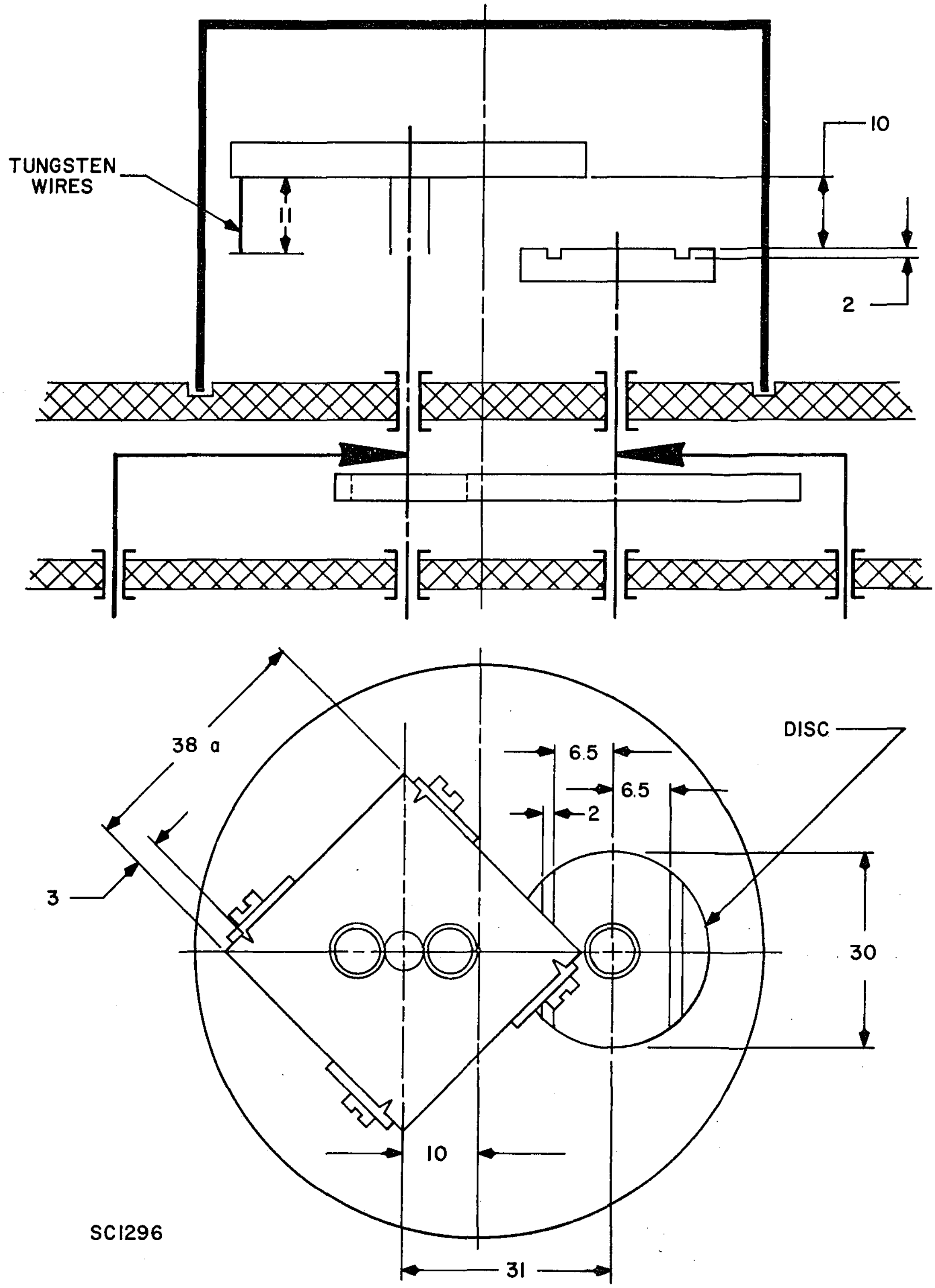
8.3.4 For Class II, Groups E, F, and G, the test mixture is to be 5.25 ± 0.25 percent propane in air or 8.3 ± 0.3 percent methane in air.

8.3.5 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.

[1] 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.

FIGURE 9
TEST APPARATUS FOR EVALUATING
INTRINSICALLY SAFE CIRCUITS

(Measurements are in millimeters)



8.4 Verification of Spark Test Apparatus.

8.4.1 The sensitivity of the spark test apparatus is to be checked before and after each test series carried out in accordance with 8.5.1 through 8.5.4. For this purpose, the test apparatus is to be operated in a 24 volt dc circuit containing a 0.095 H air-core coil. The currents in these circuits are to be set at the values given in Tables 4 and 5 for the appropriate group, and the spark test apparatus is to comply with both the "must ignite" and "must not ignite" specifications in the tables.

TABLE 4
CURENT IN CALIBRATION CIRCUIT FOR CADMIUM DISC
(TP-708)

Group	Inductive Circuit Currents, Milliamperes	
	Must Not Ignite	Must Ignite
A & B	25.5	30
C	49	65
D	71	100
a		110

[a]For tests using methane, see 8.3.4.

TABLE 5
CURENT IN CALIBRATION CIRCUIT FOR TIN DISC
(TP-709)

Group	Inductive Circuit Currents, Milliamperes	
	Must Not Ignite	Must Ignite
A & B	41	50
C	77	90
D	98	100

8.4.2 The spark test apparatus is to be run for 400 revolutions (5 minutes) of the tungsten wire-holder with the holder at positive polarity and is to be considered to be satisfactory only if at least one ignition of the test gas occurs.

8.5 Test Procedure.

8.5.1 After verification, the spark test apparatus is to be inserted in each circuit requiring test as determined in accordance with 2.2 through 2.2.4.

8.5.2 In addition to the conditions described in 2.1 through 2.1.4, for line-connected apparatus the input voltage is to be increased to 110 percent of rated line voltage.

8.5.3 Each circuit is to be tested for the following number of revolutions of the tungsten wire holder in the spark test apparatus:

(1) For dc circuits, not less than 400 revolutions (5 minutes), 200 revolutions at each polarity;

(2) For ac circuits, not less than 1,000 revolutions (12.5 minutes).

8.5.4 After each circuit test, verification of the spark test apparatus is to be repeated as follows: If the circuit test resulted in ignition, the "must not ignite" verification in 8.4.1 and 8.4.2 is to be repeated; if the circuit test did not result in ignition, the "must ignite" verification in 8.4.1 and 8.4.2 is to be repeated. If the verification does not comply with the applicable portion of 8.4.1 and 8.4.2, the spark test on the circuit under investigation is to be considered invalid.

8.6 Test Factors. An additional factor is to be used when applicable. Where an additional factor of 1.5 is required by Section 2, it may be achieved by the methods given in 3.8.5, 8.6.1, 8.6.2, or 8.6.3 or by any method of equivalent severity, for example, the use of more easily ignited test gases.

8.6.1 Inductive circuits: the energy is to be increased by a factor of 1.5 by first reducing the values of limiting resistance as much as practical, and then by increasing the voltage.

8.6.2 Resistive circuits having an inductance less than 5 uH: the energy is to be increased by a factor of 1.5 in order of preference as follows:

(1) Decreasing the values of limiting resistance;

(2) Increasing the line voltage;

(3) Increasing other supply voltages;

(4) Increasing the setting of voltage limiting devices.

8.6.3 Capacitive circuits: the energy is to be increased by a factor of 1.5 by increasing the voltage by a factor of 1.22.

8.6.4 When the test series is being carried out with a fault applied to the circuit, the additional factor is to be applied as indicated in 8.6.1 through 8.6.3 to the values of current and/or voltage that arise under fault conditions.

APPENDIXES

(These appendixes are not part of American National Standard ANSI/UL 912-1988) but are included for information only.)

NOTICE: A number in parentheses following a subsection number in these appendixes is the subsection number in the standard to which the explanatory material applies.

APPENDIX A

Additional Information

A1. General

A1.1 (1.1.1) Division 1 hazardous locations, as defined in NFPA 70-1987, National Electrical Code, include locations defined in many other countries and by the International Electrotechnical Commission (IEC) as Zone 0. Zone 0 locations are hazardous because of the presence of flammable or combustible materials within the flammable range all or a large percentage of the time. In those nations which recognize Zone 0 as well as Zone 1, in which hazardous material may be present in normal operation for a lesser percentage of the time, two sets of requirements for intrinsically safe systems are recognized: ia for Zone 0 and ib for Zone 1. For Zone 0 application, systems must not be capable of causing ignition after consideration of two faults, as in this document. See also A1.2. For systems designed to be installed only in Zone 1 locations, only one fault must be considered. Because Zone 1 is not recognized in NFPA 70-1987, National Electrical Code, intrinsically safe systems must be designed for the more hazardous Zone 0 locations.

A1.2 (1.1.2) The experimental data on which the requirements of this document are based were determined under normal laboratory atmospheric conditions. Ignition parameters are not easy to extrapolate from normal laboratory conditions to other conditions (such as might exist in process vessels) without careful engineering consideration. Increasing the initial temperature of a flammable or combustible mixture will decrease the amount of electrical energy required to cause ignition so that, at the autoignition temperature of a gas or vapor, the electrical energy required for ignition will be zero. The nature of the energy variation between these limits is not well documented. Temperature variations can also change the concentrations of flammable materials in the mixture.

A1.2.1 (1.1.2) Oxygen enrichment decreases the energy necessary for ignition. The minimum ignition energy of mixtures of flammable materials with oxygen may be one percent of that required for the same material mixed with air.

A1.2.2 (1.1.2) As a general rule, the minimum ignition energy is inversely proportional to pressure squared. When examining a situation where the gas mixture is not at atmospheric pressure, one must consider whether a flammable mixture exists under higher pressure conditions. When the mixture is at high pressure many flammable materials will condense.

A1.3 (1.4.3) The concept of intrinsic safety depends upon associated apparatus limiting energy to a safe level and then interconnecting only those intrinsically safe apparatus which can not store ignition capable amounts of energy. Traditionally, the examination was based on a combination of associated and intrinsically safe apparatus, which were specified by manufacturer's name and type number. This traditional method created a serious problem for manufacturers and users in that only a small portion of possible equipment combinations were ever evaluated by a third party testing lab. A need existed for a convenient method of determining if apparatus of different manufacturers could be interconnected in intrinsically safe loops. The entity concept was developed to satisfy this need.

A2. Evaluation of Intrinsic Safety

A2.1 (2.1.1.2) It is recognized that the real margin of safety lies in the use of a test apparatus more sensitive than any probable accident condition, the use of the ideal gas mixture in testing, and the extreme improbability of the coincidence of multiple-circuit faults and external wiring failure at the precise time and place that the ideal gas mixture is present.

A2.1.2 (2.1.1.2) It should be noted that the factors given in this standard differ from those published in the Canadian and European standards. This standard bases the 1.5 factor on energy while other standards base the 1.5 factor on current or voltage which can result in a 2.25 factor on energy. Those using this standard intending to meet standards outside of the U.S. should adjust the factors accordingly.

A2.2 (2.2.1) For evaluation of intrinsic safety, the relevant circuit parameters are open-circuit voltage, short-circuit current, capacitance and inductance.

A2.3 (2.3) The entity concept allows for associated apparatus and intrinsically safe apparatus to be evaluated as separate entities. Apparatus evaluated under the entity concept must have a control drawing that specifies the allowed apparatus and the terminals to which they may be connected. The description is not done in terms of vendor name and type number, but rather by the specified maximum voltage and the specified maximum current. The values specified may be combinations of voltage and current that are above the ignition curve.

A2.3.1 (2.3) At this time, the ignition curves only apply to associated apparatus with linear outputs. Entity listing of intrinsically safe apparatus using associated apparatus with nonlinear outputs must be the subject of special investigation. The control drawing must be explicit in identifying those parameters applicable to linear output associated apparatus and those applicable to nonlinear associated apparatus.

A2.3.2 (2.3) The evaluation does not consider possible summing of maximum output voltages which might be possible with associated apparatus having two or more outputs where the voltage is limited between the outputs, but not between the outputs and ground.

A2.4 (2.4) The output of the associated apparatus is the terminal(s) connected to intrinsically safe field wiring.

A2.5 (2.5) Intrinsically safe apparatus may have a large amount of capacitance mounted inside. A method of protection is to add series resistance. High capacitance with series resistance may be equivalent to a much lower capacitance (but not zero) with no series resistance. The test in 7.14.1 through 7.14.6 is intended to determine the equivalence. If the equivalent capacitance must be determined, it may require several spark ignition tests. The manufacturer may greatly reduce these tests by specifying what the equivalent capacitance might be. Then, after determination of C_1, one test is run with the intrinsically safe apparatus connected in parallel with an adjustable capacitor set to a value of C_1-C_i. If no ignition occurs, then the value is acceptable and must be marked on the unit as the internal capacitance. It is possible that the value specified by the manufacturer may be considerably higher than the actual equivalent capacitance which would have been determined from the more exhaustive series of tests.

A2.6 (2.6) Figure A1 is an example of information to be shown on the control drawing. The specified set(s) of parameters are evaluated to ascertain that permitted fault connections of these associated apparatus do not create an ignition capable circuit.

A2.6.1 (2.6) The phrase "normally provides power" means that if the wire to the intrinsically safe apparatus were disconnected, grounding of the wire would cause a spark when the unspecified apparatus is operating as intended. For example, if the associated apparatus is connected to a 24 volt power supply, grounding would cause a spark.

A2.6.2 (2.6.7) Application of maximum allowable cable capacitance and inductance. When cable parameters are known, the system designer adds the parameters for lengths of cable to be used to the known parameters of the intrinsically safe apparatus. The sums are then compared to the allowable parameters marked on the associated apparatus. If the electrical parameters of the cable are unknown, the following values may be used:

Capacitance - 60 pF/ft
Inductance - 0.20 uH/ft

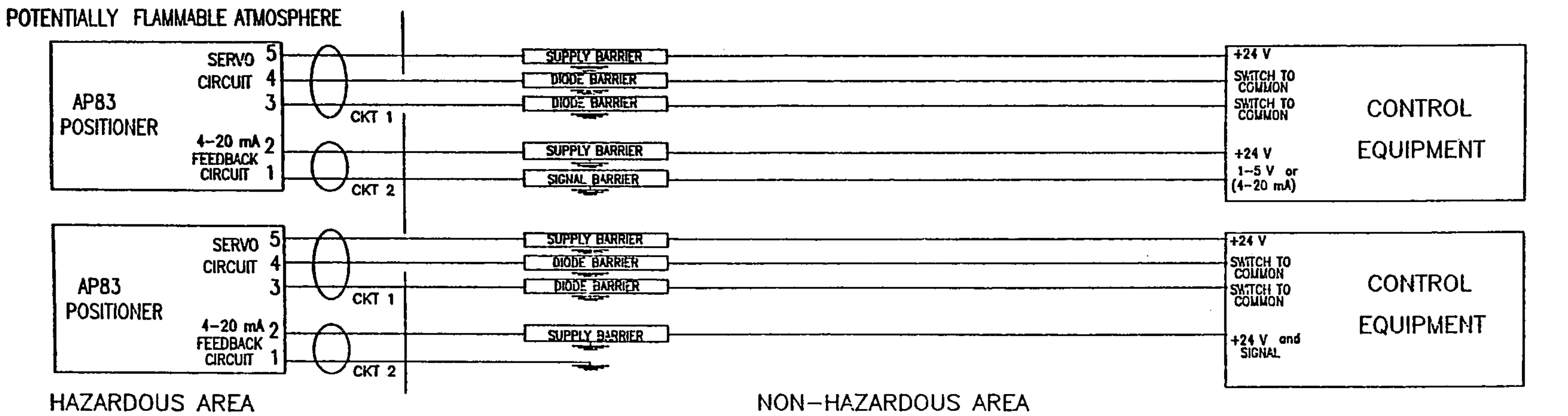
Based on a survey of manufacturer's data, few cables exceed either of these values.

A3. Construction Requirements

A3.1 (3.1) The values in Table 1 represent assumptions of accumulation of dust, dirt, and films and are quite conservative. There is a substantial body of opinion that industrial apparatus of the type which can be made intrinsically safe will remain so with spacings even below those given in Table 1.

A3.1.1 (3.1.3) For example, consider a 14 pin component that has a spacing between pins of 0.3 mm and voltage under 10 volts. Any three pins may be shorted together with one fault counted. Within any group of 6 pins only one such set of three pins will be shorted. In this case two such groups of three can be shorted and counted as two faults.

FIGURE A1
EXAMPLE CONTROL DRAWING



NOTES ON AP83 POSITIONER

1. CIRCUIT 1 AND CIRCUIT 2 MUST BE IN SEPARATE CABLES OR IN ONE CABLE WHICH HAS SUITABLE INSULATION. REFER TO INSTRUMENT SOCIETY OF AMERICAN RECOMMENDED PRACTICE ISA RP12.6 FOR INSTALLING INTRINSICALLY SAFE LOOPS.

NOTES ON BARRIERS

1. MAY BE IN A DIVISION 2 LOCATION IF SO APPROVED.
2. OUTPUT CURRENT MUST BE LIMITED BY A RESISTOR SUCH THAT THE OUTPUT VOLTAGE-CURRENT PLOT IS A STRAIGHT LINE DRAWN BETWEEN OPEN CIRCUIT VOLTAGE AND SHORT CIRCUIT CURRENT.
3. MUST BE INSTALLED IN ACCORDANCE WITH GUIDELINES PROVIDED BY THE MANUFACTURER. BARRIERS MAY NOT BE CONNECTED IN PARALLEL UNLESS ALLOWED BY THE MANUFACTURER'S APPROVAL.
4. CABLE CAPACITANCE PLUS INTRINSICALLY SAFE EQUIPMENT CAPACITANCE MUST BE LESS THAN THE MARKED CAPACITANCE (Ca) SHOWN ON ANY BARRIER USED. THE SAME APPLIES FOR INDUCTANCE.
5. SELECTED BARRIERS MUST HAVE Voc NOT EXCEEDING Vmax AND Isc NOT EXCEEDING Imax AS SHOWN FOR EACH TYPE OF BARRIER IN THE TABLE BELOW. ALL BARRIERS MUST BE OF THE SAME POLARITY.

Class I,II,III Haz Loc Group	'SUPPLY' Barrier		'SIGNAL' Barrier		'DIODE' Barrier	
	Vmax	Imax	Vmax	Imax	Vmax	Imax
A,B,C,D,F,G	40 V	150 mA	13 V	350 mA	40 V	0 mA
A,B,C,D,F,G	40 V	150 mA	40 V	0 mA	40 V	0 mA
C,D,F,G	35 V	250 mA	13 V	350 mA	40 V	0 mA

NOTES ON CONTROL EQUIPMENT

1. MAINS POWER MUST NOT EXCEED 250 VOLTS WITH RESPECT TO EARTH.

S3335

A3.1.2 (3.1.4) Where two identical intrinsically safe circuits are derived from the same power supply, lack of appropriate creepage and clearance may result in an increase in the circuit current so that it is no longer intrinsically safe. If the external circuits are assumed to be shorted or grounded, twice the current will flow into the ground connection, exceeding the current for which the circuit is designed. If the two intrinsically safe circuits are derived from different power supplies, a connection of the two circuits, as would be assumed if the creepage and clearance distances are not in accordance with the requirements of Table 1, will in almost all cases subject one of the circuits to voltages or currents higher than the design value.

A3.2 (3.2) Adherence.

The removal of creepage requirements from encapsulated components is based upon the removal of the possibility of contamination. The measurement of comparative tracking index, CTI, is, in effect, a measurement of the degree of contamination needed to cause breakdown of a separation between conducting parts. The following facts emerge from this basic consideration:

(1) If all electrical parts and substrates are totally enclosed in that nothing emerges from the encapsulation, then there is no risk of contamination and hence breakdown due to that source cannot occur.

(2) If any part of the circuit — such as a bare or insulated conductor or component or the substrate of a printed wiring board — exits the encapsulant, then contamination can enter at that interface and cause breakdown unless the encapsulant adheres at the interface.

A3.2.1 (3.2) The above facts indicate that what is required is to maintain a seal at the interfaces described and to do this it is necessary that the encapsulant adhere at those points.

A3.2.2 (3.2) Temperature. All encapsulants have a maximum temperature above which they may lose or change their specified properties. Such changes may cause cracking or decomposition which could result in surfaces hotter than the outside surface of the encapsulant being exposed to a potentially explosive atmosphere.

A3.2.3 (3.2) For this reason, it is necessary to confirm that the encapsulant does not exceed its maximum rated operating temperature when the circuits enclosed are operated under fault conditions. In achieving this it should be noted that components which are encapsulated may be hotter or colder than they would be in free air depending on the thermal conductivity of the encapsulant.

A3.3 (3.4.3) For Class 2 circuits, Article 725 of NFPA 70-1987, National Electrical Code, specifies only that insulation be suitable for the particular application. For Class 3 circuits, minimum requirements for insulation thickness are specified, primarily to ensure protection against electric shock. Should a fault occur in a Class 2 or Class 3 circuit, heat might be generated in the wiring to damage the insulation. Though this event is unlikely to result in a fire hazard in ordinary applications, it is necessary that it be given due consideration in intrinsically safe systems.

A3.4 (3.5) Requirements for components given in this section are not mandatory requirements for the construction of all intrinsically safe and associated apparatus. Protective components are not required if the circuit is still incapable of causing ignition after two components are assumed to have failed.

A3.4.1 (3.5.1.1) The insulation thickness specified for Type 1(a) transformers is less than presently interpreted as being required by European certifying authorities. In addition, although no thickness specification is given for Type 2(a) transformers, interpretation by certifying bodies in other countries has required 1 mm of insulation between the winding(s) supplying intrinsically safe circuits and other windings. Type 3 construction is permitted based on the assumption that the transformer design is such that no thermal stress on the insulation occurs when windings are short-circuited due to, for example, the rating of insulation, winding impedances, and saturation level. (See 7.1.2.3.)

A3.4.1.1 (3.5.1.1) The Type 2(a) and Type 3 transformer constructions do not include a requirement for fuses or circuit breakers in the primary wiring. This requirement differs from the Canadian and European standards which require a fuse in each ungrounded line voltage input. In these two excepted cases, the addition of a fuse or circuit breaker does nothing to enhance intrinsic breakdown primary to secondary without benefit of a fuse, and, in the Type 3 construction, there is no significant heating of the transformer leading to a breakdown.

A3.5 Protective components.

A3.5.1 (3.6.1.1) This differs from some European requirements that specify operation at not more than two thirds of rated current under fault conditions.

A3.5.2 (3.6.3) The limitations in this standard on current, voltage, and volt-amperes are in agreement with values accepted or proposed in European standards. The limits were established because of a concern that, in an enclosed volume, as in relay enclosures, ionization at arcing relay contacts in the nonintrinsically safe circuit might cause breakdown of the intrinsically safe circuit, even if creepage and clearance distance requirements in Table 1 are met.

A3.5.2.1 (3.6.3) The 5 ampere, 250 volt, 100 volt-ampere figures represent, in the absence of a technical rationale for establishing limit values, levels at which adverse conduction is presumed to be highly improbable, but which would encompass most common uses of relays. For high levels, additional precautions, as given in 3.6.3.1, are required.

A3.6 Cells and batteries.

A3.6.1 (3.8.5) Option (3) may be a more stringent test than options (1) and (2), but may be used because it simplifies testing. Failure to pass this test does not imply that the circuit is not intrinsically safe. Intrinsic safety may be verified by use of (1) or (2).

A3.6.2 (3.8.9) It may be determined by analysis or test that the battery or cells have such low energy available that no further protection is required for intrinsic safety. Such apparatus does not require charging-contact protection, output current-limiting, or any other energy-limiting components.

A3.6.2.1 (3.8.9) The circular disc probe described in item (2) is representative of a dime, the smallest U.S. coin. This probe dimension was selected on the assumption that the apparatus might be carried in the user's pocket.

A4. Additional Requirements

A4.1 (4.1) It is a fundamental requirement of intrinsically safe apparatus that it shall be incapable of causing ignition either by arcing or thermal effects. If the temperature of any part of the apparatus exposed to the flammable or combustible material is below the autoignition temperature (AIT) of the material, the apparatus is safe with regard to thermal ignition. There is much data in literature, however, which shows that surfaces of limited extent and small components may exceed the AIT without causing ignition. SMRE (Safety in Mines Research Establishment) in England and Physikalisch-Technische Bundesanstalt in Germany have shown that large resistors may exceed the AIT by 100-300°C (180-540°F), depending upon the gas and vapor involved, without causing ignition. Smaller components and wires must reach even higher temperature. (See A4.1.3.)

A4.1.1 (4.1) Reliably designed electronic equipment does not normally have component or wire surface temperatures above the AIT when operating normally. When one considers the effects of two faults, it is frequently the case that resistors or semiconductors may be exposed to voltages and currents considerably higher than they carry in normal operations. It is under fault conditions that concern for hot wire or hot surface ignition, and the need for careful analysis, is greatest.

A4.1.2 (4.1) For intrinsically safe equipment in Class II and III hazardous locations, the greatest danger is ignition of a dust layer. For classified dusts, if the surface temperature of the apparatus under normal conditions does not exceed 120°C (248°F), and under fault conditions does not exceed 165°C (329°F), it may be assumed that the device will not cause ignition as a result of high surface temperatures.

A4.1.3 (4.1) There is considerably less information in literature regarding the ability of small components to rise above the 120°C (248°F) or 165°C (329°F) value without causing ignition, but on theoretical grounds, supported by some experimental evidence, it can be concluded that even in Class II and III locations, the temperatures of small components may rise above the temperature stated. Inability of the component to cause ignition must, of course, be demonstrated by test of the actual components under fault conditions.

A4.2 (4.1.2) If I_m is unknown, it may be determined by test. The current through the wire should be increased in stages to allow thermal equilibrium before incrementing the current to the next higher stage.

A4.3 (4.1.3) The ignition temperature of gases and vapors which is listed in reference documents such as NFPA 497M is determined under conditions where a significant volume of gas is at the same temperature. When ignition is attempted with a small component, convection effects and partial oxidation at the surface of the component decrease the rate of heat transfer to the gas. Therefore the component must be at a temperature much higher than the quoted ignition temperature to ignite the flammable mixture. Typical transistors, resistors, and similar small components must have a surface temperature of 220 — 300°C to ignite diethyl ether whose ignition temperature is 160°C. Similar values have been measured in ignition tests of carbon disulfide whose ignition temperature is 100°C.

A4.3 (4.2.2) The markings may be abbreviated by using symbols as specified in Table A1.

TABLE A1
SYMBOLS FOR MARKINGS

(TM-121)

Electrical Parameter	Abbreviation Symbols	
	System A[a]	System B[b]
External Inductance-to-Resistance Ratio	L_o/R_o	L_a/R_a
Internal Inductance-to-Resistance Ratio	L_i/R_i	L_i/R_i
Maximum Input Voltage	U_i	V_{max}
Maximum Input Current	I_i	I_{max}
Maximum Internal Capacitance	C_i	C_i
Maximum Internal Inductance	L_i	L_i
Maximum Output Voltage	U_o	V_{oc}
Maximum Output Current	I_o	I_{sc}
Maximum Allowed Capacitance	C_o	C_a
Maximum Allowed Inductance	L_o	L_a

[a]This system is generally used outside the U.S.A.

[b]This system is generally used inside the U.S.A.

A5. Comparison Procedure for Determining Spark Ignition Capacity

A5.1 (5.1) The voltage and current levels specified for judging the intrinsic safety of apparatus by analysis alone after two faults are lower than those required when the apparatus is tested. A decrease in energy is imposed to allow for errors in determining circuit constants. For example, the measured inductance of many components depends on the method used. The appropriate inductance value to be used in ignition calculations may not be self-evident. The safety of systems which are analyzed is also ensured by the nature of the conditions under which the reference curves were determined. These curves were determined with the IEC test apparatus in which the contact geometry is optimized to encourage ignition at low currents.

A5.1.1 (5.1) Additionally, the ignition data represents the levels of current which will cause ignition of the flammable material in its most easily ignitible concentration more than once in a thousand attempts.[1]

A6. Apparatus for Class II and Class III Locations

A6.1 (6.2.4) If an enclosure is not dust tight the possibility of reduction of spacings by conductive dusts must be considered. Therefore, the most hazardous combination of such reduction of spacings is specified. This may necessitate the device being evaluated with all capacitors considered to be paralleled, all inductors connected in series, and the effective resistive load on circuits supplying the device to be the loads which produce the highest surface temperatures (maximum power transfer) and a short circuit (maximum igniting current).

A6.1.1 (6.2.4) Although Group G dusts are usually considered nonconductive, the same requirement is applied. It was not felt necessary to specify a different requirement and to sort out the possibility of degradation of dust characteristics over a long period of time in the presence of moisture, other conductive agents, etc. It is recognized that this requirement is excessive for Group G applications, especially where there is no possibility of the dust being wet and contaminated with conductive materials.

A6.2 (6.3) The dust-tight enclosures defined by these requirements are intended to prevent potentially hazardous accumulation of dusts. These requirements are less stringent than requirements for enclosures for nonintrinsically safe equipment in Class II, Division 1 locations. Those latter enclosures must have more stringent requirements because the apparatus inside may be ignition capable by arc or temperature in normal operation. Such is not the case with intrinsically safe apparatus.

1 The curves for Group D are based on tests with propane. The curves for methane are based on tests with methane. The curves for Group C are based on tests with ethylene. The curves for Groups A and B are based on tests with hydrogen.

A7. Protective Transformer Tests

A7.1 (7.6.4) The combined requirements of (7.6.3) and (7.6.4) are intended to ensure investigation of not only the highest temperature (7.6.3) which may exist for only a short time, but also lower temperatures which may exist for a much longer period of time (7.6.4).

A8. Spark Ignition Tests

A8.1 (8.2) The apparatus is that described in IEC Publication 79-3.[1] (See Figure 9) At currents greater than 3A, arc ignition is aided by heating of the tungsten wires so that the igniting currents determined by test are too low. For testing at higher current levels, heavier wires or a different type of apparatus may be needed. [Copper wires 0.25 mm (0.01 in.) in diameter have been used.]

A8.1.1 (8.2) The apparatus is suitable for testing circuits up to 300 volts. For tests of capacitive circuits, a modified apparatus (e.g., one with two or more of the wires removed) may be needed to allow adequate charging time.

A8.2 (8.2.2) Where field wiring is a part of the intrinsically safe circuit, it is normally assumed that cadmium or zinc is present, due to common use of these metals for corrosion protection.

[1] IEC Publication 79-3 is the International Electrotechnical Commission's "Electrical Apparatus for Explosive Gas Atmospheres - Part 3: Spark Test Apparatus for Intrinsically Safe Circuits."

APPENDIX B

Referenced Publications

B1. General

B1.1 This portion of the Appendix lists publications referenced within this document.

B1.1.1 The following publications are available from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 70-1987, National Electrical Code

NFPA 497M 1986, Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations.

B1.2 Other Publications.

ANSI C39.5, Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation, American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI C96.1, Temperature Measurement Thermocouples, American National Standards Institute, 1430 Broadway, New York, NY 10018.

ASTM D3638.77, Test Method for Comparative Tracking Index of Electrical Insulating Materials, ASTM, 1916 Race Street, Philadelphia, PA, 19103.

ANSI/ISA RP12.6, Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations, Instrument Society of America, 67 Alexander Drive, Research Triangle Park, North Carolina, USA 27709.

IEC Publication 79-3, Electrical Apparatus for Explosive Gas Atmospheres — Part 3: Spark Test Apparatus for Intrinsically Safe Circuits, International Electrotechnical Commission, 1 Rue de Varembe, Geneva, Switzerland.

NEMA Publication No. 250-1985, Enclosures for Electrical Equipment (1000 Volts Maximum), National Electrical Manufacturers Association., 2101 L St., N.W., Washington, DC 20037.

SFA 3012-1972, British Approvals Service for Electrical Equipment in Flammable Atmospheres, British Standards Institution, Linford Wood, Milton Keynes, MK4 6LE.

Some Aspects of the Design of Intrinsically Safe Circuits, Research Report 256, 1968, D. W. Widgenton, Safety in Mines Research Establishment, Sheffield, England.

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May 10, 1996

Revision pages for

Standard for

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

UL 913, Fourth Edition

Attached to this distribution notice is a revision of the Fourth edition of UL 913.

A CHANGE ON A PAGE DATED MAY 10, 1996 IS INDICATED BY A SMALL PRINT NOTE FOLLOWING THE AFFECTED ITEM, PRECEDED AND FOLLOWED BY AN ASTERISK.

THESE NEW AND REVISED REQUIREMENTS IN THIS STANDARD ARE NOW IN EFFECT EXCEPT FOR THOSE PARAGRAPHS, SECTIONS, TABLES, FIGURES, AND OTHER ELEMENTS OF THE STANDARD HAVING FUTURE EFFECTIVE DATES AS INDICATED IN THE NOTE FOLLOWING THE AFFECTED ITEM. TO RETAIN THE REQUIREMENTS IN EFFECT UNTIL THESE FUTURE EFFECTIVE DATES, DO NOT DISCARD THE PAGES REPLACED BY THOSE HAVING FUTURE EFFECTIVE DATES UNTIL THOSE DATES.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this standard unless the applicant specifically requests that the product be judged under the current requirements. However, should the applicant elect 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.

The new and/or revised requirements are substantially in accordance with UL's Bulletin on this subject dated June 30, 1995. The bulletin is now obsolete and may be discarded.

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 text of this ANSI/UL Standard.

Revised and/or additional pages may be issued from time to time.

(Continued)

With the inclusion of the accompanying material, the standard consists of pages dated as shown in the following checklist:

Page	Date
1	July 29, 1988(Reprinted May 10, 1996)
2	May 10, 1996
3, 4	July 29, 1988
5	May 10, 1996
6	July 29, 1988
7, 8	May 10, 1996
9 — 20	July 29, 1988
21, 22	May 10, 1996
23 — 26	July 29, 1988
27, 28	December 12, 1988
29 — 41	July 29, 1988
A1 — A9, B1	July 29, 1988

JULY 29, 1988
(Title Page Reprinted: May 10, 1996)

ANSI/UL 913-1988

UL 913

Standard for

Intrinsically Safe Apparatus And Associated Apparatus For Use In Class I, II, And 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 29, 1988

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated July 29, 1988. 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 2 — 4 and 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 5 and 6 are from "Some Aspects of the Design of Intrinsically Safe Circuits," Research Report 256 by D. W. Widgenton, 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 published set of revision pages.

CONTENTS

SECTION

1. General

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

1.1 Scope.

1.1.1 This standard applies to:

(1) Apparatus or parts of apparatus in Class I, II, or III, Division 1 locations[1];

(2) 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.

(3) Apparatus or parts of apparatus in Class I, Zone 0 or 1, Groups IIA, IIB, and IIC locations;

(4) 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.

Paragraph 1.1.1 revised May 10, 1996

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

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

(1) An ambient temperature of 40°C (104°F);

(2) An oxygen concentration not greater than 21 percent; and

(3) A pressure of one atmosphere.

1.1.3 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.

[1] **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 Purpose.

1.2.1 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.

1.2.2 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.

1.3 Applicability of Other Standards.

1.3.1 Except where modified by the requirements of this standard, intrinsically safe and associated apparatus shall comply with the applicable requirements for ordinary locations.[1]

1.3.2 Associated apparatus and circuits shall conform to the requirements of the location in which the apparatus and circuits are installed.[2]

1.4 Definitions.

1.4.1 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:

(1) Electrical apparatus that has an alternative type of protection for use in the appropriate potentially flammable atmosphere; or

(2) Electrical apparatus not so protected that shall not be used within a potentially flammable atmosphere.

[1] **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.**

[2] **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.**

1.4.2 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.

1.4.3* 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.

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

1.4.5 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.

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

1.4.7 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.

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

1.4.9 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.

1.4.10 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.

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

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

1.4.13 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.

1.4.14 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.

1.4.15 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.

1.4.16 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.

1.4.17 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.

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

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

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

1.4.21 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.

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

1.4.22.1 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.

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

1.4A Class I, Zone, and Group Equivalency

1.4A.1 Class I, Zone 0 and 1, Group IIA

1.4A.1.1 Apparatus or parts of apparatus intended to be marked in accordance with 4.2.1C shall comply with all the requirements for apparatus for use in Class I, Group D locations.

Paragraph 1.4A.1.1 added May 10, 1996

1.4A.2 Class I, Zone 0 and 1, Group IIB

1.4A.2.1 Apparatus or parts of apparatus intended to be marked in accordance with 4.2.1B shall comply with all the requirements for apparatus for use in Class I, Group C locations.

Paragraph 1.4A.2.1 added May 10, 1996

1.4A.3 Class I, Zone 0 and 1, Group IIC

1.4A.3.1 Apparatus or parts of apparatus intended to be marked in accordance with 4.2.1A shall comply with all the requirements for apparatus for use in both Class I, Group A and Class I, Group B locations.

Paragraph 1.4A.3.1 added May 10, 1996

1.5 Control Drawing.

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

Paragraph 1.5.1 effective September 13, 1991

1.5.2 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.

Paragraph 1.5.2 effective September 13, 1991

2. Evaluation of Intrinsic Safety

2.1 Fundamental Requirements. Intrinsically safe apparatus and circuits shall comply with the two basic requirements specified in 2.1.1 and 2.1.2.

2.1.1 The energy available in the hazardous location shall not be capable of igniting the flammable mixture specified in 8.3.1 through 8.3.5 due to arcing or hot surfaces during normal operation.

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

(1) Supply voltage at maximum rated value;

(2) Environmental conditions within the ratings given for the intrinsically safe apparatus or associated apparatus;

(3) Tolerances of all components in the combination that represents the most unfavorable condition;

(4) Adjustments at the most unfavorable settings;

(5) 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.

2.1.1.2* 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 8.6 through 8.6.4.

2.1.2 The energy available in the hazardous location shall not be capable of igniting the flammable mixture specified in 8.3.1 through 8.3.5 due to arcing or hot surfaces under fault conditions. Before faults are introduced, the apparatus is to be in normal operation as specified in 2.1.1.1.

2.1.2.1 Fault conditions are to include the following:

(1) The most unfavorable single fault and any subsequent related defects and breakdowns, with an additional test factor of 1.5 applied to energy;

(2) 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 8.6 through 8.6.4.

2.1.3 Apparatus in which no fault or only one fault can occur shall be considered acceptable if it complies with (1) the test requirements for normal operation as described in 2.1.1.1 with an additional test factor of 1.5 applied to energy, (2) the test requirements for any fault that can occur with an additional test factor of 1.5 applied to energy, and (3) the requirements of this standard.

2.1.4 All intrinsically safe and associated apparatus and circuits shall comply with the requirements in Sections 3 and 4.

2.2 Evaluation Procedure. Circuits are to be evaluated for intrinsic safety as specified in 2.2.1 through 2.2.4.

2.2.1* The circuits are to be analyzed to determine circuit parameters under the normal and fault conditions specified in 2.1 through 2.1.4. For intrinsically safe apparatus, each possible ignition point where circuit interruption, short circuit, or ground fault may occur is to be considered.

2.2.2 Construction details and temperatures are to be reviewed for compliance with Sections 3 and 4. The apparatus shall comply with the applicable test procedures of Section 7.

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

(1) Testing the circuit according to the test requirements of Section 8; or

(2) Comparing the calculated or measured values of current, voltage, and associated inductances and capacitances to the appropriate figures in Section 5 to establish that the current and voltage levels are below the specified values in 5.2.1 through 5.2.2.

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

(1) Sources of spark ignition:

(a) Discharge of a capacitive circuit;

(b) Interruption of an inductive circuit;

(c) Intermittent making and breaking of a resistive circuit;

(d) Hot wire fusing.

(2) Sources of thermal ignition:

(a) Heating of small gage wire strand;

(b) Glowing of a filament;

(c) High surface temperature of components.

4.2.1A In addition to, or as an alternative to, the marking requirement in 4.2.1(2), 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.

Paragraph 4.2.1A added May 10, 1996

4.2.1B In addition to, or as an alternative to, the marking requirement in 4.2.1(2), 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.

Paragraph 4.2.1B added May 10, 1996

4.2.1C In addition to, or as an alternative to, the marking requirement in 4.2.1(2), 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.

Paragraph 4.2.1C added May 10, 1996

4.2.1D Apparatus or parts of apparatus marked Group IIB may also be marked Group IIA.

Paragraph 4.2.1D added May 10, 1996

4.2.1E Apparatus or parts of apparatus marked Group IIC may also be marked Group IIA, Group IIB, or both Group IIA and Group IIB.

Paragraph 4.2.1E added May 10, 1996

4.2.2* In addition to the minimum marking specified in 4.2.1, 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.

(1) For intrinsically safe apparatus:

(a) An indication that the apparatus is intrinsically safe;

(b) If investigated using the entity evaluation, the maximum input voltage, maximum input current, maximum internal capacitance and maximum internal inductance;

(c) If repair is possible, a warning label worded "Warning — Substitution of Components May Impair Intrinsic Safety;" and

(d) 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.

(2) For associated apparatus:

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

(b) If repair is possible, a warning worded "Warning — Substitution of Components May Impair Intrinsic Safety;"

(c) Any other necessary information, in particular, an indication of any other type of protection and its characteristics; and

(d) 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.

Subitem (b) in item (1) and Subitem (a) in item (2) of paragraph 4.2.2 effective September 13, 1991

4.2.3 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.

4.2.4 Battery-powered apparatus shall be marked with a caution statement to (1) indicate the type, size, and voltage of batteries to be used or (2) 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."

5. Comparison Procedure for Determining Spark Ignition Capability

5.1* General.[1]

5.1.1 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 5.2.1 through 5.2.2.2.

5.1.2 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 5.2.1 through 5.2.2.2 are to be evaluated by the test procedures in Section 8.

5.1.3 Resistance Circuits. Figures 1 and 2 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.

5.1.4 Resistance-Inductance Circuits. Figures 3 and 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 5 and 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.

5.1.5 Resistance-Capacitance Circuits. Figures 7 and 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.

5.2 Maximum Voltage and Current Levels.

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

5.2.2 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 5.2.2.1 and 5.2.2.2, for given circuit constants.

5.2.2.1 For normal or single-fault operation, the current shall not exceed 80 percent of the value determined from Figures 1 through 6. The voltage shall not exceed 80 percent of the value determined from Figures 7 and 8.

5.2.2.2 For two-fault condition, the current shall not exceed 90 percent of the value determined from Figures 1 through 6. The voltage shall not exceed 90 percent of the value determined from Figures 7 and 8.

1 All figures, except Figures 5 and 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 5 and 6 are from "Some Aspects of the Design of Intrinsically Safe Circuits," Research Report 256, 1968, by D. W. Widgenton, Safety in Mines Research Establishment, Sheffield, England.