EVALUATION OF INTRINSICALLY SAFE INSTRUMENTS AND APPARATUS FOR USE IN UNDERGROUND COAL MINES

Prepared For:

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

By:

UNDERWRITERS LABORATORIES INC.
333 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS 60062

FINAL REPORT FOR MARCH 1978 - MAY 1980

CONTRACT NO. J0188046
EVALUATION OF INTRINSICALLY SAFE INSTRUMENTS
AND APPARATUS

1. Report No.

2.

3. Recipient's Accession No.

4. Title and Subtitle

EVALUATION OF INTRINSICALLY SAFE INSTRUMENTS FOR USE IN UNDERGROUND COAL MINES

5. Report Date

MAY 30, 1980 - ISSUE

6.

7. Author(s)

J. M. KURTZ, A. A. BARTKUS, P. J. SCHRAM

8. Performing Organization Report No.

9. Performing Organization Name and Address

UNDERWRITERS LABORATORIES INC.
333 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS 60062

10. Project/Task/Work Unit No.

ITEMS 1-4, 6-11/TASK I-IV

11. Contract or Grant No.

J0188046

12. Sponsoring Organization Name and Address

13. Type of Report

FINAL FOR MARCH, 1978-MAY, 1980

14.

15. Supplementary Notes

16. Abstract

Ten Methane Monitoring Systems and Machine Control Circuits were examined and tested per the requirements in CFR Title 30, Parts 18 and 27, the Standard UL 913 and the document "Test Requirements For Instruments or Apparatus to be Considered for M.E.S.A. Intrinsically Safe Certification (Tentative)". The test results indicate that none of the products complied with all parts of all requirements as interpreted by Underwriters Laboratories Inc.

17. Originator's Key Words

18. Availability Statement

19. U. S. Security Classif. of the Report

20. U. S. Security Classif. of This Page

21. No. of Pages

22. Price

FOREWORD

This Report was prepared by Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, Illinois 60062, under USBM Contract Number J0188046. The contract was initiated under the Coal Mines Health and Safety Fires and Explosion Program. It was administered under the Technical Direction of U. S. Bureau of Mines, Pittsburgh Mining and Safety Research Center, with Mr. Merle Bowser acting as Technical Project Officer. Mr. Randolph R. Cooper was Contract Administrator for the Bureau of Mines. This Report is a summary of the work recently completed as a part of this contract during the period March 22, 1978 to May 30, 1980. This Report was submitted by the authors on May 30, 1980.

This Report was prepared as an account of work sponsored by the United States Government. Neither the United States Government nor Underwriters Laboratories nor any of their employees nor any of their contractors, subcontractors, or their employees make any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or processes disclosed, or represents that its use would not infringe on privately owned rights. This Report may not be used in any way to infer or indicate acceptability for Listing, Classification, Recognition or Certificate Service by Underwriters Laboratories Inc. of any product or system.

Subsequent to the initiation of this contract, the Mine Enforcement and Health Administration (MESA) was renamed the Mine Safety and Health Administration (MSHA). All references to MESA should be interpreted as MSHA.

TABLE OF CONTENTS

Chapter	Description	Page
	References	5
1	Summary	7
2	Introduction	17
3	Discussion of Technical Adequacy of the Document "Test Requirements for Instruments or Apparatus to be Considered for M.E.S.A. Intrinsically Safe Certification (Tentative)" ("MESAP")	19
4	Impact of Adoption of "MESAP"	25
5	Examination and Testing of Methane Monitoring Systems and Machine Control Circuits according to the Code of Federal Regulations (CFR) Title 30	27
6	Examination and Testing of Methane Monitoring Systems and Machine Control Circuits according to the UL Standard for Intrinsically Safe Electrical Circuits and Apparatus for Use in Hazardous Locations and its Associated Apparatus, UL 913	133
7	Examination and Testing of Methane Monitoring systems and Machine Control Circuits according to "MESAP"	279
8	Comparison of Requirements	391
	Appendix A (MESAP)	397
	Appendix B UL 913, First Edition	433
	Appendix C Figures	461
	Appendix D Subject Inventions	479

R E F E R E N C E S

Reference	Description
(1)	Underwriters Laboratories Inc. Standard "Intrinsically Safe Electrical Circuits and Apparatus for Use in Hazardous Locations", UL 913, Second Edition, 1976.
(2)	Handbook of Chemistry and Physics, 55th Edition, 1974-75.
(3)	National Fire Protection Association Standard "Intrinsically Safe Apparatus for Use in Class I Hazardous Locations 1975", NFPA 493.
(4)	Canadian Standards Association Standard "Intrinsically Safe and Nonincendive Equipment for Use in Hazardous Locations", CSA 22.2, No. 157-M1979.
(5)	International Electrotechnical Commission Publication No. 79-11 "Electrical Apparatus for Explosive Gas Atmospheres, Part 11: Construction and Test of Intrinsically Safe and Associated Apparatus", First Edition, 1976.
(6)	EN50-020 "Electrical Equipment for Explosive Atmospheres - Intrinsic Security" completed by extracts of European Standard Number EN50-014 "Equipment for Explosive Atmospheres - General Rules", dated September, 1976.
(7)	Underwriters Laboratories Inc. Standard "Intrinsically Safe Electrical Circuits and Equipment for Use in Hazardous Locations," UL 913, First Edition, 1971.
(8)	Code of Federal Regulations, Title 30, Mineral Resources.
(9)	Test Requirements for Instruments or Apparatus to be Considered for M.E.S.A. Intrinsically Safe Certification (Tentative). (Included as Appendix A.)

CHAPTER 1

S U M M A R Y

1.1 HISTORICAL BACKGROUND

1.1.1 The following background for the initiation of this Report was furnished by the Bureau of Mines:

"During 1977, the Bureau of Mines (BOM) and the Mining Enforcement and Safety Administration (MESA) (later the Mine Safety and Health Administration (MSHA)) were working in close cooperation to develop revised requirements for the intrinsic safety of electrical/electronic equipment that would be used in environments containing flammable natural gas-air mixtures and coal dust. It woon became evident that new requirements would be significantly different from existing requirements of Title 30 of the Code of Federal Regulations(8).

"Consequently a request for proposals was generated by BOM in cooperation with MESA to assess the impact of proposed requirements for intrinsic safety on previously accepted mining instrumentation. Three primary objectives were to be attained by the resulting contract:

1. MESA would be provided with an independent interpretation of existing requirements for intrinsic safety as expressed in 30 CFR, Parts 18 and 27(8); the interpretation to be based on the current state-of-the-art of measurement techniques and anlysis procedures.

2. A representative sample of mine instruments were to be evaluated using three sets of criteria:

    (a) The contractor's interpretation of 30 CFR, Parts 18 and 27(8);

    (b) UL Standard 913(1); and

    (c) The contractor's interpretation of the proposed MESA Standard(9).

Results of these evaluations would assist MESA in determining the impact of the proposed requirements on existing electrical/electronic mine equipment.

3. Since the circuits selected for evaluation were previously accepted over a long time interval, starting in 1956, these evaluations would assist MESA in determining the impact of applying present requirements of 30 CFR to these circuits.

4. The contractor was to comment on the technical adequacy of the proposed MESA requirements for intrinsic safety, and also to provide his assessment of the impact of the proposed requirements on the availability of intrinsically safe equipment for use in mines."

1.2 SUMMATION OF SCIENTIFIC FINDINGS

Nature of Hazards

1.2.1 The following discussion is provided as an aid to understanding the significance of this Report.

1.2.2 In order to initiate an explosion the following three conditions must exist simultaneously:

(a) A flammable gas or combustable dust must be present.

(b) The flammable gas concentration in mixture with air (oxygen) must be within the upper and lower explosive or flammable limits. The combustable dust must be in suspension in the air (oxygen) in quantities sufficient to produce explosive or ignitable mixture.

(c) An ignition source such as an ignition capable spark or heated part must be present.

1.2.3 Frequently, it is necessary to test the ability of electrical equipment to produce sparking which is capable of igniting the specific hazardous atmospheres that are of interest. In such tests, the nature of the sparking contacts has a significant effect on the ignition capability of the spark produced. Contact materials, contact size and shape, and rate of contact make and break affect the spark energy released into the atmosphere and, therefore, the ignition capability of the spark. The mechanism used for spark testing of equipment intended to be intrinsically safe is, therefore, critical in determining compliance with the requirements.

1.2.4 The spark testing equipment uses contact materials and configurations which are designed to be more likely to produce ignition in any given situation than most spark producing mechanisms (such as broken wires or relay contacts) of installed equipment and in addition the test mechanism produces many sparks in rapid succession. Further, the test gas used is in its most easily ignited concentration.

1.2.5 Three mechanisms for spark testing are described in the First Edition of UL 913 (7). Of these, the test mechanism most likely to cause ignition was used here to determine compliance with requirements in Parts 18 and 27, CFR Title 30(8). This test mechanism uses tungsten and brass contacts but is otherwise identical to the mechanism described in the Second Edition of UL 913 (1) and in the document "Test Requirements for Instruments or Apparatus to be Considered for M.E.S.A. Intrinsically Safe Certification (Tentative)" ("MESAP")(9), see paragraph 19.4 of Appendix A. The mechanism described in the latter documents uses tungsten and cadmium contacts which are known to produce sparking that is more likely to produce ignition than the sparking produced by tungsten and brass contacts.

1.2.6 The circuits selected for test are those most likely to cause ignition. Before testing, faults may be introduced and a test (safety) factor may be applied to further increase the available spark energy. In the Second Edition of UL 913 (1) and in "MESAP"(9), opening, shorting or grounding of field-installed wiring are considered to be conditions of normal operation, not faults.

Results of Investigation

1.2.7 The indicated methane monitoring systems and machine control circuits were examined and tested. None of the devices complied with all parts of all of the requirements as interpreted by UL and used in their evaluation. The results of the investigation are depicted in Tables I, II and III.

1.3 REQUIREMENTS OF PARTS 18 AND 27 OF CFR TITLE 30(8) AS COMPARED TO CURRENT NATIONAL AND INTERNATIONAL STANDARDS

1.3.1 The requirements of Parts 18 and 27 of CFR Title 30(8) are compared below to the requirements of UL 913(1). The requirements of UL 913 (1) are the same as, or quite similar to, the requirements of other National and International standards currently used to determine the acceptability of intrinsically safe equipment.

1.3.2 ELECTRICAL SPACINGS

1.3.2.1 Specific dimensional requirements are not provided in Title 30(8). In UL 913(1) the specific dimensional requirements are included. Also, detailed spacing requirements for nonhazardous location equipment are referenced.

1.3.3 AUXILIARY EQUIPMENT

1.3.3.1 According to requirements in UL 913(1), items of intrinsically safe and associated electrical equipment which are intended to be used in conjunction with other pieces of electrical equipment or auxiliary equipment would be investigated with the specific equipment since intrinsic safety is evaluated for a complete system. This is necessary because the use of other types of equipment not anticipated at the time of the investigation may affect the intrinsic safety of the system as a whole.

1.3.3.2 This consideration is not a part of CFR Title 30(8). Therefore, the use of unspecified auxiliary equipment in conjunction with certified devices appears to be in compliance with requirements in Title 30(8), even though the use of the unspecified auxiliary equipment could increase the risk of ignition.

1.3.4 SPARK IGNITION TESTS

1.3.4.1 The requirements in UL 913(1) specify the critical construction details of the spark test apparatus and the procedure to be employed in calibrating the specific test mixture, both before and after the test. Experience has shown that even small changes in the test apparatus can have a significant effect on the test results. For example, the use of a cadmium disc produces a more sensitive test than does the use of a brass disc for a particular test mixture, and therefore increases the likelihood of ignition during the test. As a consequence, a circuit which meets the test requirements with a brass disc may not meet the test requirements when a cadmium disc is used in the apparatus. Calibration of the test mixture is important since it verifies that the particular gas-air mixture being used is the most easily ignitable mixture.

1.3.4.2 Circuits subjected to spark ignition tests according to UL 913(1) are selected during Circuit Fault Analysis where one and two faults of components (except protective components) are used with an appropriate test (safety) factor. The requirements in UL 913(1) specify introduction of a test (safety) factor of 1.5 with one fault and a test (safety) factor of 1.0 with two faults. Faults may be introduced where electrical spacings are less than required in UL 913(1).

1.3.4.3 The requirements in CFR Title 30(8) for spark ignition testing are nonspecific. They do not identify the type of apparatus or methodology to be used. Calibration of the test mixture both before and after the test is not specified in Title 30(8). The circuits selected for test according to Part 18 of Title 30(8) may be subjected to a single component fault, including protective components not likely to fault. Test (safety) factors are not introduced into the circuit under test. The spark ignition tests conducted according to Part 27 of Title 30(8) use circuits with no faults introduced and a voltage test (safety) factor of 1.25. This may or may not be more severe than the requirements in UL 913(1), depending on the circuit involved.

1.3.5 PROTECTIVE COMPONENTS

1.3.5.1 In UL 913(1) some components (e.g., transformers, resistors, diode) which affect intrinsic safety and which meet specified performance and construction requirements designed to verify their reliability may be considered as protective components not subject to fault during fault analysis.

1.3.5.2 In CFR Title 30(8), components which affect intrinsic safety are not required to be subjected to performance tests. For example the testing of resistors which are intended to limit the current to an intrinsically safe circuit does not include a determination of whether or not the resistors will short-circuit, and therefore result in loss of protection, when subjected to the maximum voltage available under fault conditions. Also, the testing of a line voltage transformer does not include a determination of whether or not the transformer will effectively isolate a high voltage primary from a low voltage secondary circuit when subjected to conditions such as an overload or short circuit of the isolated low voltage secondary winding.

1.3.6 SEPARATION OF CIRCUITS

1.3.6.1 UL 913(1) requires that internal wiring of intrinsically safe circuits be positively separated from wiring of nonintrinsically safe circuits. Also, the construction of the equipment is required to be such that the field-installed conductors of an intrinsically safe circuit are separated from field- and factory-installed conductors connected to any other circuit and uninsulated live parts of any other circuit.

1.3.6.2 The CFR Title 30(8) specifies that wiring for non-intrinsically safe circuits is not to be intermingled with wiring for intrinsically safe circuits. The requirement in Title 30(8) does not specify that wiring of intrinsically safe circuits is to be separated from uninsulated live parts of nonintrinsically safe circuits, other than wiring. As a result, careless wiring in the factory or during field installation may permit intrinsically safe conductors to be in contact with uninsulated line voltage parts.

1.3.7 MARKING

1.3.7.1 UL 913(1) requires intrinsically safe equipment to be marked "Intrinsically Safe". Battery-powered equipment is required to be marked to indicate the manufacturer's name and catalog designation or equivalent of the battery intended to be used and the appropriate ratings.

1.3.7.2 Title 30(8) requires circuits and components of intrinsically safe equipment to be "adequately identified" by marking or labeling. The level of adequacy is not amplified in the requirements.

1.3.7.3 In addition, UL 913(1) requires marking of such details as the name of the manufacturer responsible for the device, catalog designations, cautionary statements to service personnel, etc. as appropriate on the equipment. Each individual apparatus of the system is required to be identified as part of the system. These markings are not required in Title 30(8).

1.3.8 ELECTRICAL COMPONENTS

1.3.8.1 Component electrical parts of equipment are required by UL 913(1) to meet applicable construction and performance requirements for the type of component. For example, components are required to have electrical insulation which will withstand the temperatures and voltages to which the component will be subjected. For investigations according to UL 913(1) each component part is usually covered by a different UL Standard. CFR Title 30(8) does not specify that component electrical parts comply with any requirements.

1.3.9 TEST FOR ACCUMULATION OF STATIC ELECTRICITY

1.3.9.1 To determine whether or not any plastic enclosure will store an electrostatic charge, it is tested in accordance with detailed requirements in UL 913(1).

1.3.9.2 The requirements in Title 30(8) specify that non-metallic rotating parts must be provided with means to prevent accumulation of static electricity. No method is specified for determining the adequacy of the preventative means employed.

TABLE I – SUMMARY OF COMPLIANCE WITH CFR TITLE 30 REQUIREMENTS PERTAINING TO INTRINSIC SAFETY

EXAMINATION / TESTS

ITEM	REPORT SECTION	SPACINGS	SEPARATION OF WIRING	TRANSFORMER CONSTRUCTION	PROTECTIVE COMPONENT	MARKING	FASTENINGS/ VIBRATION RESISTANCE	WORKMANSHIP	VOLTAGE LIMITATION	CABLE CLAMPS AND GRIPS	TEMPERATURE	DIELECTRIC WITHSTAND	SPARK IGNITION	COMPONENT OPERATION	TRANSISTOR THERMAL RUNAWAY	STRAND OF WIRE
1	5.4	X	X	—	N/A	X	—	—	N/A	—	—	—	X	N/A	—	—
2	5.6	X	X	—	X	X	X	—	N/A	—	—	—	X	—	N/A	—
3	5.10	X	X	—	—	X	X	—	N/A	—	—	—	X	—	N/A	—
4	5.7	X	X	—	N/A	X	X	X	N/A	—	—	—	—	N/A	N/A	—
6	5.9	X	X	—	—	X	—	—	N/A	—	—	—	X	—	—	—
7	5.8	X	X	—	—	X	—	—	N/A	—	—	—	X	—	—	—
8	5.5	X	X	—	X	X	X	—	N/A	—	—	—	X	X	N/A	N/A
9	5.11	—	—	—	X	X	—	—	N/A	N/A	—	X	X	—	N/A	—
10	5.2	X	X	N/A	X	X	X	—	N/A	N/A	—	—	X	—	N/A	N/A
11	5.3	X	X	—	X	X	X	—	N/A	N/A	—	—	X	—	N/A	N/A

X – Device did not meet applicable requirements.

— – Device did meet applicable requirements.

N/A – Not applicable.

TABLE I – SUMMARY OF COMPLIANCE WITH CFR TITLE 30 REQUIREMENTS PERTAINING TO INTRINSIC SAFETY

TABLE II - SUMMARY OF COMPLIANCE WITH UL 913(1) REQUIREMENTS

← EXAMINATION → ← TEST →

ITEM	REPORT SECTION	SPACINGS	SEPARATION OF WIRING	FIELD WIRING CONNECTIONS	PROTECTIVE TRANSFORMER CONSTRUCTION	OTHER PROTECTIVE COMPONENT	MARKING	ELECTRICAL COMPONENT	TEMPERATURE	CIRCUITS DIELECTRIC WITHSTAND	SPARK IGNITION	PROTECTIVE COMPONENT TESTS	TRANSFORMER ABNORMAL OPERATION	TRANSFORMER DIELECTRIC WITHSTAND	OVER/UNDER VOLTAGE	BATTERY RUPTURE	STATIC
1	6.4	X	X	X	X	X	X	X	–	–	X	–	X	N/A	–	–	–
2	6.6	X	X	X	X	X	X	X	–	–	X	N/A	X	N/A	–	N/A	N/A
3	6.10	X	X	–	X	N/A	X	X	–	–	X	N/A	X	N/A	–	N/A	N/A
4	6.7	X	X	X	X	X	X	X	–	–	X	N/A	X	–	–	N/A	N/A
6	6.9	X	X	X	X	X	X	X	–	–	X	–	X	N/A	–	N/A	N/A
7	6.8	X	X	X	X	X	X	X	–	–	X	N/A	X	X	–	N/A	N/A
8	6.5	X	X	X	X	–	X	–	–	–	X	–	X	N/A	N/A	N/A	N/A
9	6.11	X	X	–	X	–	X	X	–	X	X	–	X	–	–	N/A	N/A
10	6.2	X	X	X	N/A	X	X	X	–	–	X	–	N/A	N/A	X	N/A	N/A
11	6.3	X	X	X	X	X	X	X	–	–	X	–	X	N/A	–	N/A	N/A

X – Device did not meet applicable requirements.

– – Device did meet applicable requirements.

N/A – Not applicable.

TABLE II SUMMARY OF COMPLIANCE WITH UL913 REQUIREMENTS.

TABLE III – SUMMARY OF COMPLIANCE WITH "MESAP" REQUIREMENTS

		EXAMINATION									TESTS						
ITEM	REPORT SECTION	SPACINGS	SEPARATION OF WIRING	FIELD WIRING CONNECTIONS	PROTECTIVE TRANSFORMER CONSTRUCTION	OTHER PROTECTIVE COMPONENT	MARKING	ELECTRICAL COMPONENT	TEMPERATURE	CIRCUITS DIELECTRIC WITHSTAND	SPARK IGNITION	PROTECTIVE COMPONENT	TRANSFORMER ABNORMAL OPERATION	TRANSFORMER DIELECTRIC WITHSTAND	OVER/UNDER VOLTAGE	BATTERY RUPTURE	STATIC
1	7.4	X	X	X	X	X	X	X	–	–	X	–	X	N/A	–	–	–
2	7.6	X	X	X	X	X	X	X	–	–	X	N/A	X	N/A	–	N/A	N/A
3	7.10	X	X	–	X	N/A	X	X	–	–	X	N/A	X	N/A	–	N/A	N/A
4	7.7	X	X	X	X	X	X	X	–	–	X	N/A	X	–	–	N/A	N/A
6	7.9	X	X	X	X	X	X	X	–	–	X	–	X	N/A	–	N/A	N/A
7	7.8	X	X	X	X	X	X	X	–	–	X	N/A	X	X	–	N/A	N/A
8	7.5	X	X	X	X	–	X	–	–	–	X	–	X	N/A	N/A	N/A	N/A
9	7.11	X	X	–	X	–	X	X	–	X	X	–	X	–	–	N/A	N/A
10	7.2	X	X	X	N/A	X	X	X	–	–	X	–	N/A	N/A	X	N/A	N/A
11	7.3	X	X	X	X	X	X	X	–	–	X	–	X	N/A	–	N/A	N/A

X – Device did not meet applicable requirements.

– – Device did meet applicable requirements.

N/A – Not applicable.

TABLE III – SUMMARY OF COMPLIANCE WITH "MESAP" REQUIREMENTS.

CHAPTER 2

I N T R O D U C T I O N

2.1 Chapter 3 of this Report evaluates the technical adequacy of the document "Test Requirements For Instruments or Apparatus to be considered for M.E.S.A. Intrinsically Safe Certification (Tentative)", hereafter referred to as "MESAP"(9), see Appendix A. The evaluation is based on a comparison with the Standard, UL 913(1).

2.2 Chapter 4 of this Report estimates the impact of the proposed adoption of the document "MESAP"(9) upon existing and future intrinsically safe certification by M.E.S.A. with regard to approvals or disapprovals. This impact estimation does not include estimates of financial impact, but only the availability of equipment and apparatus.

2.2.1 The estimate is based on the application of the requirements pertaining to intrinsic safety only of Parts 18 and 27 of Title 30(8) and "MESAP"(9) to the investigation of ten items of equipment: Methane Monitoring Systems or Machine Control Circuits. Reports of these investigations are contained in Chapters 5 and 7 of this Report.

2.3 The equipment described in Chapters 5, 6, and 7 was examined and tested to determine compliance with the requirements in CFR Title 30(8), UL 913(1) and "MESAP"(9), respectively.

2.4 Chapter 8 of this Report discusses the suitability for Certification according to CFR Title 30(8) and Standard UL 913(1), as compared with certification according to the requirements in "MESAP"(9).

CHAPTER 3

DISCUSSION OF TECHNICAL ADEQUACY

3.1 The tentative document "MESAP"(9), was examined with respect to its technical adequacy for evaluating instruments or apparatus for intrinsically safe certification by M.E.S.A. for use in underground coal mines. The examination is based on a comparison with the Standard, UL 913(1). The paragraphs below describe items or requirements which need further clarification. Suggested modifications to the requirements are indicated. The paragraphs referenced are those in the document "MESAP"(9) which is included in Appendix A. Editorial modifications intended to clarify the document are described in paragraph 3.2 which follows.

3.1.1 Paragraph 4.6 - The requirement is not specific as to the location (hazardous location not protected, hazardous location protected in a permissable enclosure, nonhazardous location) of the conductor or conductor strand. Clarification to indicate that the conductor or conductor strand is in an intrinsically safe circuit in the hazardous location, and not in a permissable enclosure, is needed. If any wire in the intrinsically safe circuit is intended to be field-installed, the installation instructions should specify the minimum strand diameter and material based on the spark test apparatus used to qualify the circuit. See comments in paragraph 3.1.16.1.

3.1.2 Paragraph 4.8 - Field wiring includes field wiring of nonintrinsically safe circuits. We suggest that the words "to the field wiring or" be deleted as it is not necessary to be concerned about faults in nonintrinsically safe circuits causing the passage of ignition-capable energy to non-intrinsically safe field wiring, and because the words "to an intrinsically safe circuit" already include intrinsically safe field wiring.

3.1.3 Paragraph 5.16 - If the intent of the requirement is not to limit shunt safety components to diodes, the reference to diodes in the second sentence should be changed to "shunt safety components". If such a change is not made the requirements in the second sentence do not apply to resistors, etc., used as shunt safety components.

3.1.4 Paragraph 5.22 - In order for a single barrier (on one side of the line only) to be effective when ground faults are introduced into a system, the barrier must be grounded, even if used on an isolated system. This paragraph implies that the barrier may be connected to a "common bus" rather than to ground. We suggest the words "common bus" be changed to "ground". By "ground" it is meant that there is an electrical bonding between all noncurrent-carrying metal parts including the enclosure and the power supply common.

3.1.5 Paragraph 6.1 - The intent of the words "or faults" is not clear. A fuse does not prevent a fault, but may limit the time current flows during a fault. We suggest "or faults" be deleted.

3.1.6 Paragraph 8.1 -

3.1.6.1 - The last sentence in paragraph 8.1 specifies a test of Category B associated apparatus, yet complete details of the test and acceptance or rejection criteria are not given.

3.1.6.2 - Since Table 8.1A applies only to Category A associated apparatus, and Table 8.1B spacings are suggested rather than required minimums, the spacings in Category B associated apparatus are permitted to be less than required minimums for Category A associated apparatus. We do not believe this was really intended and it should not be permitted. If they adversely affect intrinsic safety, the spacings should apply in associated apparatus as well as in the intrinsically safe circuits. We suggest, as one possible solution, that the end of the first sentence of paragraph 8.1 be revised to read: "...Table 8.1A for circuits of both Categories A and B associated apparatus".

3.1.7 Table 8.1B - In Footnote a of Table 8.1B it is recommended that the electrical spacings be no less than the electrical spacings in Table 8.1A. We believe it should be required that Category B associated apparatus have the same minimum spacings as Category A associated apparatus because the use of a permissible enclosure is unlikely to reduce the probability of a component fault, and a fault would have the same result regardless of the location of the associated apparatus. The change recommended in 3.1.6.2 would take care of part of the problem. In addition, the phrase "but it is recommended that they not be less than the spacings of Table 8.1A" should be deleted from Footnote a of Table 8.1B.

3.1.8 Paragraph 8.3 - The last sentence indicates that dielectric withstand tests may be conducted if deemed necessary in the opinion of the testing agency. This sentence appears to be unnecessary since the dielectric withstand test is required in paragraph 22.1. If this dielectric withstand test is intended to evaluate the adequacy of the casting resin discussed in paragraph 8.3, then we recommend additional details concerning when this test is needed, and how it is to be conducted.

3.1.9 Paragraph 9.4 - The intent of requiring a partition is to separate wiring of intrinsically safe and other circuits that may affect intrinsic safety from nonintrinsically safe circuits. If a metal partition is not grounded, both circuits intended to be separated may short to the partition and thus be connected to each other. We believe the requirement in paragraph 9.4 needs to specify that a metal partition be grounded. Otherwise its effectiveness may be nullified.

3.1.10 Paragraph 10.4 - Field wiring of nonintrinsically safe circuits may be routed in the vicinity of intrinsically safe wiring. Presently this condition is not addressed. We recommend the wording of the paragraph should be changed to add "...separation of intrinsically safe or associated field-installed conductors from other field-installed conductors and uninsulated live parts of the device connected to different circuits..." to clarify the intent (added material is underlined).

3.1.11 Paragraph 11.1 - The intent of this requirement is to separate field wiring terminals for intrinsically safe circuits from wiring or uninsulated live parts of any other circuits. Therefore it is recommended that the wording be changed to "... or may have wiring terminals for intrinsically safe circuits separated by a distance of not less than 50 mm (2.0 in.) from uninsulated live parts and wiring of any other circuit if clear..." (added material is underlined).

3.1.12 Paragraph 12.2 - The requirements in paragraph 12.2 cover intrinsically safe batteries. The reference "...batteries shall comply with 16.3" needs clarification since paragraph 16.3 indicates requirements pertaining to devices or equipment in permissible enclosures.

3.1.13 Paragraph 13.2 - Since there is no Table 8.1, the reference should be to 8.1A. See also our comments in paragraphs 3.1.6.2 and 3.1.7.

3.1.14 Paragraph 16.2 - The term "operating temperature" requires definition as well as the conditions under which it is determined. The coal dust blanket needs some quantitative description, such as thickness, type of coal, and sieve size.

3.1.15 Paragraph 16.3 - Same as comments for paragraph 16.2. Also, reference to 100 C may not be pertinent if the box surface temperature is the only determining factor.

3.1.16 Paragraph 19.6 -

3.1.16.1 - The requirement in the second sentence of paragraph 19.6 may make it impossible to conduct the test in accordance with the other requirements in "MESAP"(9). It may be difficult to obtain a wire of the same material as that used in the circuit and having a cross sectional area not exceeding 50 percent of that of the circuit wiring. Additionally, small wires, about 0.004 in. diameter and less, have little rigidity and tend to bend when they first contact the disc in the spark test mechanism, so that the mechanism will not produce sparks as intended. Since the test already incorporates a test (safety) factor we recommend that the smallest conductor strand be used for the test and, a 0.005 in. minimum strand diameter in the construction requirements. Alternatively, we recommend that no minimum diameter be specified in the construction requirements and the test be conducted as described in UL 913(1).

3.1.16.2 - For certain test circuits, it may not be possible to test in compliance with both paragraphs 19.5 and 19.6. For example, the test circuit for Item 4 having parameters of 6.3 v d c, 30.15 amp (paragraph 7.7.28) is required to be tested using wires in the test mechanism having a diameter of about 0.004 in. since circuit wiring at the point of test incorporates 0.006 in. diameter strands. The resistance of a 0.004 in. diameter (No. 38 AWG) strand of copper wire is 0.02164 ohm per centimeter(2). For the 11 mm long strand used in the test mechanism, the resistance is 0.0238 ohm. At the 30.15 amp test current, the voltage drop across the 11 mm strand is 0.718 v, representing 11.4 percent of the initial source voltage of 6.3 v. According to paragraph 19.5 the voltage loss permitted in the system wiring is limited to 5 percent, therefore, it is not possible to conduct the test in accordance with "MESAP"(9). If the intent is to limit the impedance of the test mechanism, excluding the 11 mm long wire used for sparking, we recommend the requirement be revised to so indicate. This would eliminate the problems of small diameter wire strand resistance.

3.1.17 Paragraph 19.8 - Same as comment for paragraph 19.6.

3.1.18 Paragraph 25.1 - Same as comment for paragraph 16.2.

3.1.19 Paragraph 26.1 - The acceptance criteria is not clear from the present wording. We recommend that a differentiation be made between coal dust ignition (glowing) and gas-air mixture ignition. If it is intended that ignition of either the coal dust or gas-air mixture, or both, constitute a test failure then it should be so stated. The coal dust layer also needs some quantitative description (see paragraph 3.1.14).

3.1.20 Paragraph 30.8 - Equipment using batteries which are not intrinsically safe as shown by tests per paragraph 12.2 is not required to be marked to alert service personnel to replace batteries in a nonhazardous atmosphere only. We recommend that this type of equipment be required to be marked with the statement "Caution: To prevent ignition of hazardous atmospheres, batteries must be replaced in a nonhazardous location only," or equal.

3.2 The following paragraphs describe items or requirements where editorial rather than technical revision or modification of "MESAP"(9) is judged necessary.

3.2.1 Paragraph 4.2 - Since paragraph 4.2 applies to many different types of apparatus and components which are covered by standards it appears to be more appropriate to make reference to a specific standard as an example only. The reference to ANSI C19.3 requires, for example, equipment such as methane monitors, telephones, and flashlights and lanterns to meet the requirements for industrial control equipment. We recommend that the wording be changed to "...with the applicable ANSI requirements..." (added material is underlined). The reference to ANSI 19.3 can then be omitted or left in as an example only.

3.2.2 Paragraph 4.5 - Same type of comment as for paragraph 4.2 above.

3.2.3 Paragraph 5.3 - The reference to an ANSI Standard in paragraph 5.3 is incomplete. We recommend that the wording be changed to "...complies with the appropriate ANSI requirements..." (added material is underlined). The reference to an ANSI Standard can be completed and left in as an example or omitted.

3.2.4 Paragraph 5.12 - The referenece should be to paragraph 20.3, not 20.2.

3.2.5 Paragraph 5.20 - The reference to 350 v should include a definition, such as Peak, RMS or DC, as appropriate. The value stated in UL 913(1) is 250 v RMS.

3.2.6 Paragraph 5.25 - This specifies that an encapsulated diode barrier is required to pass a dielectric withstand test in paragraph 22.1. This appears to contradict paragraph 22.1, which states that zener barriers are not required to be subjected to this test. In UL 913(1), zener barriers are not subjected to a dielectric withstand test. If this dielectric withstand test is intended to evaluate the adequacy of the encapsulating material then we recommend additional details concerning when this test is needed, and how it is to be conducted.

3.2.7 Table 8.1A - The through air and over surface columns are reversed.

3.2.8 Paragraph 19.10 - This provides a formula which is used to determine the correct calibration current to be used for a specific value of inductance for the spark test apparatus. We recommend including the units for I (current) and L (inductance) and extending the square root symbol over the "L" to clarify the formula. Additionally, the constants in the formula could be combined into a single constant unless there is some special significance to the present form.

3.2.9 Paragraph 26.1 - The word "tests" in the second sentence should be "test".

3.2.10 Paragraph 30.3 - The required minimum marking should be required to be permanent.

CHAPTER 4

IMPACT OF "MESAP"

4.1 GENERAL

In this chapter an estimate is made of the impact of the proposed adoption of the document "MESAP"(9) upon existing and future intrinsically safe certification by M.E.S.A. with regard to approvals or disapprovals. This impact estimation does not include estimates of financial impact, but only the availability of equipment and apparatus.

4.2 EXISTING INTRINSICALLY SAFE CERTIFICATION BY MESA

4.2.1 If the ten items of equipment investigated as described in Chapter 5 are representative of all M.E.S.A. Certified intrinsically safe equipment, it would appear that most if not all of the presently Certified intrinsically safe equipment will require some degree of redesign to bring it into compliance with "MESAP"(9). This would include the major items as:

4.2.1.1 Redesign of printed wiring boards to provide greater electrical spacings between circuit conductors affecting intrinsic safety.

4.2.1.2 Redesign of step-down isolation transformers to meet the new requirements for transformers as protective components.

4.2.1.3 Rearrangement of internal wiring, components and wiring terminals to meet the requirements for separation of circuits.

4.2.1.4 Reduction in energy available to intrinsically safe circuits under both normal and fault conditions.

4.2.2 In addition, markings on the product and information, such as installation instructions, sent out with the product would require modification.

4.3 FUTURE INTRINSICALLY SAFE CERTIFICATION BY MESA

4.3.1 It does not appear that manufacturers will have any major problems complying with the proposed requirements in "MESAP"(9) if these requirements are revised to incorporate the suggested modifications in Chapter 3. The requirements appear to be based on, and are quite similar to, the requirements in such Standards as:

a) NFPA 493(3).
b) UL 913(1).
c) CSA 22.2(4).
d) IEC Publication 79-11(5).
e) EN50-020(6).

4.3.2 These Standards, or very similar ones, are currently used and have been used for several years by the various testing laboratories and certifying or approval bodies throughout the world to determine the acceptability of intrinsically safe equipment for both mining and nonmining applications. A great deal of intrinsically safe equipment has already been designed to meet these requirements and is currently in production and use.

4.3.3 Adoption of the "MESAP"(9) requirements with the modifications recommended here will help unify MESA's requirements for intrinsically safe equipment and circuits with the requirements applied by other testing laboratories and certifying and approval bodies. Also, the more stringent requirements of "MESAP"(9) should provide an increased level of safety over that presently provided by the requirements of CFR Title 30(8) for intrinsically safe equipment.

CHAPTER 5

EXAMINATION AND TESTING OF METHANE MONITORING SYSTEMS AND MACHINE CONTROL CIRCUITS IN ACCORDANCE WITH THE CODE OF FEDERAL REGULATIONS (CFR) TITLE 30(8)

5.1 GENERAL

5.1.1 The examination and testing of the following equipment is based on the application of the requirements pertaining to intrinsic safety only of Parts 18 and 27 of Title 30(8) of the Code of Federal Regulations, as interpreted by the authors.

5.1.2 The results of these investigations indicate that none of the Methane Monitoring Systems and Machine Control Circuits comply with the requirements of Title 30(8) based on the interpretation of the requirements by UL and identified in the individual Sections. Examination of each device disclosed features of construction which do not comply with the requirements, and testing of each device caused ignition of the explosive gas-air mixture, except Item 4 which successfully completed the ignition test.

5.2 ENSIGN ELECTRIC AND MANUFACTURING COMPANY, I.S.R. CIRCUIT, ITEM 10

Product Description

5.2.1 Intrinsically safe relay, Part No. 6651-005, manufactured by Ensign Electric Division, Harvey Hubbell Inc., of Huntington, West Virginia. The coil is rated 230 v dc, shunt duty, and the contacts are rated 250 v d c, 2 amp. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe, which may extend into the hazardous area of the underground mine.

5.2.2 Three complete sample devices along with additional component parts were purchased from the manufacturer since a distributor for this device is not available in this area, and were subjected to the examination and tests described below.

5.2.3 The results indicate that the construction of the device does not comply with the requirements nor does the performance of the device comply with the requirements since ignition of methane-air mixture was obtained during spark ignition tests at the I.S.C. terminals with no faults introduced.

Examination of Construction

GENERAL

5.2.4 Instructions covering installation of the devices were not supplied as part of the equipment. Instructions were provided upon request. The electrical schematic is shown in Figure 1.

5.2.5 The type of pilot device which is intended to be used with this equipment and located in the hazardous area is not specified or limited.

5.2.6 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

ELECTRICAL SPACINGS, SECTIONS 18.24 and 18.60(e), TITLE 30(8)

5.2.7 In determining compliance with Sections 18.24 and 18.60(e) the level of adequacy was based on the requirements in UL 913(7).

5.2.8 The wiring terminals provided on the device extend both above and below the mounting base. This, coupled with the lack of adequate installation instructions, make it difficult to insure that electrical spacings to grounded parts will be maintained after installation. Also, the size and the shape of the mounting screws may result in inadequate spacings.

5.2.9 Field wiring connections are made at terminals which are used for factory-installed wiring. When connecting the field-installed wiring, tightening the terminal nuts causes the factory-installed wiring crimp-on connectors to turn. This may result in reduced electrical spacings. The through air spacings between the terminals and the isolated metal bracket supporting the resistor and the diode may be reduced to zero in their most unfavorable positions. This does not comply with paragraphs 294, 295 and Table 13 of UL 913(7), which require a spacing of 1/4 in. through air. The above conditions may short out the 2500 ohm resistor.

5.2.10 The through air spacing between the factory-installed crimp-on connector at the intrinsically safe "one" terminal and the uninsulated line voltage terminal at the diode was measured to be 1/8 in. with the crimp-on connector in the most unfavorable position. This does not comply with paragraphs 294, 295 and Table 13 of UL 913(7), which require a spacing of 1/4 in. through air.

FASTENINGS, SECTION 18.60(h), TITLE 30(8)

5.2.11 Attachment of the coil frame to the base is accomplished by means of two machine screws without lock washers. This is not considered to be adequately secured against vibration.

5.2.12 Fastening of wiring terminals is not adequate since installation of field wiring caused the plus terminal to turn.

TESTS FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.2.13 The current limiting resistor is not duplicated, therefore the construction does not comply with Section 18.68(a)(3)(i).

5.2.14 Since the current limiting resistor and the diode are attached to their supporting frame without employing lock washers, they are not considered as being mounted as to provide protection against shock and vibration as required in Section 18.68(a)(3)(ii).

5.2.15 The polarity of the input terminals is not identified on one of the samples examined. Therefore, adequate precautions have not been taken to insure against accidental reversal of polarity as required in Section 18.68(b)(7).

5.2.16 Installation instructions do not specify that the relay is to be installed in an explosion proof enclosure as it is required to be in Section 18.68(c)(2).

5.2.17 Intrinsically safe internal wiring of the device is intermingled with nonintrinsically safe wiring. Also, field connected, nonintrinsically safe wiring may be intermingled with intrinsically safe wiring. This does not comply with Section 18.68(c)(3).

5.2.18 Intrinsically safe circuits are not identified as required in Section 18.68(e).

Test Record

GENERAL

5.2.19 The samples and component parts of the device identified in paragraphs 5.2.1 and 5.2.2 were subjected to the following tests to determine compliance with the specified requirements for intrinsically safe certification in CFR Title 30(8), except for the dielectric withstand test which is described in paragraph 6.2.27.

5.2.20 In the following, reference is made to requirements in UL 913(7) in Appendix B.

5.2.21 Input-Output Test

METHOD

A sample of the relay was connected to the source of supply and load indicated. Input and output at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured		
Designation	Nos.	V	V	Amps	W
Input	+ And -	250 DC	250 DC	0.051	-
Output	1 And 2	-	250 DC+	0.051++	-

+ - Open circuit volts.

++ - Short circuit current.

5.2.22 Undervoltage and Overvoltage Test

METHOD

Immediately following the Normal Temperature Test, the sample was subjected to the following tests.

Undervoltage Test - The input voltage was reduced to 80 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated, V	Undervoltage Test, V	Results
250 DC	200 DC	Coil would not pull in.

Overvoltage Test - Following the Undervoltage Test, the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times. The relay coil temperature was not recorded.

Rated, V	Standard Test, V	Overvoltage Test, V	Results
250 DC	250 DC	275 DC	Operated Properly

RESULTS

The results do not comply with the requirements in paragraphs 240 through 242 of UL 913(7) since the coil would not pull in at the undervoltage test voltage when the coil was in a heated condition.

5.2.23 Normal Temperature Test

METHOD

A sample of the relay was subjected to this test. The sample was connected to the source of supply and load indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument except as noted. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals Designation	Terminals Nos.	Voltage Source	Load
Input	+ and -	250 V DC	
Output	1 and 2	-	Short Circuit

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7) since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Coil Insulation	85(+)
2	Contacts	29
3	Insulating Base at Coil	56
4	Internal Wire	38
5	Diode, Top	33
6	Resistor, Top	68
7	Resistor, Side, Middle	87

Test Time - 7 Hr.

(+) - Measured by change-of-resistance method.

5.2.24 Component Operation Test

METHOD

With the apparatus connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Input Volts	Output Load
250 DC	(+)

(+) - The output load was varied from open to short circuit conditions. The measured values recorded under results represent the highes values obtainable from under these conditions.

RESULTS

The results are recorded in the following tabulation.

Component		Rated					Measured				
Type	P/N	Peak Inverse Volts	Amps	W	Ohms	V	Percent Rated Volts+	Amps	Percent Rated Amps+	W	Percent Rated W+
Resistor	F423	-	-	40	2500	124	-	-	-	6.15	15
Diode	FMCA7 SD-0606	480 DC	0.56	-	-	126	26.3	0.0022	0.4	-	-

+ - Calculated value.

The results comply with the requirements in Section 18.68 of CFR Title 30(8) since the current limiting components did not operate at more than 50 percent of their ratings and the semiconductors did not operate at more than two-thirds of their rated current and peak inverse voltage.

5.2.25 Spark Ignition Test

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits, the polarity was reversed after not less than 500 make and break sparks.

The input voltage for the test was adjusted by the appropriate voltage factor indicated based on a rating of 250 v dc.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	I.S.C. Terminals 1 and 2 with no faults introduced.
2	Same as Test Circuit 1 with polarity reversed.
3	Short circuit 2500 ohm resistor.
4	Same as Test Circuit 3 with polarity reversed.
5	Open shunt diode.
6	Same as Test Circuit 5 with polarity reversed.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit Volts	Short Circuit Ma	Number of Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.2	Brass	300 DC	59.7	8	Ignition	32	-
2	1	0	1.0	Brass	250 DC	49.2	5	Ignition	-	268

The results do not comply with the requirements in Section 18.69 of CFR Title 30(8) since ignition of the methane air mixture was obtained in less than 1000 minimum make and break sparks.

5.3 ENSIGN ELECTRIC AND MANUFACTURING COMPANY, I.S.R. CONTROL CIRCUIT PART NO. 6651-004, ITEM 11

Product Description

5.3.1 Intrinsically safe relay, Part No. 6651-004, manufactured by Ensign Electric Division, Harvey Hubbell, Inc. of Huntington, West Virginia. The device is rated 575 v ac, and the contacts are rated 110 v ac, 10 amp. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe which may extend into the hazardous area of the underground mine.

5.3.2 Three complete sample devices along with additional component parts were purchased from the manufacturer since a distributor for this device is not available in this area, and were subjected to the examination and tests described below.

5.3.3 The results indicate that the construction of the device does not comply with the requirements nor does the performance of the device comply with the requirements since ignition of methane-air mixture was obtained during spark ignition tests at Terminals 7 and 9 with one fault introduced.

Examination of Construction

GENERAL

5.3.4 Instructions covering installation of the devices were not supplied as part of the equipment. Instructions were provided upon request. The wiring and schematic diagram is shown in Figure 2.

5.3.5 The type of pilot device which is intended to be used with the equipment and located in the hazardous area is not specified or limited.

5.3.6 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.3.7 In determining compliance with Sections 18.24 and 18.60(e) the level of adequacy was based on the requirements in UL 913(7).

5.3.8 The over surface spacing between uninsulated 120 v relay line voltage conductors and intrinsically safe uninsulated conductors within the relay socket was measured to be 3/64 in. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of 1/4 in.

5.3.9 The through air spacing betwen uninsulated 120 v line voltage terminal pins and intrinsically safe uninsulated terminal pins on the relay was measured to be 5/32 in. This does not comply with paragraph 294 and Table 13 which require a spacing of 1/4 in.

FASTENINGS, SECTION 18.60(h), TITLE 30(8)

5.3.10 The relay is not provided with any means of securement other than friction with the socket, which does not comply with Section 18.60(h).

TESTS FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.3.11 The 100 ohm current limiting resistor is not duplicated. Therefore the construction does not comply with Section 18.68.

5.3.12 Attachment of resistors is accomplished by means of two machine screws threaded into a steel plate. Lock washers are not used. This does not comply with Section 18.68(a)(3)(ii) since the mounting may not provide adequate protection against shock and vibration.

5.3.13 Installation instructions do not specify that the relay is to be installed in an explosion-proof enclosure, as it is required to be in Section 18.68(c)(2).

5.3.14 Intrinsically safe internal wiring of the device is intermingled with nonintrinsically safe wiring. The transformer secondary wiring is bunched together with the intrinsically safe wiring leading to Terminal 7 and inside the relay, the wiring of the contact circuits, which are rated 120 v, is in contact with the relay coil, part of the intrinsically safe circuit. See Figure 2. Also, field-connected nonintrinsically safe wiring may be intermingled with intrinsically safe wiring. This does not comply with Section 18.68(c)(3).

5.3.15 The intrinsically safe circuit is not identified as required in Section 18.68(e).

5.3.16 The transformer is not identified as required in Section 18.68(e).

Test Record

GENERAL

5.3.17 The samples and component parts of the device identified in paragraphs 5.3.1 and 5.3.2 were subjected to the following tests to determine compliance with the requirements for intrinsically safe certification in CFR Title 30(8) except for the dielectric withstand test which is described in paragraph 6.3.27.

5.3.18 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.3.19 Input-Output Test

METHOD

A sample of the relay was connected to the source of supply and load indicated. Input and output at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured		
Designation	Nos.	V, Cy	V, Cy	Amp	W
Input		600, 60 Hz	600, 60 Hz	0.0156	4.25
Output	7 and 9	-	36.8+ DC	0.119++	

+ - Open circuit volts.

++ - Short circuit current.

5.3.20 Normal Temperature Test

METHOD

A sample of the relay was subjected to this test. The sample was connected to the source of supply and load indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument except as noted. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals		Voltage Source	Load
Designation	Nos.		
Input	-	600 v, 60 Hz	-
Output	7 and 9		Short Circuit

RESULTS

The results are recorded in the following tabulation. The results comply with the requirements in paragraphs 226 through 235 of UL 913(7) since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Transformer Core	37
2	Transformer Primary Winding	33
3	Transformer Secondary Winding	33
4	1000 Ohm Coil Shunt No. 1	51
5	1000 Ohm Coil Shunt No. 2	54
6	1000 Ohm Transformer Shunt	65
7	100 Ohm Resistor	66
8	Relay Socket Near Coil Terminal	39
9	Relay Coil	93(+)

Test Time 6 Hr.

(+) - Measured by change-of-resistance method.

5.3.21 Undervoltage and Overvoltage Test

METHOD

Immediately following the Normal Temperature Test the sample was subjected to the following tests. Tests were conducted at rated frequency unless otherwise stated.

Undervoltage Test - The input voltage was reduced to 85 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated, V Cy	Undervoltage Test, V	Results
575, 60 Hz	488.75	Normal Operation

Overvoltage Test - Following the Undervoltage Test the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times. The relay coil temperature was not recorded.

Rated, V, Cy	Standard Test, V	Overvoltage Test, V	Results
575, 60 Hz	600	660	Normal Operation

RESULTS

The results comply with the requirements in paragraphs 240 through 242 of UL 913(7) since the coils were not damaged during the test and they could cause the electromagnets to function in the intended manner.

5.3.22 TRANSFORMER OUTPUT

METHOD

Samples of the protective transformers were subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Transformer Rated		Test		Secondary	
				Open	Short Circuit Amp
V	Hz	V	Hz	Circuit, V	After 1 Min
575	60	600	60	37.1	5.68

5.3.23 COMPONENT OPERATION TEST

METHOD

With the apparatus connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Input Volts	Output Load
600, 60 Hz	(+)

(+) - The output load was varied from open to short circuit conditions. The measured values recorded under results represent the highest values obtainable under these conditions.

RESULTS

The results are recorded in the following tabulation:

Component		Rated		Measured		
Type	P/N	Watts	Ohms	Volts	W (+)	Percent Rated W+
Resistor	F210	20	100	12.08	1.46	7.3
Resistor (Across Transformer Secondary)	HLM-20-10Z	20	1000	36.1	1.3	6.5

(+) - Calculated value.

The results comply with the requirements in Section 18.68 of CFR Title 30(8) since the current limiting components did not operate at more than 50 percent of their ratings.

5.3.24 SPARK IGNITION TEST

METHOD

The circuit selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source, in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated.

The input voltage for the test was adjusted by the appropriate voltage factor indicated based on a rating of 575 v, 60 Hz.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe Terminals 7 and 9 with no faults introduced.
2	Same as Circuit 1 with the 100 ohm resistor shorted.
3	Same as Circuit 1 with one 1000 ohm resistor shunting coil open.
4	Same as Circuit 1 with the 1000 ohm transformer secondary shunt resistor open.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit Volts	Short Circuit Ma	Number Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.2	Brass	42.3	134.1	5000	No Ignition	80	48
2	2	1	1.2	Brass	42.3	231	8	Ignition	48	-
3	2	1	1.0	Brass	35.3	134.5	524	Ignition	192	-
4	3	1	1.2	Brass	42.5	127	5000	No Ignition	20	88
5	4	1	1.2	Brass	42.5	134	5000	No Ignition	44	112

The results do not comply with the requirements in Section 18.68 of CFR Title 30(8) since ignition of the methane-air mixture was obtained in less than 5000 minimum make and break sparks.

5.4 MSA, MODEL VI METHANE MONITOR, ITEM 1

Product Description

5.4.1 Model VI Methane Monitoring System, manufactured by Mine Safety Appliances Company of Pittsburgh, Pennsylvania. The system consists of an AC power supply and contact driver, Part No. 458175 (Figure 3), a monitor Part No. 456960 and a detector Part No. 458120 (Figure 4). Additionally, an auxiliary battery power source Part No. 95554 is available to power the monitor. The power supply intended to be mounted within an explosion-proof enclosure, has circuits claimed to be intrinsically safe which are connected to the monitor and the detector, each claimed to be intrinsically safe. The power supply is rated 550 v ac input, the battery is rated 4 v dc.

5.4.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributor for this device is not available in this area, and subjected to the examination and tests described below.

5.4.3 The results indicate that the construction of the device does not comply with the requirements nor does the performance of the device comply with the requirements since ignition was obtained during spark ignition tests at Terminals 9 and 10 of the AC power supply and contact driver with one fault introduced and also with a series configuration of twice the normal battery compliment.

Examination of Construction

GENERAL

5.4.4 The electrical schematics for the equipment are shown in Figures 3 and 4.

5.4.5 Interconnection of the power supply and monitor is accomplished by a seven conductor cable of which only three conductors are used. Additional conductors are provided for connection to unspecified remote meter and relay which are not supplied with the equipment. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe.

5.4.6 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

APPLICATIONS, SECTION 18.6, TITLE 30(8)

5.4.7 The wiring diagrams were not marked with a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition as is required in Section 18.6(e).

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.4.8 In determining compliance with Sections 18.24 and 18.60(e) the level of adequacy was based on the requirements in UL 913(7). The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6. The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those indicated in Column 301-600 of Table 13.

5.4.9 In the power supply, the through air spacings between an uninsulated conductor on Resistor RX and uninsulated live part on ABC-2 fuseholder, see Figure 3, can be reduced to 0 since the fuseholder was free to turn. This does not comply with paragraph 295 and Table 13 of UL 913(7) which require 3/8 in. through air spacing.

TEST FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.4.10 The power supply is not provided with an explosion-proof enclosure as is required in Section 18.68(c)(2).

5.4.11 In the power supply, line voltage and conductors intended to be intrinsically safe are bunched togther for routing. Field connected nonintrinsically safe wiring may be intermingled with wiring intended to be intrinsically safe since all field wiring is completed on the same terminal block. Also, in the cable provided for interconnecting the power supply and monitor, the additional conductors which may be used for connection to the unspecified remote meter and relay permit uninsulated conductor ends to contact uninsulated line voltage parts which may result in transmission of line voltage to equipment intended to be intrinsically safe and located in the hazardous area. This does not comply with Section 18.68(c)(3).

5.4.12 Circuits and terminals of the power supply and the monitor and detector intended to be intrinsically safe are not so identified. This does not comply with Section 18.68(e).

5.4.13 The monitor is not marked to indicate the manufacturer, type or ratings of the battery to be used. This does not comply with Section 18.68(e).

Test Record

GENERAL

5.4.14 The samples and component parts of the device identified in paragraphs 5.4.1 and 5.4.2 were subjected to the following tests to determine compliance with the specified requirements for intrinsically safe certification in CFR Title 30(8) except for the dielectric withstand test which is described in paragraph 6.4.34.

5.4.15 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.4.16 INPUT-OUTPUT TEST

METHOD

A sample of the methane monitoring system was connected to the source of supply and loads indicated. Inputs and outputs at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured			
Designation	Nos.	V	V	Amp	W	Remarks
Power Supply Input	2 & 3	440 60 Hz	480, 60 Hz	0.049	22.5	
Power Supply Output	9 & 10	4 DC	4.33 (+)	3.94 DC (++)	-	2 amp fuse opened
Power Supply Output	8 & 10	-	4.27 (+)	0.016 DC (++)	-	
Monitor Output	3 & 5	-	4.20 (+)	1.36 DC (++)	-	
Monitor Ouput	14 & 1	-	4.33 (+)	0.004 DC (++)	-	Terminals for remote meter

(+) - Open circuit volts.

(++) - Short circuit current.

5.4.17 BATTERY OUTPUT TEST

METHOD

Three samples of the batteries supplied for use with the equipment were tested to determine their outputs. Each battery was in a fully charged state at the beginning of each test.

The battery output current measured with 50 mv, 50 amp shunt and Tektronix 466 oscilloscope.

RESULTS

Battery Type, Part No.	Test No.	Sample No.	Maximum Open Circuit Volts	Maximum Short Circuit Current, Amps	Note
Lead Acid, 95554	1	1	4.74	27	1
	2	2	4.74	27	1
	3	1	4.85	30	1
	4	2	4.80	26	1
	5	2	4.79	28	1
	6	1	4.80	28	1
	7	2	4.80	29	1
	8	1	4.82	29	1
	9	1	4.71	4.43	2
	10	3	4.80	42	3
	11	3	4.78	38	3
	12	3	4.77	39	3
	13	3	4.83	39.5	3
	14	3	4.79	30.5	3
	15	3	4.74	40	3
	16	3	4.73	41	3
	17	3	4.99	42	3

Notes

1 Battery protective device opened the circuit in each case. Protector in battery Sample No. 1 opened in about 160 m sec and the protection battery Sample No. 2 opened in about 200 m sec.

2 Sufficient series resistance was added to maintain continuous current flow without opening protector.

3 Battery protective device short-circuited.

5.4.18 NORMAL TEMPERATURE TEST

METHOD

A sample of the methane monitoring system was subjected to this test. The sample was connected to the source of supply and loads indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals Designation	Terminals Nos.	Voltage Source	Load
Power Supply Input	3 & 2	480 v, 60 Hz	-
Power Supply Output	8, 9 & 10	-	Monitor
Power Supply Output	6 & 7	-	15 amps
Monitor	3, 4, 5 & 6	-	Sensor

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7), since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Line Transformer, Core	52
2	Transformer Windings	50
3	Capacitor, 4500 muf	34
4	Relay Coil	69.5 (+)
5	Lead Wire at 2 amp Fuse	35
6	Monitor Pilot Lamp	43
7	Monitor Enclosure, Hot Spot	27
8	Monitor Lamp Lead Wire	27
9	Sensor, 40 ohm resistor	30
10	Sensor Lead Wire	27
11	Sensor Head	31

Test Time 7 Hr.

(+) - Measured by change-of-resistance method.

5.4.19 UNDERVOLTAGE AND OVERVOLTAGE TEST

METHOD

Immediately following the Normal Temperature Test, the sample was subjected to the following tests. Tests were conducted at rated frequency unless otherwise stated.

Undervoltage Test The input voltage was reduced to 85 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated, V	Undervoltage Test, V	Results
440, 60 Hz	374	Relay Operated Properly

Overvoltage Test - Following the Undervoltage Test, the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times. The relay coil temperature was not recorded.

Rated, V	Standard Test, V	Overvoltage Test, V	Results
440, 60 Hz	480	528	Relay Operated Properly

RESULTS

The results comply with the requirements in paragraphs 240 through 242 of UL 913(7), since the coils were not damaged during the test and they would cause the electromagnets to function in the intended manner.

5.4.20 TRANSFORMER OUTPUT

METHOD

Samples of the transformers were subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Sample No.	Transformer Part No.	Rated V	Rated Hz	Test V	Test Hz	Secondary Open Circuit, V	Secondary Short Circuit Amps After 1 Min
1	68386	110	60	120	60	9.56	18.35
2	68386	220	60	240	60	9.59	18.87
3	68386	440	60	480	60	9.97	18.32
4	68386	550	60	600	60	9.91	18.35

5.4.21 THERMAL RUNAWAY TEST

METHOD

Each transistor located in equipment intended to be intrinsically safe was, in turn, subjected to this test. The transistor collector and emitter were connected in series with the power source. The polarity was such that the emitter junction was forward biased. A variable resistor was connected between the transistor base and collector. The resistance was slowly decreased until thermal runaway condition occurred, or until maximum heating of the component was noted. The test was continued under these conditions until maximum temperatures were attained. The temperatures were measured by means of thermocouples.

The power supply was a 12.80 v dc source with the maximum short circuit current limited to 12.35 amps, representing the output at Terminals 9 and 10 of the power supply with one fault introduced.

The results were recorded in the following table.

RESULTS

Test No.	Transistor Type	Current At Maximum Temperature, Ma	Maximum Temperature, Degrees C	Ambient Air, Degrees C	Supply Source V	Supply Source Amp	Remarks
1	2N3676,NPN	112	128	40	12.80	12.35	Transistor opened the circuit
2	2N4948,PNP	27	67	40	12.80	12.35	No runaway
3	D42C2,NPN	2000	263	40	12.80	12.35	Runaway
4	D43C2,PNP	1000	251	40	12.80	12.35	Runaway

The surface temperatures obtained on the transistors tested did not exceed 540 C (1004 F), the ignition temperature of methane.

5.4.22 THERMAL IGNITION - HEATING OF SMALL GAUGE WIRE STRAND TEST

METHOD

The indicated wire strands from the wire used in the intrinsically safe apparatus intended for use in the hazardous location were shorted across a supply circuit representing the maximum current under fault conditions in the intrinsically safe apparatus in the prescence of an explosive gas-air mixture.

The explosive gas-air mixture was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The tests were conducted in a test chamber measuring approximately 4 by 5-1/2 by 3 in. high. The test chamber was filled from the top. The inlet and outlet valves to the test chamber were then closed and the power applied to the wire strand.

One side of the test chamber consisted of a transparent plastic film to permit observation of the wire strand under test and to serve as a blow-out panel in the event of ignition.

Prior to the test, the inside of the chamber was heated to the temperature indicated.

RESULTS

Apparatus Cat. No.	Maximum Short Circuit Current, Amps	Wire Strand Diameter, In.	Wire Strand Length, In.	Chamber Ambient Air Temperature, Degrees C	Gas	Percent By Volume In Mixture With Air	Test Time, Min	Number Of Samples Tested	Results
95554 Battery	4.7	0.004	1/2	40	Methane	7.45	Wire Immediately Opened	11	No ignition
95554 Battery	8.65	0.006	1/2	40	Methane	7.45	Wire Glowed 30 Sec then Opened	13	No ignition
95554 Battery	8.72	0.010	1/2	40	Methane	7.45	3 Min	7	No ignition

5.4.23 SPARK IGNITION TEST

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348C of UL 913(7), with copper wires 0.008 in. diameter replacing the tungsten wires.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitible explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source in series with a 95 mh inductor and a variable resistor which was adjusted for 150 ma.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated. For direct current circuits, the polarity was reversed after not less than 500 make and break sparks.

When batteries were used during the test, four trials with fresh or fully charged batteries, two for each polarity, were used for each test circuit. The input voltage for the tests was adjusted by the appropriate voltage factor indicated based on a rating of 440 v, 60 Hz for line voltage power supply.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe Terminals 9 and 10, fuses shorted, no faults introduced.
2	A single battery.
3	Same as Circuit No. 2 with protector shorted.
4	Two batteries in parallel, with protectors shorted.
5	Two batteries in series, with protectors shorted.
6	Short 2N3055 collector to emitter, in power supply.
7	Same as Circuit No. 1 except normal input voltage was increased sufficiently to provide 125 percent normal output voltage at Terminals 9 and 10.
8	Same as Circuit No. 5 with sufficient series resistance added to represent the protectors closed circuit resistance (0.100 ohm as determined from 5.4.17 Battery Output Test).

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit V DC	Short Circuit Amps	Number of Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.2	Brass	4.40	4.07	1600	No ignition	112	24
2(+)	2	0	1.0	Brass	4.70	Note 1	1600	No ignition	24	248
3	3	1	1.0	Brass	4.72	Note 2	1600	No ignition	248	80
4	4	0	1.0	Brass	4.56	Note 3	4000	No ignition	80	160
5	5	0	2.0	Brass	9.26	Note 2	28	Ignition	160	-
6	6	1	1.2	Brass	12.80	12.35	12	Ignition	96	-
7	7	0	1.25 (++)	Brass	4.55	4.14	1600	No ignition	108	88
8	8	0	2.0	Brass	9.25	Note 4	4	Ignition	372	-

See following page for notes.

Notes

1 Current available was approximately 27 amps until the protector opened the circuit, as based on 5.4.17 Battery Output Test and test circuit.

2 Current available was approximately 40 amps as based on 5.4.17 Battery Output Test and test circuit.

3 Current available was approximately 80 amps as based on 5.4.17 Battery Output Test and test circuit.

4 Current available was approximately 4 amps as based on 5.4.17 Battery Output Test and test circuit.

(+) - Spark mechanism operation was adjusted to allow for protector to reset.

(++) - Applied to intrinsically safe output.

The results do not comply with the requirements in Sections 18.68 and 26.34 of CFR Title 30(8), since ignition of the methane air mixture was obtained in less than 1000 minimum make and break sparks in Tests Nos. 6 and 8.

5.5 SERVICE MACHINE COMPANY, B-742-001 POWER SUPPLY, ITEM 8

Product Description

5.5.1 Intrinsically safe power supply, Part No. B-742-001, manufactured by Service Machine Company of Huntington, West Virginia. The supply is rated 115 v, 60 Hz input, 5 through 12 v dc, in 1 v increments, output. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe, which may extend into the hazardous area of the underground mine to operate unspecified horns, buzzers, solenoids or relays.

5.5.2 A complete sample of the device along with additional component parts were purchased from the manufacturer, since a distributor for this device is not available in this area, and were subjected to the examination and test described below.

5.5.3 The results indicate that the construction of the device does not comply with the requirements nor does the performance comply with the requirements since ignition of a methane-air mixture was obtained during spark ignition tests at Terminals 7 and 9 with a 1 mh inductor in series with the spark mechanism and one fault introduced.

Examination of Construction

GENERAL

5.5.4 A schematic diagram and instructions covering installation of the devices were not supplied as part of the equipment. Instructions were provided upon request. The Schematic diagram is shown in Figure 5.

5.5.5 The equipment intended to be used with this device and located in the hazardous area was not provided, specified or limited. The connection of unknown electrical equipment to this device may result in the system not being intrinsically safe.

5.5.6 In the following reference is made to requirements in UL 913(7), which are described in Appendix B.

APPLICATIONS, SECTION 18.6, TITLE 30(8)

5.5.7 The wiring diagram shown in Figure 5, does not include a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition. This does not comply with Section 18.6(e).

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.5.8 In determining compliance with Sections 18.24 and 18.60(e) the level of adequacy was based on the requirements in UL 913(7). The required spacings for line voltage circuits are those indicated in Column 51-300, 2 kva maximum of Table 6. The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those indicated in Column 51-150 of Table 13.

5.5.9 The through air spacing between the uninsulated fuse terminals and grounded parts of the 7.5 ohm resistor can be reduced to 0 since the fuse holder was not prevented from rotating. This does not comply with paragraph 196 and Table 6 of UL 913(7) which require a 1/16 in. through air spacing.

TESTS FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.5.10 The current limiting resistor is not duplicated, therefore the construction does not comply with Section 18.68(a)(3)(i).

5.5.11 Since the current limiting resistor and the transformer are attached to their supporting frame without employing lock washers, they are not considered as being mounted as to provide protection against shock and vibration as required in Section 18.68(a)(3)(ii).

5.5.12 The polarity of the output terminals is not identified on the sample. Therefore, adequate precautions have not been taken to ensure against accidental reversal of polarity as required in Section 18.68(b)(7).

5.5.12 Installation instructions do not specify that the power supply is to be installed in an explosion-proof enclosure as it is required to be in Section 18.68(c)(2).

5.5.14 Intrinsically safe internal wiring of the device is intermingled with nonintrinsically safe wiring. Also, field connected nonintrinsically safe wiring may be intermingled with intrinsically safe wiring. This does not comply with Section 18.68(c)(3).

5.5.15 Intrinsically safe circuits are not identified as required in Section 18.68(e).

Test Record

GENERAL

5.5.16 The samples and component parts of the device identified in paragraphs 5.5.1 and 5.5.2 were subjected to the following tests to determine compliance with the specified requirements for intrinsically safe certification in CFR Title 30(8) except for the dielectric withstand test which is described in paragraph 6.5.26. Since the equipment which can be connected to the power supply was not specified, and since the equipment may have inductance, a 1 mh, coil was used in one of the spark ignition tests to indicate the inductive effect.

5.5.17 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.5.18 INPUT-OUTPUT TEST

METHOD

The sample was connected to the source of supply and load indicated. Input and output at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured			
Designation	Nos.	V, Hz	V, Hz	Amp	W	Remarks
Input	H1 & H2	115, 60	120, 60	0.181	21.3	No load.
Output	H1 & H2	115, 60	120, 60	0.326	39.3	With output Terminals 1 and 3 shorted.
Output	1 & 2	-	4.89 dc+	0.036++	-	
Output	1 & 3	12 dc	12.25 dc+	1.021++		

(+) - Open circuit volts.

(++) - Short circuit current.

5.5.19 NORMAL TEMPERATURE TEST

METHOD

The sample was connected to the source of supply and load indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals			
Designation	Nos.	Voltage Source	Load
Input	H1 & H2	120 v, 60 Hz	-
Output	1 & 3	-	Short Circuit

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7) since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraphs 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 27 C Ambient
1	Transformer Winding	52
2	Transformer Winding	48
3	Transformer Core	45
4	Capacitor	55
5	Rectifier	60
6	7.5 Ohm Resistor	101
7	Voltage Regulator	102
8	Internal Wiring	32
9	Diode	36
	Test Time 6 Hr.	

5.5.20 TRANSFORMER OUTPUT

METHOD

Samples of the protective transformers were subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Sample No.	Transformer Part No.	Rated V	Rated Hz	Test V	Test Hz	Secondary Open Circuit, V	Secondary Short Circuit Amp Instant	Secondary Short Circuit Amp 1 Min
1	TR12463	115	60	120	60	18.50	20.9	14.2
2	TR12463	115	60	120	60	18.50	21.1	14.3
3	TR12463	115	60	120	60	18.54	21.3	14.2

5.5.21 COMPONENT OPERATION TEST

METHOD

With the apparatus connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Input Volts	Output Load
120 v, 60 Hz	(+)

(+) - The output load was varied from open to short circuit conditions. The measured values recorded under results, represent the highest values obtainable under these conditions.

The results are recorded in the following tabulation.

RESULTS

Component		Rated				Measured				
Type	P/N	Volts	Amp	Watts	Ohms	Volts	Amp	Percent Rated Amp+	Watts+	Percent Rated Watts+
Resistor	4105A	-	-	1.5	350	7.35	0.021	-	0.154	10.3
Resistor	4104	-	-	1.5	300	4.90	0.016	-	0.08	5.3
Resistor	RH-50	-	-	50	7.5	12.74	1.66	-	21.6	43.2
Diode	1N3314A	15	0.83	50	-	13.94	0.745	89.8	-	-

(+) - Calculated value.

The results for the resistors comply with the requirements in Section 18.68 of CFR Title 30(8) since they did not operate at more than 50 percent of their ratings. The results for the Zener diodes do not comply with the requirements since they operated at more than two-thirds of their rated current.

5.5.22 SPARK IGNITION TEST

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinder.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source, in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated. For direct-current circuits the polarity was reversed after not less than 500 operations.

The input voltage for the tests was adjusted by the appropriate voltage factor indicated based on a rating of 115 v, 60 Hz.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe Terminals 1 and 3 with no faults introduced.
2	Same as Circuit 1 with Transistor MLM309K shorted from E to B.
3	Same as Circuit 1 with 7.50 ohm resistor shorted.
4	Same as Circuit 2 with a 1.005 mh, 0.126 ohm coil in series with spark mechanism to simulate an unspecified field connected device.
5	Same as Circuit 2 with 7.5 ohm resistor shorted. Circuit considered as representing only one fault since wiring from diodes to transistor were identified as "I.S. Wire".

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.2	Brass	12.28 dc	1.9	5600	No Ignition	44	272
2	2	1	1.2	Brass	14.62 dc	2.38	5600	No Ignition	48	264
3	3	1	1.2	Brass	12.35 dc	0.72	4000	No Ignition	236	268
4	4	1	1.2	Brass	14.62 dc	1.56	56	Ignition	552	-
5	5	1	1.2	Brass	15.8 dc	15(++)	(+)	Ignition	232	-

(+) - Less than 4.

(++) - Tungsten wires replaced with copper wires.

Ignition of the methane air mixture was obtained in less than 1000 make and break sparks in Test Nos. 4 and 5.

5.6 GENERAL MONITORS, MODEL 420 METHANE MONITOR, ITEM 2

Product Description

5.6.1 Model 420 Methane Monitoring System, manufactured by General Monitors, Inc. of Costa Mesa, California. The system consists of a Power Supply/Cut-Off Relay, Serial No. 8080-4008 (Figure 6), Control Indicator Unit, Part No. 18-00-810-1 (Figure 7) and a Remote Sensing Head, Part No. 18-00-823-1 (Figure 7). The Power Supply/Monitor Cut-Off Relay is intended to be mounted within an explosion-proof enclosure and has circuits to provide power to the Control Indicator Unit. The Control Indicator Unit is provided with an explosion-proof enclosure and has circuits claimed to be intrinsically safe which are connected to the Sensor Head. The power supply is rated 550 v, 60 Hz maximum input.

5.6.2 A complete sample system along with additional component parts were purchased through the National Mine Service Company, of Nashville, Illinois a local distributor for the equipment. The samples were subjected to the examination and tests described below.

5.6.3 The results indicate that the construction of the device does not comply with the requirements nor does the performance of the device comply with the requirements since ignition of a methane-air mixture was obtained during spark ignition tests at Sensor Head Terminals 1 and 3 with one fault introduced.

Examination of Construction

GENERAL

5.6.4 The electrical schematics for the equipment are shown in Figures 6 and 7.

5.6.5 Interconnection of the Power Supply and Monitor Cut-Off Relay to the Control Indicator Unit is accomplished by means of a five conductor cable of which only three conductors are used. The additional conductors provided may be connected to unspecified auxiliary equipment which is not supplied with the equipment. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe.

5.6.6 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

APPLICATIONS, SECTION 18.6, TITLE 30(8)

5.6.7 The wiring diagrams provided for the equipment did not include a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition as is required in Section 18.6(e).

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(c), TITLE 30(8)

5.6.8 In determining compliance with Sections 18.24 and 18.60(e), the level of adequacy was based on the requirements in UL 913(7). The required spacings in line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6, except Cut-Off Relay Contact Circuits are those indicated in Column 301-600, unlimited VA of Table 6. The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those indicated in Column 301-600 of Table 13.

5.6.9 The full wave rectifier (secondary circuit) is connected to the monitor cut-off relay terminals. The through air spacing between the uninsulated live parts of the rectifier circuit to adjacent line voltage relay terminals was measured to be 3/16 in. This does not comply with paragraphs 185, 295, and Tables 6 and 13 of UL 913(7) which require 3/8 in.

TEST FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.6.10 The Power Supply and Monitor Cut-Off Relay is not provided with an explosionproof enclosure as is required in Section 18.68(c)(2).

5.6.11 In the control indicator unit, intrinsically safe internal wiring is intermingled with nonintrinsically safe wiring. Field-installed line voltage wiring may intermingle with field-installed wiring supplying intrinsically safe circuitry since all field wiring in the power supply is completed on the same terminal block. Also, in the cable provided for interconnecting the power supply and control indicator unit, the additional conductors, which may be used for connection to unspecified equipment, permit uninsulated conductor ends to contact uninsulated line voltage parts which may result in transmission of line voltage to equipment intended to be intrinsically safe and located in the hazardous area. The above does not comply with Section 18.68(c)(3).

5.6.12 Intrinsically safe circuits of the control indicator unit are not identified. The Remote Sensing Head, claimed to be intrinsically safe, is not identified. The wiring terminal connections at the Monitor Cut-Off Relay are not identified. The above does no comply with Section 18.68(e).

5.6.13 The 10 ohm Resistor R8 in the Control Indicator Unit is not duplicated, therefore the construction does not comply with Section 18.68(a)(3)(i).

METHANE MONITORING SYSTEM, SECTION 27.21, TITLE 30(8)

5.6.14 Attachment of component parts is accomplished by means of machine screws and tapped holes. Since lock washers are not used, this is not considered to be adequately secured against vibration as required in Section 27.21(b).

Test Record

GENERAL

5.6.15 The samples and component parts of the device identified in paragraphs 5.6.1 and 5.6.2 were subjected to the following tests to determine compliance with the specified requirements for intrinsically safe certification in CFR Title 30(8) except for the dielectric withstand test which is described in paragraph 6.6.29.

5.6.16 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.6.17 INPUT-OUTPUT TEST

METHOD

The sample was connected to the source of supply and loads indicated. Input and outputs at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured		
Designation	Nos.	V, Hz	V, Hz	Amp	W
Input, P.S.	1 & 2	110, 60	120, 60	0.137	15.0
Output, P.S.	5 & 6	11.5, 60	12.10, 60	0.332++	-
Output, P.S.	6 & 7	14, 60	14.82, 60	15.30++	-
Output, P.S.	5 & 7	-	3.13, 60	0.043++	-
Output, C.I.U.	6 & 7	-	11.95, dc+	0.022++	-
Output, C.I.U.	7 & 8	-	8.82, dc+	0.016++	-
Output, C.I.U.	6 & 8	-	18.40, dc+	0.315++	-

P.S. - Power Supply.

C.I.U. - Control Indicator Unit.

(+) - Open circuit volts.

(++) - Short circuit current.

5.6.18 NORMAL TEMPERATURE TEST

METHOD

The sample was connected to the source of supply and loads indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals			
Designation	Nos.	Voltage Source	Load
Input, Power Supply	1 & 2	120 v, 60 Hz	-
Output, Power Supply	6 & 7	14.82 v, 60 Hz	Control Indicator Unit
Output, Control Indicator Unit	6 & 8	18.40 v dc	Sensor Head

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7) since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Transformer Winding, P.S.	33
2	Transformer Winding, P.S.	36
3	Transformer Core, P.S.	36
4	Cut-Off Relay Coil, P.S.	36
5	Cut-Off Relay Rectifier, P.S.	36
6	Cut-Off Relay Coil Bobbin, P.S.	48
7	Malfunction Relay Coil, C.I.U.	54
8	Malfunction Relay Bobbin, C.I.U.	54
9	Malfunction Relay Socket, C.I.U.	49
10	Resistor, R8, 10 ohm, 2 w, C.I.U.	57
11	Capacitor, C1, 1000 uf, 25 v, C.I.U.	43
12	Wire Harness, C.I.U.	39
13	Enclosure Window, Outside, C.I.U.	32

Test Time 7 Hr.

P.S. - Power Supply

C.I.U. - Control Indicator Unit

S.H. - Sensor Head.

5.6.19 UNDERVOLTAGE AND OVERVOLTAGE TEST

METHOD

Immediately following the Normal Temperature Test the sample was subjected to the following tests. Tests were conducted at rated frequency unless other wise stated.

Undervoltage Test The input voltage was reduced to 85 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated V, Hz	Undervoltage Test, V	Results
120, 60	102	Device Operated Normally

Overvoltage Test - Following the Undervoltage test the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times.

Rated V, Hz	Standard Test, V	Over-voltage Test V	Test Time	Temperature, Degrees C: Relay Coil	Temperature, Degrees C: Ambient	Results
120, 60	120	132	2 Hr	54	23	Device Operated Normally

RESULTS

The results comply with the requirements in paragraphs 240 through 242 of UL 913(7) since the coils were not damaged during the test and they would cause the electromagnets to function in the intended manner.

5.6.20 TRANSFORMER OUTPUT

METHOD

Samples of the transformers were subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Sample No.	Rated		Test		Secondary: Open Circuit, V		Secondary: Short Circuit Amp Instant	
	Volts	Hz	Volts	Hz	WDG1	WDG2	WDG1	WDG2
1	120	60	120	60	15.18	12.08	22.0	25.6
1	240	60	240	60	15.23	12.08	23.3	25.9
1	470	60	480	60	15.46	12.23	24.5	27.9
1	580	60	600	60	15.65	12.36	24.8	27.9

5.6.21 COMPONENT OPERATION TEST

METHOD

With the apparatus connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Apparatus	Input Volts	Output Load
Power Supply	120, 60 Hz	Control Indicator Unit and Sensing Head

RESULTS

The results are recorded in the following tabulation.

Component		Rated			Measured	
Type	P/N	Watts	Ohms	Volts	Watts(+)	Percent Rated Watts (+)
Resistor	R8	2	10	2.71	0.734	36.7

(+) - Calculated value.

The results comply with the requirements in Section 18.68 of CFR Title 30(8) since the current limiting components did not operate at more than 50 percent of their ratings.

5.6.22 THERMAL IGNITION - HEATING OF SMALL GAUGE WIRE STRAND TEST

METHOD

The indicated wire strands from the wire used in the intrinsically safe apparatus intended for use in the hazardous location were shorted across a supply circuit representing the maximum current under fault conditions in the intrinsically safe apparatus in the presence of an explosive gas-air mixture.

The explosive gas-air mixture was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The tests were conducted in a test chamber measuring approximately 4 by 4-1/2 by 3 in. high. The test chamber was filled from the top. The inlet and outlet valves to the test chamber were then closed and the power applied to the wire strand.

One side of the test chamber consisted of a transparent plastic film to permit observation of the wire strand under test and to serve as a blow-out panel in the event of ignition.

Prior to the test the inside of the chamber was heated to the temperature indicated.

RESULTS

Apparatus Model No.	Wire Strand		Chamber Ambient Air Temperature Degrees C	Gas	Percent By Volume In Mixture With Air	Test Time, Min	Number of Samples Tested	Results
	Diameter	Length						
420	0.010	1/2	40	Methane	7.45	5	6	No Ignition

5.6.23 SPARK IGNITION TEST

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitible explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source, in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of indicated. For direct current circuits the polarity was reversed after not less than 500 make-break sparks.

The input voltage for the test was adjusted by the appropriate voltage factor indicated based on a rating of 120 v, 60 Hz.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe Terminals 1 and 3 of sensor head with no faults introduced.
2	Same as Circuit 1 with 10 ohm R8 shunt resistor opened.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit, Volts	Short Circuit, Ma	Number of Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.20	Brass	22.5	954	1600	No Ignition	232	20
2	1	0	1.25(+)	Brass	23.0	400	1600	No Ignition	20	56
3	2	1	1.20	Brass	22.5	800	16	Ignition	56	

(+) - Voltage factor applied to intrinsically safe terminal voltage under normal operating conditions, 18.40 v dc.

The results do not comply with the requirements in Section 18.68 of CFR Title 30(8) since ignition of the methane-air mixture was obtained in less than 1000 minimum make and break sparks.

5.7 BENDIX, METHANE DETECTION SYSTEM, PART NO. 2417032, ITEM 4

Product Description

5.7.1 Methane Monitoring System, Part No. 2417032-1000, manufactured by the Bendix Corporation, Environmental Science Division in Baltimore, Maryland. The system consists of a Control Assembly, Series 2415899, provided with an explosion-proof housing (Figures 8 and 9), a Relay Assembly, Part No. 2417030 intended to be mounted in an explosion-proof enclosure and Detector Assembly Part No. 2415905-0003. The Control Assembly incorporates the power converter control and readout circuitry. The Control Assembly has circuits claimed to be intrinsically safe (Terminals 1, 2 and 3, Figure 9) which are connected to the Detector Assembly, claimed to be intrinsically safe. The Detector Assembly houses a sensing cell intended to sense the presence of methane in air.

5.7.2 A complete sample system along with additional component parts were purchased through the Preiser Mine Company in St. Albans, West Virginia, a distributer for the equipment in this area. The samples were subjected to the examination and tests described below.

5.7.3 The results indicate that the construction of the device does not comply with the requirements. Performance of the device does comply with the requirements, since no ignition of the methane-air mixture was obtained during spark ignition tests at Terminals 1, 2 or 3 with one fault introduced.

Examination of Construction

GENERAL

5.7.4 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

APPLICATIONS, SECTION 18.6, TITLE 30(8)

5.7.5 The wiring diagrams and schematics supplied with the device did not include a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition. This does not comply with Section 18.6.

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.7.6 In determining compliance with Sections 18.24 and 18.60(e) the level of adequacy was based on the requirements in UL 913(7). The required spacings for circuits in the transformer primary are those shown in Column 301-600 v, 2 kva maximum of Table 6. The required spacings for circuits in the transformer secondary are those shown in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those shown in Column 301-600 of Table 13.

5.7.7 The over surface spacing between the 550 v, Pin 17 on the printed wiring board and a grounded mounting screw was measured to be 9/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which requires a spacing of 3/8 in.

5.7.8 The over surface spacing between the 550 v, Pin 18 on the printed wiring board and a grounded mounting screw was measured to be 3/16 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which requires a spacing of 3/8 in.

5.7.9 The through air spacing between 550 v live parts of the terminal board and the enclosure were measured to be 5/16 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of 1/2 in.

5.7.10 The over surface spacing between uninsulated live part of Fuse F2 in the transformer secondary circuit was measured to be 3/32 in. to Collector and 7/32 in. to Emitter on Transistor Q5 in the primary circuit. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of 1/2 in.

5.7.11 The over surface spacing between uninsulated live part of Diode CR22 in the transformer secondary circuit was measured to be 9/64 in. to the Emitter on Transistor Q5 and 3/32 to Resistor R5 both in the primary circuit. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of 1/2 in.

5.7.12 The through air spacing between uninsulated live part of Capacitor C8 in the transformer secondary circuit was measured to be 5/32 in. to the collector on Transistor Q5 in the primary circuit. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of 3/8 in.

5.7.13 Depending upon the position of the uninsulated jumper on the relay assembly contact circuit. The through air spacing between the jumper (line voltage part) and terminal in relay assembly coil circuit (part of transformer secondary circuit) may be reduced to 0 in. when the coil is energized. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of 3/8 in.

DETAILED INSPECTION OF COMPONENTS, SECTION 18.60(a), TITLE 30(8)

5.7.14 A detailed check of control circuit board components against the electrical schematic (Figure 9) showed additional components in the actual circuit which were not shown on the schematic. The following additional components were noted:

a) 3000 mfd capacitor between wiring station Pins 15 and 16.

b) From Pin 8, a forward biased diode in series with a 100 mfd capacitor to Pin 24.

c) From the cathode of the diode in (b) above, a 1K ohm resistor in series with a foreward biased diode to Pin 23.

TESTS FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.7.15 The relay assembly is not provided with an explosion-proof enclosure as required in Section 18.68(c)(2).

5.7.16 Internal intrinsically safe circuit conductors are routed together with nonintrinsically safe conductors. Field connected nonintrinsically safe wiring at the relay may be intermingled with wiring of intrinsically safe circuits. This does not comply with Section 18.68(c)(3).

5.7.17 Intrinsically safe circuits are not identified as required in Section 18.68(e).

SECURITY OF PARTS, SECTION 27.21(b), TITLE 30(8)

5.7.18 The Inductors L1 and L3 are mounted to the bottom plate of the Power Converter by means of epoxy. One of the inductors was loose in the sample received. This does not comply with Section 27.21(b).

5.7.19 The Power Converter printed wiring board assembly is mounted with machine screws without locking washers. This does not comply with Section 27.21(b).

Test Record

GENERAL

5.7.20 The samples and component parts of the device identified in paragraphs 5.7.1 and 5.7.2 were subjected to the following tests to determine compliance with the requirements for intrinsically safe certification in CFR Title 30(8) except for the dielectric withstand test described in paragraph 6.7.30.

5.7.21 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.7.22 INPUT-OUTPUT TEST

METHOD

The sample was connected to the source of supply and load indicated. Input and output at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured	
Designation	Nos.	V	V	Amp
Input	7 & 9	550, 60 Hz	600, 60 Hz	0.0136
Output	1 & 2	-	1.53, dc+	0.0113++
Output	1 & 3	-	2.37, dc+	1.90++
Output	2 & 3	-	1.6, dc+	0.02++

(+) - Open circuit volts.

(++) - Short circuit current.

5.7.23 NORMAL TEMPERATURE TEST

METHOD

The sample was connected to the source of supply and load indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals Designation	Nos.	Voltage Source	Load
Input	7 & 9	600 v, 60 Hz	-
Output	1, 2 & 3	-	Detector Assembly

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7), since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Coil L1	41
2	Coil L2	48.5
3	Coil L3	40
4	Coil L4	39
5	Capacitor C5	48
6	Capacitor C8	41
7	Relay Coil	41
	Test Time 6 Hr.	

5.7.24 UNDERVOLTAGE AND OVERVOLTAGE TEST

METHOD

Immediately following the Normal Temperature Test the sample was subjected to the following tests. Tests were conducted at rated frequency unless otherwise stated.

Undervoltage Test - The input voltage was reduced to 85 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated, V	Undervoltage Test, V	Results
220-550, 60 Hz	187	Device Operated Normally

Overvoltage Test - Following the Undervoltage Test the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times.

Rated, V	Standard Test, V	Over-voltage Test V	Test Time	Temperature, Degrees C Relay Coil	Ambient	Results
550, 60 Hz	600	600	2	44	23	Device Operated Normally

RESULTS

The results comply with the requirements in paragraphs 240 through 242 of UL 913(7) since the coils were not damaged during the test and they would cause the electromagnets to function in the intended manner.

5.7.25 THERMAL IGNITION - HEATING OF SMALL GAUGE WIRE STRAND TEST

METHOD

The indicated wire strands from the wire used in the intrinsically safe apparatus intended for use in the hazardous location were shorted across a supply circuit representing the maximum current under fault conditions in the intrinsically safe apparatus in the presence of an explosive gas-air mixture.

The explosive gas-air mixture was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The tests were conducted in a test chamber measuring approximately 4 by 5-1/2 by 3 in. high. The test chamber was filled from the top. The inlet and outlet valves to the test chamber were then closed and the power applied to the wire strand.

One side of the test chamber consisted of a transparent plastic film to permit observation of the wire strand under test and to serve as a blow-out panel in the event of ignition.

Prior to the test the inside of the chamber was heated to the temperature indicated.

RESULTS

Apparatus Part No.	Maximum Short Circuit Current Available, Amp	Wire Strand Diameter	Wire Strand Length	Chamber Ambient Air Temperature, Degrees C	Gas	Percent By Volume In Mixture With Air	Test Time, Min	Number Of Samples Tested	Results
91-4876-03	2.97	0.006 in.	1/2 in.	40	Methane	7.45	3	4	No ignition, wires did not glow or open.

5.7.26 SPARK IGNITION TEST

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated. For direct current circuits the polarity was reversed after not less than 500 make and break sparks.

The input voltage for the test was adjusted by the appropriate voltage factor indicated based on a rating of 550 V, 60 Hz.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe Terminals 1 and 3 (to detector) with no faults introduced.
2	Same as Circuit No. 1 with OP Amp U3 on the control circuit board shorted from pin Terminal 12 to 3.
3	Same as Circuit No. 1 with Resistor R9 on the control circuit board shorted.
4	Same as Circuit No. 1 with Transistor Q2 on the control circuit board shorted from C to E.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit, Volts	Short Circuit, Ma	Number of Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.2	Brass	2.37 dc	1900	1600	No Ignition	96	32
2	2	1	1.2	Brass	8.55 dc	69	1600	No Ignition	128	24
3	3	1	1.2	Brass	2.37 dc	2970	1600	No Ignition	48	168
4	4	1	1.2	Brass	2.37 dc	1968	1600	No Ignition	168	104
5	1	0	1.25+	Brass	2.97 dc	2375	1600	No Ignition	40	8

(+) - Applied to intrinsically safe output.

The results comply with the requirements in Sections 18.68 and 27.34 of CFR Title 30(8) since ignition of the methane air mixture was not obtained in at least 1000 make and break sparks.

5.8 APPALACHIAN, MODEL 102A METHANE MONITOR, ITEM 7

Product Description

5.8.1 Model 102A Methane Monitoring System, manufactured by Appalachian Electronic Instruments, Inc. of Ronceverte, West Virginia. The system consists of an AC power supply/shutdown relay unit, Part No. 7163 (Figure 16), an amplifier readout unit, Part No. 7158, and detector, Part No. 7162. The AC power supply/shutdown relay unit intended to be mounted within an explosion-proof enclosure has circuits claimed to be intrinsically safe which are connected to the amplifier readout unit and detector, each claimed to be intrinsically safe. The AC power supply is rated 575 v ac input maximum.

5.8.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

5.8.3 The results indicate that the construction of the device does not comply with the requirements, nor does the performance of the device comply with the requirements, since ignition of methane air mixture was obtained during spark ignition tests at Terminals 1 and 3 of the Power Supply with one fault introduced.

Examination of Construction

GENERAL

5.8.4 Schematic diagrams were not supplied as part of the equipment but were provided upon request. The Power Supply schematic diagram is shown in Figure 16.

5.8.5 The shutdown relay unit supplied with the equipment was not marked with its appropriate contact ratings, nor were the ratings provided in the instruction manual.

5.8.6 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

APPLICATIONS, SECTION 18.6, TITLE 30(8)

5.8.7 The wiring diagrams do not include a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition. This does not comply with Section 18.6(e).

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.8.8 In determining compliance with Sections 18.24 and 18.60(e) the level of adequacy was based on the requirements in UL 913(7). The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6. The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those indicated in Column 301-600 of Table 13. For the purposes of measuring electrical spacings of the shutdown relay contact circuits, it was assumed that the relay contacts have the same voltage rating as the AC power supply, since the ratings were not provided.

5.8.9 The through air spacing between the uninsulated, line voltage terminal on the transformer primary Fuse F1 and the uninsulated terminal on the transformer secondary fuse was measured to be 9/64 in. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require 3/8 in. minimum.

5.8.10 The through air spacing between the uninsulated, line voltage terminal on the shutdown relay contact circuit and the grounded metal frame was measured to be 5/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require 3/16 in. minimum. It should be noted that in the event that the relay contact circuit ratings exceed 2 kva, the through air spacing required would be 3/8 in. minimum.

5.8.11 The through air spacing between the uninsulated, line voltage terminal on the shutdown relay contact circuit and the uninsulated terminal on the relay coil circuit was measured to be 1/4 in. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require 3/8 in. through air minimum.

DETAILED INSPECTION OF COMPONENTS, SECTION 18.60(a), TITLE 30(8)

5.8.12 A detailed check of the AC power supply/shutdown relay unit components against the electrical schematic (Figure 16) dislosed that the 1N5061 Diode and TN55 Transistor on the schematic had been replaced by a 1N4937 Diode and TP55 Transistor, respectively. This does not comply with Section 18.60(a).

TEST FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.8.13 The power supply is not provided with an explosion-proof enclosure as is required in Section 18.68(c)(2). Installation instructions do require that it be installed within such an enclosure.

5.8.14 In the power supply, line voltage conductors and conductors intended to be intrinsically safe are bunched together for routing. Field connected nonintrinsically safe wiring may be intermingled with wiring of circuits intended to be intrinsically safe. This does not comply with Section 18.68(c)(3).

5.8.15 Circuits and terminals of the power supply and the amplifier readout unit and detector intended to be intrinsically safe are not so identified. This does not comply with Section 18.68(e).

Test Record

GENERAL

5.8.16 The samples and component parts of the device identified in paragraphs 5.8.1 and 5.8.2 were subjected to the following tests to determine compliance with the specified requirements for intrinsically safe certification in CFR Title 30(8), except for the dielectric withstand test which is described in paragraph 6.8.28.

5.8.17 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.8.18 INPUT-OUTPUT TEST

METHOD

The Methane Monitoring System was connected to the source of supply and loads indicated. Input and outputs at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured	
Designation	Nos.	V, Hz	V, Hz	Amp
Input	1 & 5	575, 60	600, 60	0.017
Output	1 & 3	-	12.20, dc+	2.17++
Output	1 & 2	-	12.20, dc+	1.6++

(+) - Open circuit volts.

(++) - Short circuit current.

5.8.19 NORMAL TEMPERATURE TEST

METHOD

The sample was connected to the source of supply and loads indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals			
Designation	Nos.	Voltage Source	Load
Power Supply Input	1 & 5	600 v, 60 Hz	
Power Supply Output	1, 2, 3 &4	-	Amplifier Readout Unit
Amplifier Readout Unit Output	1, 2, 3	-	Detector

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7), since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Transformer Winding	59
2	Transformer Core	55
3	Capacitor, 500 mfd	40
4	Relay Coil Side	54
5	Relay Coil Bobbin, Top	56
6	Bridge Rectifier	65
7	Power Diode	42
8	Regulator	47
	Test Time 7 Hr.	

5.8.20 UNDERVOLTAGE AND OVERVOLTAGE TEST

METHOD

Immediately following the Normal Temperature Test the sample was subjected to the following tests. Tests were conducted at rated frequency unless otherwise stated.

Undervoltage Test - The input voltage was reduced to 85 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated, V, Hz	Undervoltage Test, V	Results
575, 60	488.75	Relay Operated Properly

Overvoltage Test - Following the Undervoltage Test the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times.

Rated, V, Hz	Standard Test, V	Over-voltage Test V	Test Time Hr	Temperature, Degrees C		Results
				Relay Coil	Ambient	
575, 60	600	660	2	52	23	Relay Operated Properly

RESULTS

The results comply with the requirements in paragraphs 240 through 242 of UL 913(7), since the coils were not damaged during the test and they would cause the electromagnets to function in the intended manner.

5.8.21 TRANSFORMER OUTPUT

METHOD

Samples of the transformers were subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Sample No.	Transformer Mfg.	Transformer P/N	Rated V	Rated Hz	Test V	Test Hz	Secondary Open Circuit, V	Secondary Short Circuit Amp Instant	Secondary Short Circuit Amp 1 Min
1	Raeco	XD-690A	120	60	120	60	20.6	9.2	6.70
2	Raeco	XD-690A	240	60	240	60	20.6	10.62	7.42
3	Raeco	XD-690A	480	60	480	60	20.7	10.28	7.08
1	Raeco	XD-690A	575	60	575	60	20.7	10.83	7.29
2	Raeco	XD-690A	575	60	600	60	21.5	11.06	7.35

5.8.22 COMPONENT OPERATION TEST

METHOD

With the apparatus connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Apparatus	Input Volts	Output Load
Power Supply	600, 60 Hz	Amplifier Readout Unit
Amplifier Readout Unit	-	Detector

RESULTS

The results are recorded in the following tabulation.

Component		Rated			Measured			
						Percent		Percent
Type	P/N	Volts	Amp	Watts	Volts	Rated Volts+	Amp	Rated Amps+
Regulator	LM-340-15	15.6	1.5	-	15.5	-	0.67	44.7
Regulator	LM-340-12	12.5	1.5	-	12.2	-	0.67	44.7
Diode	1N4937	600	2	-	12.20	2	0	0
Diode	1N2979B	15	-	10	12.20	-	0	0
Diode	1N4937(++)	600	2	-	10.39	1.7	0	0

(+) - Calculated Value.

(++) - Coil shunt diodes.

The results comply with the requirements in Section 18.68 of CFR Title 30(8) since the semiconductors did not operate at more than two-thirds of their rated current and peak voltage.

5.8.23 THERMAL RUNAWAY TEST

METHOD

Each transistor located in equipment intended to be intrinsically safe was, in turn, subjected to this test. The transistor collector and emitter were connected in series with the power source. The polarity was such that the emitter junction was forward biased. A variable resistor was connected between the transistor base and collector. The resistance was slowly decreased until thermal runaway condition occurred, or until maximum heating of the component was noted. The test was continued under these conditions until maximum temperatures were attained. The temperatures were measured by means of thermocouples.

The power supply was a 15.45 v dc source with the short circuit current limited to 2.17 amp, representing the maximum output at Terminals 1, 2 and 3 of the power supply with one fault introduced.

RESULTS

The results were recorded in the following table.

Test No.	Transistor Type	Current At Maximum Temperature Ampere	Maximum Temperature Degrees C	Ambient Air Degrees C	Supply Source V	Supply Source Amp	Remarks
1	2N4402 PNP	2.0	128	40	15.45	2.17	No Runaway
2	2N4424	1.58	110	40	15.45	2.17	No Runaway

The surface temperatures obtained on the transistors tested did not exceed 540 C (1004 F), the ignition temperature of methane.

5.8.24 THERMAL IGNITION - HEATING OF SMALL GAUGE WIRE STRAND TEST

METHOD

The indicated wire strands from the wire used in the intrinsically safe apparatus intended for use in the hazardous location were shorted across a supply circuit representing the maximum current under fault conditions in the intrinsically safe apparatus in the presence of an explosive gas-air mixture.

The explosive gas-air mixture was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The tests were conducted in a test chamber measuring approximately 4 by 5-1/2 by 3 in. high. The test chamber was filled from the top. Samples of the explosive mixtures were withdrawn from the test chamber exhaust line for analysis. The inlet and outlet valves to the test chamber were then closed and the power applied to the wire strand.

One side of the test chamber consisted of a transparent plastic film to permit observation of the wire stranded under test and to serve as a blow-out panel in the event of ignition.

Prior to the test the inside of the chamber was heated to the temperature indicated.

RESULTS

Apparatus Model No.	Maximum Short Circuit Current Amp	Wire Strand Diameter In.	Wire Strand Length In.	Chamber Ambient Air Temperature, Degrees C	Gas	Percent By Volumn In Mixture With Air	Test Time, Min	Number of Samples Tested	Results
102A	2.17	0.008	1/2	40	Methane	7.7	3	3	No ignition, wire did not open.
102A	2.17	0.010	1/2	40	Methane	7.7	3	3	No ignition, wire did not open.

5.8.25 SPARK IGNITION TEST

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated. For direct current circuits the polarity was reversed after not less than 500 make and break sparks.

The input voltage for the tests was adjusted by the appropriate voltage factor indicated based on a rating of 575 v, 60 Hz for the line voltage power supply.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe Terminals 1 and 3 of the power supply, fuses shorted, no faults introduced.
2	Same as Circuit 1 with Regulator LM-340-12 shorted from B to E.
3	Same as Circuit 1 with Regulator LM-340-15 shorted from B to E.
4	Intrinsically safe Terminals 2 and 3 of the power supply with fuses shorted and Transistor TP55 shorted from C to B.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit, Volts	Short Circuit, Ampere	Number of Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks: Before Test	After Test
1	1	0	1.2	Brass	12.20	2.17	1600	No Ignition	272	228
2	1	0	1.25+	Brass	15.25	2.72	1600	No Ignition	20	48
3	2	1	1.2	Brass	15.43	0.311	836	Ignition	228	-
4	3	1	1.2	Brass	12.15	0.55	820	Ignition	20	-
5	4	1	1.2	Brass	11.83	0.162	1600	No Ignition	52	28

(+) - Applied to intrinsically safe output.

The results do not comply with the requirements in Section 18.68 of CFR Title 30(8), since ignition of the methane air mixture was obtained in less than 1000 minimum make and break sparks in Test Nos. 3 and 4.

5.9 BACHARACH, MINNIE METHANE MONITORING SYSTEM, ITEM 6

Product Description

5.9.1 Minnie Monitor Systems, manufactured by the Bacharach Instrument Company, Division of AMBAC Industries, Inc. of Pittsburgh, Pennsylvania. The system Part No. 23-7582 consists of an AC Power Supply, Part No. 23-7282 (Figure 10), a Readout Enclosure Assembly, Part No. 23-7298, a Detector Head Assembly, Part No. 23-7288 and a Power Cut-Off Relay, Part No. 04-5196 (Figure 11). The AC power supply and power cut-off relay are mounted together in an explosion-proof housing. The power supply has circuits claimed to be intrinsically safe which are connected to the readout enclosure assembly, and detector head assembly each claimed to be intrinsically safe. The power supply is rated 550 v, 60 Hz input, 4 v dc output.

5.9.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

5.9.3 The results indicate that the construction of the device does not comply with the requirements, nor does the performance of the device comply with the requirements, since ignition of methane-air mixture was obtained during spark ignition tests at Terminals Red and Orange of the Power Supply with one fault introduced.

Examination of Construction

GENERAL

5.9.4 The electrical schematics for the equipment are shown in Figures 10 and 11.

5.9.5 The readout enclosure assembly is provided with additional terminals for connection to unspecified remote auxiliary recorder which is not supplied with the equipment. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe.

5.9.6 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

APPLICATIONS, SECTION 18.6, TITLE 30(8)

5.9.7 The wiring diagrams were not marked with a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition as is required in Section 18.6(e).

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.9.8 In determining compliance with Sections 18.24 and 18.60(e), the level of adequacy was based on the requirements in UL 913(7). The required spacings for circuits in the transformer primary are those shown in Column 301-600 v, 2 kva maximum of Table 6. The required spacings for circuits in the transformer secondary are those shown in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those shown in Column 301-600 of Table 13.

5.9.9 The through air spacing between 550 v terminal on the printed wiring board and the enclosure was measured to be 15/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/2 in.

5.9.10 The over surface spacing on the printed wiring board of the power supply between the uninsulated soldered terminal connections for the 550 v and the 480 v line voltage connections was measured to be 5/32 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

5.9.11 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered terminal connections for the 480 v and the 440 v line voltage connections was measured to be 3/16 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

5.9.12 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered terminal connections for the 440 v and the 240 v line voltage connections was measured to be 3/16 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

5.9.13 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered 550 v terminal and the uninsulated foil conductor at the Anode of Transistor Q3, secondary circuit, was measured to be 7/16 in. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of at least 1/2 in.

5.9.14 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered 480 v terminal and the uninsulated foil conductor at the Anode of Transistor Q3, secondary circuit, was measured to be 3/32 in. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of at least 1/2 in.

5.9.15 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered 440 v terminal and the uninsulated foil conductor at the Anode of Transistor Q3, secondary circuit, was measured to be 9/32 in. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of at least 1/2 in.

5.9.16 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered 240 v terminal and the uninsulated foil conductor at the Anode of Transistor Q3, secondary circuit, was measured to be 3/16 in. This does not comply with paragraph 294 and Table 13 of UL 913(7) which require a spacing of at least 3/8 in.

5.9.17 The over surface spacing between the Transistor Q1 collector (secondary circuit) and the grounded metal bracket to which it is mounted was measured to be 1/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

TESTS FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.9.18 Internal intrinsically safe circuit conductors are routed together with nonintrinsically safe conductors. This does not comply with Section 18.68(c)(3).

5.9.19 Intrinsically safe circuits of the power supply are not identified. The readout enclosure assembly and detector head assembly, claimed to be intrinsically safe, are not identified. This does not comply with Section 18.68(e).

Test Record

GENERAL

5.9.20 The samples and component parts of the device identified in paragraphs 5.9.1 and 5.9.2 were subjected to the following tests to determine compliance with the requirements for intrinsically safe certification in CFR Title 30(8), except for the dielectric withstand test which is described in paragraph 6.9.33.

5.9.21 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.9.22 INPUT-OUTPUT TEST

METHOD

The sample was connected to the source of supply and load indicated. Input and output at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured			
Designation	Nos.	V, Hz	V, Hz	Amp	W	Remarks
Power Supply Input	Blk/Wht	550, 60	600	0.036	21.25	
Power Supply Output	Red/Org	4 dc	4.23, dc+	0.65++		+++
Readout Enclosure Assy Output	Blu/Brn	-	3.92, dc+	0.98++		
Readout Enclosure Assy Output	Yel/Brn	-	1.40, dc+	0.001++		
Readout Enclosure Assy Output	Blu/Yel	-	2.52, dc+	0.003++		

(+) - Open circuit volts.

(++) - Short circuit current.

(+++) - 1.8 amp was obtained with a 2 ohm load.

5.9.23 NORMAL TEMPERATURE TEST

METHOD

The sample was connected to the source of supply and load indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument. The tips of the thermocouples were secured to the heated parts by tape or sodium silicate.

Terminals Designation	Nos.	Voltage Source	Load
Power Supply Input	Blk/Wht	600 v, 60 Hz	
Power Supply Output	Red/Org		Readout Enclosure Assembly
Relay Input	-	Low Voltage	25 Amp

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7) since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Transformer Windings	35
2	Transformer Core	47
3	Regulator 2N3055	131
4	Capacitor, 13000 muf	45
5	Resistor, R8	77
6	Rectifier Diode	61
7	Lead Wire Insulation	79
8	Relay Coil, Side	53
9	Relay Coil Bobbin, Top	54
10	Relay Contact	67
11	Sensor	65
	Test Time 8 Hr.	

5.9.24 UNDERVOLTAGE AND OVERVOLTAGE TEST

METHOD

Immediately following the Normal Temperature Test the sample was subjected to the following tests. Tests were conducted at rated frequency unless otherwise stated.

Undervoltage Test - The input voltage was reduced to 85 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated, V, Hz	Undervoltage Test, V	Results
550, 60	465.5	Device Operated Normally

Overvoltage Test - Following the Undervoltage Test the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times.

Rated, V, Hz	Standard Test V	Over-voltage Test V	Test Time Hr	Temperature Degrees C		Results
				Relay Coil	Ambient	
550, 60	600	660	2	57	23	Device Operated Normally

RESULTS

The results comply with the requirements in paragraphs 240 through 242 of UL 913(7) since the coils were not damaged during the test and they would cause the electromagnets to function in the intended manner.

5.9.25 TRANSFORMER OUTPUT

METHOD

A sample of the transformer was subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Rated		Test		Secondary		
				Open	Short Circuit Ampere	
V	Hz	V	Hz	Circuit, V	Instant	1 Min
550	60	600	60	17.37	30.3	20.0

5.9.26 THERMAL RUNAWAY TEST

METHOD

Each transistor was, in turn, subjected to this test. The transistor collector and emitter were connected in series with the power source. The polarity was such that the emitter junction was forward biased. A variable resistor was connected between the transistor base and collector. The resistance was slowly decreased until thermal runaway condition occurred, or until maximum heating of the component was noted. The test was continued under these conditions until maximum temperatures were attained. The temperatures were measured by means of thermocouples.

The power supply was a 4.23 dc source with the maximum short circuit current limited to 1.8 amp representing the output available from the power supply with no faults introduced.

The results were recorded in the following table.

RESULTS

Transistor Type	Sample No.	Current At Maximum Temperature, Ma	Maximum Temperature, Degrees C	Ambient Air Degrees C	Supply Source V	Supply Source Ma	Remarks
2N1305 PNP	1	1472	123	40	4.23	1800	Transistor shorted, no runaway.
MPS5137 NPN	1	383	86	40	4.23	1800	Transistor opened, no runaway.
5139741 PNP	1	263	97	40	4.23	1800	No runaway.
5138708 PNP	1	298	105	40	4.23	1800	No runaway.
626371 PNP	1	816	116	40	4.23	1800	No runaway.

The surface temperatures obtained on the transistors tested did not exceed 540 C (1004 F), the ignition temperature of methane.

5.9.27 COMPONENT OPERATION TEST

METHOD

With the apparatus connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Input Volts	Output Load
600, 60 Hz	(+)

(+) - The output load was varied from open to short circuit conditions. The measured values recorded under results, represent the highest values obtainable under these conditions.

RESULTS

The results are recorded in the following tabulation.

Component		Rated				Measured					
Type	P/N	Peak Volts	Amp	Watts	Ohms	Volts	Percent Rated Volts+	Ma	Percent Rated Amp+	Watts+	Percent Rated Watts+
Resistor	R7&R8	-	-	2	0.82	0.231	-	-	-	0.065	3.25
Thyristor	2N4441	50	8	-	-	23.2	46	0.001	++	-	-

(+) - Calculated value.

(++) - Less than 0.001 percent.

The results comply with the requirements in Section 18.68 of CFR Title 30(8), since the current limiting components did not operate at more than 50 percent of their ratings and the semiconductors did not operate at more than two-thirds of their rated current and peak voltage.

5.9.28 THERMAL IGNITION - HEATING OF SMALL GAUGE WIRE STRAND TEST

METHOD

The indicated wire strands from the wire used in the intrinsically safe apparatus intended for use in the hazardous location were shorted across a supply circuit representing the maximum current under fault conditions in the intrinsically safe apparatus in the presence of an explosive gas-air mixture.

The explosive gas-air mixture was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The tests were conducted in a test chamber measuring approximately 4 by 5-1/2 by 3 in. high. The test chamber was filled from the top. Samples of the explosive mixtures were withdrawn from the test chamber exhaust line for analysis. The inlet and outlet valves to the test chamber were then closed and the power applied to the wire strand.

One side of the test chamber consisted of a transparent plastic film to permit observation of the wire strand under test and to serve as a blow-out panel in the event of ignition.

Prior to the test the inside of the chamber was heated to the temperature indicated.

RESULTS

Apparatus Cat. No.	Maximum Short Current, Amp	Wire Strand		Chamber Ambient Air Temperature, Degrees C	Gas	Percent By Volume In Mixture With Air	Test Time, Min	Number of Samples Tested	Results
		Diameter In.	Length In.						
23-7584	1.812	0.010	1/2	40	Methane	7.7	3	4	No ignition, wire did not open.

5.9.29 SPARK IGNITION TEST:

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7). For test currents exceeding 3 amp, the tungsten wires were replaced with copper wires, 0.008 in. diameter.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source in series with a 95 mh inductor and a variable resistor which was adjusted to 120 ma. Calibration was conducted with tungsten wires.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated. For direct current circuits the polarity was reversed after not less than 500 make and break sparks.

The input voltage for the tests was adjusted by the appropriate voltage factor indicated based on a rating of 550 v, 60 Hz.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe terminals red and orange in the power supply, fuses shorted, no faults introduced.
2	Same as Circuit 1 except open Terminal "A" on Q3.
3	Spark mechanism in series with "+" relay lead on Readout Enclosure Assembly Printed Wiring Board with one fault introduced: Open coil shunt diode.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.2	Brass	4.28	0.70	1600	No ignition	12	20
2	2	1	1.2	Brass	23.8	14.52	(+)	Ignition	28	-
3	1	0	1.25++	Brass	5.35	0.875	1600	No ignition	28	24
4	3	1	1.2	Brass	5.36	0.333	(+)	Ignition	16	-

(+) - Less than 4.

(++) - Applied to intrinsically safe output.

The results do not comply with the requirements in Section 18.68 of CFR Title 30(8), since ignition of the methane air mixture was obtained in less than 1000 make and break sparks in Test Nos. 2 and 4.

5.10 BACHARACH, LOW PROFILE METHANOMETER, ITEM 3

Product Description

5.10.1 Methane Monitoring System, Part No. 23-7167, manufactured by the Bacharach Instrument Company, Division of AMBAC Industries, Inc. of Pittsburgh, Pennsylvania. The system consists of a Control Housing, a Remote Meter Housing, Code 23-7157, a Detector Head Assembly, Code 23-7141, and a Power Cut-Off Relay, Code 23-1378. The control housing incorporates the Power Supply, Code 23-7259 (Figure 12) and the Control Chassis, Code 23-7154 (Figure 13) and is supplied with an explosion-proof enclosure. The control housing has circuits, claimed to be intrinsically safe (Terminals R, C, and A, Figure 13) which are connected to the detector head assembly claimed to be intrinsically safe. The Remote Meter Housing is provided with an explosion-proof enclosure and is supplied by circuits of the Control Housing. The power cut-off relay is not provided with an enclosure but is intended to be mounted in the mining machine contactor case.

5.10.2 A complete sample system along with additional component parts were purchased from the manufacturer, since a distributer for this device is not available in this area, and were subjected to the examination and tests described below.

5.10.3 The results indicate that the construction of the device does not comply with the requirements nor does the performance of the device comply with the requirements, since ignition of methane-air mixture was obtained during spark ignition tests at control housing Terminals 11 and 13 with one fault introduced.

Examination of Construction

GENERAL

5.10.4 The electrical schematics for the equipment are shown in Figures 12 and 13.

5.10.5 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

APPLICATIONS, SECTION 18.6, TITLE 30(8)

5.10.6 The wiring diagrams were not marked with a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition as is required in Section 18.6(e).

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.10.7 In determining compliance with Sections 18.24 and 18.60(e), the level of adequacy was based on the requirements in UL 913(7). The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6. The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those indicated in Column 301-600 of Table 13.

5.10.8 The power supply capacitor is secured in place by a metal bracket, the use of which does not prevent movement along the major axis of the capacitor. The through air electrical spacing between an uninsulated capacitor terminal and an input terminal on the rectifier is reduced to zero with the capacitor in its most unfavorable position. This does not comply with paragraph 196 and Table 6 of UL 913(7)which require a spacing of at least 1/16 in.

5.10.9 In the control housing, the over surface spacing between the Transistor Q21, Figure 13, collector and the grounded mounting plate was measured to be 1/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

5.10.10 In the control housing on printed circuit board No. 23-1245 (Figure 13) the over surface spacing between the foil conductor of the "V+" terminal and the foil conductor of the "PX" terminal was measured to be 1/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

5.10.11 In the control housing on printed circuit board No. 23-1245 (Figure 13) the over surface spacing between the foil conductor of the "V+" terminal and the foil conductor of the "C+" terminal was measured to be 1/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

TESTS FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.10.12 Intrinsically safe internal wiring of the control housing is intermingled with nonintrinsically safe wiring. This does not comply with Section 18.68(c)(3).

5.10.13 The relay assembly is not provided with an explosion-proof enclosure as required in Section 18.68(c)(2).

5.10.14 Circuits of the Control Housing intended to be intrinsically safe are not so identified. The Detector Head Assembly, claimed to be intrinsically safe, is not identified. This does not comply with Section 18.68(e).

SECURITY OF PARTS, SECTION 27.21(b), TITLE 30(8)

5.10.15 The power supply capacitor is secured in place by means of a metal strap and hex nuts with elastomeric inserts. The capacitor in one of the power supplies was free to move axially. This does not comply with Section 27.21(b).

Test Record

GENERAL

5.10.16 The samples and component parts of the device identified in paragraphs 5.10.1 and 5.10.2 were subjected to the following tests to determine compliance with the requirements for intrinsically safe certification in CFR Title 30(8), except for the dielectric withstand test which is described in paragraph 6.10.29.

5.10.17 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.10.18 INPUT-OUTPUT TEST

METHOD

A sample was connected to the source of supply and loads indicated. Input and output at the terminals indicated were measured using suitable instruments.

RESULTS

Terminals		Rated	Measured			
Designation	Nos.	Volts	V	Amp	W	Remarks
Control Housing Input	1 & 2	550, 60 Hz	660, 60 Hz	0.051	28.8	
Power Supply Output	1 & 2	-	21.1, dc+	14.13 ++	-	
Control Housing Output	R & C	-	2.25, dc+	0.029 ++	-	(+++)
Control Housing Output	R & A	2.8, dc	4.08, dc+	1.2 ++	-	(+++)
Control Housing Output	C & A	-	1.84, dc+	0.024 ++	-	(+++)

(+) - Open circuit volts.

(++) - Short circuit current.

(+++) - System controls adjusted to give highest readings.

5.10.19 NORMAL TEMPERATURE TEST

METHOD

The sample was connected to the source of supply and loads indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples and a suitable instrument. The tips of the thermocouples were secured to the heated parts by solder, tape or sodium silicate.

Terminals		Voltage Source	Load
Designation	Nos.		
Control Housing Input	1 & 2	600 v, 60 Hz	-
Control Housing	R, C, & A	-	Detector Head Assembly
Control Housing Output	1 - 8	-	Remote Meter Assembly

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7) since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 23 C Ambient
1	Transformer, Winding	53
2	Transformer, Core	50
3	Capacitor, 1800 mfd	33
4	Fuse	36
5	Rectifier	51
6	Enclosure, Outside	31
7	Sensor	69

Test Time 7 Hr

5.10.20 UNDERVOLTAGE AND OVERVOLTAGE TEST

METHOD

Immediately following the Normal Temperature Test the sample was subjected to the following tests. Tests were conducted at rated frequency unless otherwise stated.

Undervoltage Test - The input voltage was reduced to 85 percent of the rated voltage. Then, the circuit was opened and closed several times.

Rated, V	Undervoltage Test, V	Results
550, 60 Hz	467.5	Device Operated Normally

Overvoltage Test - Following the Undervoltage Test the input voltage was increased to 110 percent of the standard test voltage and held at the increased value until constant temperatures were reached on all parts being measured. Then, the voltage was reduced to the standard test voltage and the control circuit was opened and closed several times.

Apparatus Part No.	Rated, V	Standard Test, V	Over-voltage Test V	Test Time, Hr	Temperature, Degrees C		Results
					Relay Coil	Ambient	
23-7167	550, 60 Hz	600	660	3	36	23	Device Operated Normally

RESULTS

The results comply with the requirements in paragraphs 240 through 242 of UL 913(7) since the coils were not damaged during the test and they would cause the electromagnets to function in the intended manner.

5.10.21 COMPONENT OPERATION TEST

METHOD

With the apparatus connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Apparatus	Input Volts	Output Load
Control Housing	660, 60 Hz	Remote Meter and Detector Head Assemblies

RESULTS

The results are recorded in the following tabulation.

Component		Rated				Measured					
		Peak					Percent Rated		Percent Rated		Percent Rated
Type	P/N	Volts	Amp	Watts	Ohms	Volts	Volts+	Amp	Amp+	Watts+	Watts+
Resistor	R21	-	-	1	1.78	0.89	-	-	-	0.445	44.5
Resistor	R51	-	-	3	1	0.78	-	-	-	0.61	20.3
Resistor	R56	-	-	2	0.39	0.32	-	-	-	0.26	13.1
Transistor	2N3055	60	15	25	-	11.65	19.4	1.1	7.3	-	-

(+) - Calculated Value.

The results comply with the requirements in Section 18.68 of CFR Title 30(8) since the current limiting components did not operate at more than 50 percent of their ratings and the semiconductors did not operate at more than two-thirds of their rated current and peak voltage.

5.10.22 TRANSFORMER OUTPUT

METHOD

A sample of the transformer was subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Rated		Test		Secondary		
				Open	Amp	
V	Hz	V	Hz	Circuit, V	Instant	1 Min
550	60	600	60	15.79	20.9	14.1

5.10.23 THERMAL IGNITION - HEATING OF SMALL GAUGE WIRE STRAND TEST

METHOD

The indicated wire strands from the wire used in the intrinsically safe apparatus intended for use in the hazardous location were shorted across a supply circuit representing the maximum current under fault conditions in the intrinsically safe apparatus in the presence of an explosive gas-air mixture.

The explosive gas-air mixture was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The tests were conducted in a test chamber measuring approximately 4 by 5-1/2 by 3 in. high. The test chamber was filled from the top. Samples of the explosive mixtures were withdrawn from the test chamber exhaust line for analysis. The inlet and outlet valves to the test chamber were then closed and the power applied to the wire strand.

One side of the test chamber consisted of a transparent plastic film to permit observation of the wire strand under test and to serve as a blow-out panel in the event of ignition.

Prior to the test the inside of the chamber was heated to the temperature indicated.

RESULTS

Apparatus Part No.	Maximum Short Circuit Current Available, Amp	Wire Strand Diameter In.	Wire Strand Length In.	Chamber Ambient Air Temperature, Degrees C	Gas	Percent By Volume In Mixture With Air	Test Time Min	Number of Samples Tested	Results
23-7167	2.93	0.010	1/2	40	Methane	7.7	3	6	No ignition, wires did not glow or open.

5.10.24 SPARK IGNITION TEST

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7), with copper wires 0.008 in. diameter replacing the tungsten wires when the test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source, in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma. The tungsten wires were used for calibration.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated. For direct current circuits the polarity was reversed after not less than 500 operations.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated based on a rating of 550 v, 60 Hz.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe Terminals R and A of the control housing with fuses shorted and no faults introduced.
2	Same as Circuit 1 with Transistor 2N3055 (Q21, Figure 13) shorted from C to E.
3	Same as Circuit 1 with I.C. A1, Figure 13, shorted from Pin 8 to Pin 10.
4	Same as Circuit 1 with I.C. A1, Figure 13, shorted from Pin 8 to Pin 1.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Make-Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make-Break Sparks Before Test	After Test
1	1	0	1.2	Brass	4.08 dc	1.20	1600	No ignition	32	144
2	2	1	1.2	Brass	15.47 dc	2.93	1600	No ignition	112	4
3	3	1	1.2	Brass	23.5 dc	6.46	1	Ignition	12	-
4	4	1	1.2	Brass	23.5 dc	7.3	1	Ignition	32	-

The results do not comply with the requirements in Section 18.68 of CFR Title 30(8) since ignition of the methane air mixtures was obtained in less than 1000 minimum make and break sparks in Tests 3 and 4. Tests with output at Terminals R and A adjusted to 125 percent normal output voltage are considered to be covered by Test No. 2 above.

5.11 BERTEA, VALVE CONTROL SYSTEM, ITEM 9

Product Description

5.11.1 Intrinsically safe system for control of electrohydraulic valves, manufactured by Bertea Corporation, Industrial Products Division of Costa Mesa, California. The system consists of an AC Power Supply, Part No. 261861 (Figure 14), Sixteen Pilot Valve Assemblies, Part No. 234912, Sixteen Hand Controllers, Part No. 26436039. Two resistor terminal boards, Part No. 2618201 and a terminal board, Part No. 261814-1. Interconnection of the system components is depicted schematically in Figure 15. The AC Power Supply, intended to be mounted within an explosion-proof enclosure, has circuits claimed to be intrinsically safe which are connected to the terminal boards, hand controllers and pilot valves. The hand controllers and pilot valves are claimed to be intrinsically safe. The AC Power Supply is rated 575 v ac, 60 Hz input.

5.11.2 A complete sample of the system along with additional component parts were purchased through Weldon Engineering Company of Des Plaines, Illinois, a local distributor for the equipment. The samples were subjected to the examination and tests described below.

5.11.3 The results indicate that the construction of the system does not comply with the requirements nor does the performance of the system comply with the requirements since ignition of the methane-air mixture was obtained during spark ignition tests at the +6 v dc and neutral terminals of the power supply with one fault introduced.

Examination of Construction

GENERAL

5.11.4 Electrical schematics and instructions covering installation of the system were not supplied as part of the equipment. They were provided upon request. The electrical schematics are shown in Figures 14 and 15.

5.11.5 The electrical schematic shown in Figure 15 depicts the use of an optional indicator lamp, an unspecified pilot valve and a function selector switch, not supplied as part of the system. The use of this unspecified equipment may result in the whole system not being intrinsically safe.

5.11.6 In the following, reference is made to requirements in UL 913(7), which are described in Appendix B.

APPLICATION, SECTION 18.6, TITLE 30(8)

5.11.7 The electrical schematic and wiring diagram shown in Figures 14 and 15 do not include a warning statement that any changes in the intrinsically safe circuitry or components may result in an unsafe condition. This does not comply with Section 18.6(e).

ELECTRICAL SPACINGS, SECTIONS 18.24 AND 18.60(e), TITLE 30(8)

5.11.8 In determining compliance with Sections 18.24 and 18.60(e), the level of adequacy was based on the requirements in UL 913(7). The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6. The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6. The required spacings between intrinsically safe circuits and line connected circuits are those indicated in Column 301-600 of Table 13.

5.11.9 The through air spacing between uninsulated 575 v, soldered connector on the terminal board and a grounded metal mounting leg for the terminal board was measured to be 3/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require at least 3/16 in.

5.11.10 The through air spacing between the uninsulated soldered connection of the "+6 volts" terminal and the uninsulated transformer secondary terminal was measured to be 0.055 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

5.11.11 The over surface spacing between the Transistor Q1 collector and grounded foil conductor on the printed wiring board was measured to be 1/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

5.11.12 The over surface spacing between the Transistor Q2 collector and grounded foil conductor on the printed wiring board was measured to be 1/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

5.11.13 The over surface spacing between foil conductor on printed circuit board at "+6 volt" transformer secondary pin No. 1 and pin No. 2 was measured to be 1/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of opposite polarity.

5.11.14 The over surface spacing between foil conductors on printed circuit board at "+6 volt" transformer secondary pin No. 3 and pin No. 2 was measured to be less than 1/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of opposite polarity.

5.11.15 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2 and "-6 volts" transformer secondary pin No. 3 at Diode CR4 was measured to be less than 1/32 in. at two places. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

5.11.16 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 1 and "-6 volts" transformer secondary pin Nos. 2 and 3 were measured to be 1/32 in. and just over 1/32 in. respectively. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

5.11.17 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2, at Capacitor C2 and "-6 volts" transformer secondary pin just over 1/32 in. each. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

5.11.18 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2 and "-6 volts" transformer secondary pin No. 1 was measured to be less than 1/32 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

5.11.19 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 3 and "-6 volts" transformer secondary pin Nos. 1 and 2 were measured to be less than 1/32 in. and 1/32 in. respectively. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

DETAILED INSPECTION OF COMPONENTS. SECTION 18.60(a), TITLE 30(8)

5.11.20 A detailed check of the power supply transformers against the Bertea specifications for the transformer disclosed that the transformers were not marked with vendor name. This does not comply with Section 18.60(a).

5.11.21 The hand controllers are each equipped with a switch which is not shown in Figure 15. This does not comply with Section 18.60(a).

TESTS FOR INTRINSIC SAFETY, SECTION 18.68, TITLE 30(8)

5.11.22 The 0.47 ohm wire wound resistors (Figure 14) are not duplicated. Therefore the construction does not comply with Section 18.68.

5.11.23 Internal wiring of the device intended to be intrinsically safe is intermingled with nonintrinsically safe transformer secondary circuit conductors. This does not comply with Section 18.68(c)(3).

5.11.24 Circuits and terminals of the power supply intended to be intrinsically safe are not so identified. The pilot valves and hand controllers are not identified as being intrinsically safe. This does not comply with Section 18.68(e).

Test Record

GENERAL

5.11.25 The samples and component parts of the device identified in paragraphs 5.11.1 and 5.11.2 were subjected to the following tests to determine compliance with the requirements for intrinsically safe certification in CFR Title 30(8), except for the dielectric withstand test which is described in paragraph 6.11.31.

5.11.26 In the following, reference is made to requirements in UL 913(7) which are described in Appendix B.

5.11.27 INPUT-OUTPUT TEST

METHOD

An electrohydraulic valve control system consisting of a power supply, hand controller, and pilot valve with 39 ohm limiting resistor was connected to the source of supply and load indicated. Input and outputs at the terminals indicated were measured using suitable instruments.

Terminals		Rated	Measured	
Designation	Nos.	Volts	V	Amp
Input	Lo/Hi	575, 60 Hz	600, 60 Hz	0.032
Power Supply Output	Plus Volts/ 0 Volts	6	6.02, dc+	1.22++
Power Supply Output	Plus Volts/ Minus Volts	12	12.05 dc+	1.22++
Power Supply Output	0 Volts/ Minus Volts	6	6.05 dc+	1.15++
Pilot Valve Input	-	-	3.23 dc	0.039
Pilot Valve	(+++)	-	3.25 dc+	0.123 (++)

(+) - Open circuit volts.

(++) - Short circuit current.

(+++) - Terminals to which pilot valve is connected.

5.11.28 NORMAL TEMPERATURE TEST

METHOD

The sample was connected to the source of supply and load indicated. The sample was operated continuously until constant temperatures were reached on all parts being measured. All temperatures were measured by thermocouples were secured to the heated parts by solder, tape or sodium silicate.

Terminals		Voltage Source	Load
Designation	Nos.		
Power Supply Input	Lo/Hi	600 v, 60 Hz	-
Power Supply Output	Plus Volts/ 0 Volts/ Minus Volts	-	Sixteen P/N 234912 Pilot Valves (+)

(+) - Each valve was connected in series with a 39 ohm resistor and a P/N 264360-39 hand controller.

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraphs 226 through 235 of UL 913(7) since the temperatures obtained were within the allowable limits.

The results comply with the requirements in paragraph 18.23 of CFR Title 30(8) since external surface temperatures did not exceed 150 C.

No.	Thermocouple Location	Maximum Temperature, Degrees C At 22 C Ambient
1	Transformer Core	39
2	Transformer Windings	38
3	Capacitor, 1000 uf, C1	26
4	Zener Diode, CR6	36
5	Transistor, Q1	41
6	Resistor R4	48
7	Resistor R5	51
8	Resistor, 39 Ohm	24
9	Pilot Valve Coil	23
	Test Time 8 Hr	

5.11.29 TRANSFORMER OUTPUT

METHOD

A sample of the transformer was subjected to this test. The primary was connected to a source of supply as indicated. Open circuit voltage and short circuit current were measured with suitable meters.

RESULTS

Transformer	Rated		Test			Secondary	
Part No.	V	Hz	V	Hz	Terminals	Open Circuit, V	Short Circuit Amp Instant
261866	575	60	600	60	Red/Wht	12.4	30.2
					Red/Red	24.9	21.1
					Wht/Red	12.5	28.0
					Blk/Grn	12.5	27.1
					Blk/Blk	24.9	21.5
					Grn/Blk	12.4	26.1

5.11.30 COMPONENT OPERATION TEST

METHOD

With the power supply connected to the indicated source of supply and operated in its intended manner, the voltage and/or current were measured with suitable instruments at each component which affects intrinsic safety.

Input Volts	Output Load
600, 60 Hz	Sixteen Hand Controllers and Pilot Valves

RESULTS

The results are recorded in the following tabulation.

Component		Rated				Measured					
Type	P/N	Peak Volts	Amp	Watts	Ohms	Volts	Percent Rated Volts+	Amp	Percent Rated Amps+	Watts+	Percent Rated Watts+
Resistor	R4	-	-	3.25	0.47	0.59	-	-	-	0.74	22.8
Resistor	R5	-	-	3.25	0.71	0.88	-	-	-	1.09	33.5
Resistor	R6	-	-	3.25	0.71	0.90	-	-	-	1.14	35.1
Resistor	R10	-	-	3.25	0.47	0.585	-	-	-	0.73	22.5
Resistor	R11	-	-	3.25	0.71	0.90	-	-	-	1.14	35.1
Resistor	R12	-	-	3.25	0.71	0.89	-	-	-	1.12	34.5
Transistor	Q1	40	10	-	-	11.2	28	1.26	12.6	-	-
Transistor	Q2	40	10	-	-	11.3	28.3	1.27	12.7	-	-
Resistor	21J39R	-	-	1	39	-	-	0.039	-	0.06	6

(+) - Calculated Value.

The results comply with the requirements in Section 18.68 of CFR Title 30(8) since the current limiting components did not operate at more than 50 percent of their ratings and the semiconductors did not operate at more than two-thirds of their rated current and peak voltage.

5.11.31 THERMAL IGNITION - HEATING OF SMALL GAUGE WIRE STRAND TEST

METHOD

The indicated wire strands from the wire used in the intrinsically safe apparatus intended for use in the hazardous location were shorted across a supply circuit representing the maximum current under fault conditions in the intrinsically safe apparatus in the presence of an explosive gas-air mixture.

The explosive gas-air mixture was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The tests were conducted in a test chamber measuring approximately 4 by 5-1/2 by 3 in. high. The test chamber was filled from the top. The inlet and outlet valves to the test chamber were then closed and the power applied to the wire strand.

One side of the test chamber consisted of a transparent plastic film to permit observation of the wire strand under test and to serve as a blow-out panel in the event of ignition.

Prior to the test the inside of the chamber was heated to the temperature indicated.

RESULTS

Apparatus Part No.	Maximum Short Circuit Current Available, Amp	Wire Strand Diameter In.	Wire Strand Length In.	Chamber Ambient Air Temperature, Degrees C	Gas	Percent By Volume In Mixture With Air	Test Time Min	Number of Samples Tested	Results
Hand Controller 264360-39	5.54	0.006	0.5	40	Methane	7.8	3	3	No ignition, wires did not glow or open.

5.11.32 SPARK IGNITION TEST

METHOD

The circuits selected during fault analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in paragraph 348-C of UL 913(7), with copper wires 0.008 in. diameter replacing the tungsten wires when the current of the test circuit exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit consisted of a 24 v dc source in series with a 95 mh inductor and a variable resistor which was adjusted for 120 ma. Calibration was with tungsten wires.

In turn, each circuit was connected to the test mechanism. The test mechanism was operated to make and break the circuit for the number of operations indicated. For direct current circuits the polarity was reversed after not less than 500 make and break sparks.

The input voltage for the test was adjusted by the appropriate voltage factor indicated based on a rating of 575 v, 60 Hz.

The circuits selected for test are described below:

Circuit No.	Circuit Description
1	Intrinsically safe terminals "+6V" and "-6V" of the power supply with no faults introduced.
2	Intrinsically safe terminals "+6V" and "-6V" of the power supply with I.C. U1 (Figure 14) shorted from Pin 4 to Pin 12.
3	Intrinsically safe terminals "+6V" and "0V" of the power supply with I.C. U1 (Figure 14) shorted from Pin 4 to Pin 12.
4	Intrinsically safe pilot valve connected to power supply terminals "+6V" and "0V", spark mechanism in series with the pilot valve, 39 ohm resistor short-circuited.
5	Intrinsically safe pilot valve connected across the test Circuit 1, with the 39 ohm resistor and the spark mechanism in series.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Make and Break Sparks	Results	Spark Test Mechanism Calibration: Number of Make and Break Sparks — Before Test	Spark Test Mechanism Calibration: Number of Make and Break Sparks — After Test
1	1	0	1.2	Brass	12.05	1.22	1600	No ignition	12	8
2	2	1	1.2	Brass	25.4	2.5	832	Ignition	32	-
3	3	1	1.2	Brass	19.23	5.54	218	Ignition	8	-
4	4	1	1.2	Brass	6.05	0.095	1600	No ignition	8	4
5	5	1	1.2	Brass	19.23	0.19	1600	No ignition	8	4

The results do not comply with the requirements in Section 18.68 of CFR Title 30(8), since ignition of the methane air mixture was obtained in Test Nos. 2 and 3.

CHAPTER 6

EXAMINATION AND TESTING OF METHANE MONITORING SYSTEMS AND MACHINE CONTROL CIRCUITS IN ACCORDANCE WITH THE STANDARD, UL 913 (1)

6.1 GENERAL

6.1.1 The equipment described in the following Sections was examined and tested to determine compliance with the requirements in the Standard, UL 913(1), and applicable revisions as of April 8, 1976 except for paragraphs 4.2 and 4.4 as limited below, with respect to its use in atmospheres of methane.

6.1.2 Paragraph 4.2 of UL 913(1) requires that the equipment comply with requirements for similar equipment for use in ordinary, nonhazardous locations. The examination and testing of the equipment included all applicable ordinary location construction and performance requirements of UL, except for reliability and accuracy of operation of gas monitors. The examination and tests were based on the requirements of Part I of UL 913, First Edition (7), in Appendix B. All test methods and results are included in this Report; but only construction features not in compliance with the UL requirements are reported. If not reported as not in compliance with UL requirements, the construction was judged in compliance with UL requirements. Tests include one or more of the following: Input-Output, Normal Temperature, Undervoltage and Overvoltage, Transformer Output, and Dielectric Withstand Tests.

6.1.3 Paragraph 4.4 of UL 913(1) requires that components comply with the requirements for that component. Usually a separate UL Standard is involved. Some component constructions and performance, e.g., printed wiring boards, wiring material, etc., cannot be readily evaluated when they are part of an assembled product and such evaluation was not conducted. Some components, e.g., relays, can be examined and tested for compliance with the ordinary location UL requirements in accordance with paragraph 6.1.2 and such evaluation was conducted when appropriate. However, overload and endurance tests on the relay contacts were not conducted. If wiring material, or other component, is UL Listed or Component Recognized and is used as intended, such part meets the UL requirements. Components which should meet the requirements but could not be identified as UL Listed or Component Recognized are identified in this Report.

6.1.4 Some features need to comply with both intrinsically safe and electrical construction requirements. In such cases where a feature was not in compliance with either of the requirements, such as spacings, it is reported as not in compliance with the requirements affecting intrinsic safety.

6.1.5 Some of the associated circuits and equipment were provided with explosion-proof enclosures. Evaluation of the explosion-proof features of construction is not included in this Report. The method of installation of cable- or cord-connected equipment for use in mines was not evaluated since UL requirements only cover permanent (fixed) equipment installations in accordance with the National Electrical Code (NEC) NFPA No. 70-1978.

6.1.6 The results indicate that none of the Methane Monitoring Systems and Machine Control Circuits comply with UL requirements. Examination of each device disclosed features of construction which do not comply with the requirements, and testing of each device caused ignition of the explosive gas-air mixture specified in the test records. Therefore, none of the Methane Monitoring Systems or machine control circuits are suitable for Listing by UL.

6.2 ENSIGN ELECTRIC AND MANUFACTURING COMPANY, I. S. R. CIRCUIT PART NO. 6651-005, ITEM 10

Product Description

6.2.1 Intrinsically Safe Relay, Part No. 6651-005, manufactured by Ensign Electric Division, Harvey Hubbell, Inc., of Huntington, West Virginia. The coil is rated 230 v dc, shunt duty, and the contacts are rated 250 v dc, 2 amp. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe, which may extend into the hazardous area of the underground mine.

6.2.2 Three complete sample devices along with additional component parts were purchased from the manufacturer since a distributor for this device is not available in this area, and were subjected to the examination and tests described below.

6.2.3 Instructions covering installation of the device were not supplied as part of the equipment. Instructions were provided upon request. The electrical schematic is shown in Figure 1.

Ordinary Location Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

6.2.4 The wiring terminals provided on the device extend both above and below the mounting base. This, coupled with the lack of adequate installation instructions, make it difficult to insure that electrical spacings to grounded parts will be maintained after installation. Also, the size and shape of the mounting screws may result in inadequate spacings.

ELECTRICAL COMPONENTS

6.2.5 The Part No. 162HXH101 relay could not be identified as being UL Listed or Recognized.

Intrinsically Safe Electrical Construction

GENERAL, PARAGRAPHS 4.1, 4.3, 4.5-4.8, UL 913(1)

6.2.6 The Relay is not provided with an enclosure. The installation instructions do not specify that the Relay must be provided with means of protection such as an explosion-proof enclosure or that the Relay must be mounted outside of the hazardous location. This does not comply with paragraph 4.5.

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.2.7 Shunt Safety Components.

6.2.7.1 The coil is provided with a single shunt diode, see Figure 1. The diode is connected across the coil with separate crimp-on connectors at the wiring terminals used for field-installed wiring. The diode is not duplicated so that the assembly remains safe if one diode becomes defective and it is connected across the coil in such a manner that it may be disconnected from the circuit, leaving the coil in the circuit, while making the field wiring connections. This does not comply with paragraph 5.15, and is to be considered as subject to fault. See Circuit Fault Analysis paragraph 6.2.32.

6.2.8 Damping Winding.

6.2.8.1 The coil is provided with a damping winding consisting of two layers of copper wire wound over the coil bobbin. The ends of the windings are soldered together. Since the windings are not continuously short-circuited together by soldering or equivalent means in accordance with paragraph 5.13 it is to be considered as subject to fault. See Circuit Fault Analysis paragraph 6.2.32.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.2.9 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault under Circuit Fault Analysis, paragraph 6.2.32, unless the spacings are greater than or equal to those given in Table 8.1 for the specified potential. A spacing not less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.2.10 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined.

6.2.11 TABULATION OF ELECTRICAL SPACINGS

Fig.	Spacings		Provided, MM		Required, MM	
	From	To	Through Air	Over Surface	Through Air	Over Surface
1	N.O. Contact, "+" Term (250 v dc)	Grounded Mounting Plate (+++)	4-1/2 (+)	-	6	10
1	"+" Term, (250 v dc)	Ungrounded Diode Bracket	0 (++)	9 (+)	6	10
1	"1" Term	Ungrounded Diode Bracket	0 (++)	9 (+)	6	10
1	Ungrounded Diode Bracket	Grounded Mounting Plate	1 (++)	-	6	10
1	Diode Terms, (250 v dc)	Ungrounded Diode Bracket	-	7-1/2 (+)	6	10
1	"-" Term, Diode (250 v dc)	"1" Term	3-1/2 (+)	-	6	10

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

(+++) - A grounded mounting plate was not provided as part of the equipment. It was assumed that the relay may be mounted on a grounded mounting plate, or surface.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, UL 913(1)

6.2.12 The internal wiring between the 2500 ohm resistor and the line voltage "+" terminal contacts the wiring between the intrinsically safe "1" terminal and the resistor. This does not comply with paragraph 9.1, since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

6.2.13 The internal wiring between the coil shunt diode and the line voltage "-" terminal contacts the wiring between the intrinsically safe "2" terminal and the diode. This does not comply with paragraph 9.1, since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, UL 913(1)

6.2.14 The wiring terminals for intrinsically safe and nonintrinsically safe circuits are separated by a distance of at least 50 mm. This complies with the requirements for panel installed equipment. However, clear installation instructions regarding wire routing and field connections are not provided. This does not comply with paragraph 11.1.

SOURCES OF IGNITION, PARAGRAPH 14.1, UL 913(1)

6.2.15 The type of pilot device which is intended to be used in the hazardous area is not specified or limited. The pilot device used may affect the intrinsic safety of the system. The pilot device is required to be identified so this consideration can be made during Circuit Fault Analysis.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913(1)

6.2.16 The Relay was not marked with the designation of the hazardous location in which the intrinsically safe circuit is to be used in accordance with paragraph 31.4, Item C.

6.2.17 The intrinsically safe circuit is identified as "ISC" on the wiring diagram (Figure 1). This is not considered sufficient marking as required in paragraph 31.4, Item F.

6.2.18 The warning statement given on the installation instructions (Figure 1) is not considered as equivalent to the cautionary statement "Caution: Any substitution of components may impair intrinsic safety" given in paragraph 31.5 since any change in the product may affect intrinsic safety. Additionally, this marking was not provided on the relay in accordance with paragraph 31.5. This marking should be visible after the relay is installed.

6.2.19 Instructions covering connection of the pilot device in the field are not given nor is information on the type of device to be used with the relay provided, as required in paragraph 31.8.

6.2.20 The pilot device to be used with the relay would need to be marked to indicate that it is part of the system. In this case, the pilot device was not provided and compliance with paragraph 31.9 cannot be determined.

6.2.21 The "Intrinsically Safe" terminals on two of the relays obtained were not identified. The "Intrinsically Safe" and the input terminals on the third relay were not identified. This construction does not comply with paragraph 31.10.

6.2.22 The polarity of the DC input leads was not marked on one of the relays as required in paragraph 31.12.

Test Record

6.2.23 The samples and component parts of the device identified in paragraphs 6.2.1 and 6.2.2 were subjected to the following tests.

6.2.24 INPUT-OUTPUT TEST

Test previously conducted with acceptable results. See paragraph 5.2.21.

6.2.25 NORMAL TEMPERATURE TEST

Test previously conducted with acceptable results. See paragraph 5.2.23.

6.2.26 UNDERVOLTAGE AND OVERVOLTAGE TEST

Test previously conducted with unacceptable results. See paragraph 5.2.22.

6.2.27 TRANSFORMER OUTPUT TEST

Not applicable.

6.2.28 DIELECTRIC WITHSTAND TESTS

METHOD

The relay was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1 of UL 913(1) since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Intrinsically safe circuits and nonintrinsically safe circuit terminals.	1500	No breakdown
2	Line voltage live parts and dead-metal parts.	1500	No breakdown
3	Line voltage live parts of different circuits.	1500	No breakdown

6.2.29 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

RESULTS

Coil		Direct Current	Inductance at
Type	Part No.	Resistance, Ohms	1 KHz mh
Shunt Duty Relay	162HXH101	2481	2114

6.2.30 PROTECTIVE DIODE ABNORMAL TESTS

METHOD

The diode indicated below was connected to a variable direct current source of supply. The current was adjusted to equal that which would exist if the diode short-circuited in the circuit under consideration. The test was continued for 7 hr or until opening of the diode occurred.

RESULTS

The results are recorded in the following tabulation.

Diode		Rated	Current, Ma		Test	Ambient Temperature,
Mfg.	Type	V	Short Circuit	Test	Time, Hr	Degrees C
FMC	SD-0606	480	100	100	7	23

The results comply with the requirements in paragraph 5.16 of UL 913(1) since the diode used as a shunt safety component was able to carry the specified current without opening the circuit.

6.2.31 CURRENT LIMITING RESISTOR TESTS

METHOD

A sample of the current limiting resistor indicated was subjected to this test. Each resistor was connected across a variable voltage source of supply. The voltage was applied to the resistor gradually or instantaneously until reaching the value indicated. The tests included application to the resistor a potential of 1.5 times the maximum fault voltage determined during the Circuit Fault Analysis.

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraph 5.14 of UL 913(1).

| Resistor | | Rated | | 1.5 Times Maximum | | Test | | Test |
Mfg.	P/N	Ohms	Watts	Fault Volts	Test Voltage	Ohms(+)	Amp	Time
Ohmite	F423	2500	22	375	375	2642	0.123	7 Hr

(+) - Calculated at minimum value point during the test - ohms = volts/amperes.

6.2.32 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests. In the analysis, two simultaneous independant faults of components (except protective components) and short spacings in accordance with UL 913(1), were considered.

2. In the analysis, consideration was given to the following items:

A. Only the unspecified pilot device is to be located in the hazardous area. The relay is intended to be either housed in an explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment it appears that the following components are intended to be protective components.

Component		
Type	Designation	Remarks
Diode	SD-0606	Note 1
Resistor	F423	Note 2
Damping Winding		Note 3

Note -

1. The coil shunt diode may be open-circuited during spark ignition testing since the diode is not duplicated nor is it reliably connected in the circuit, see paragraph 6.2.7. The diode did meet the applicable performance test, see paragraph 6.2.27.

2. The resistor may be short-circuited during spark ignition testing without its being counted as a fault since adequate electrical spacings are not provided, see paragraph 6.2.11. The resistor did meet the applicable performance test, see paragraph 6.2.30.

3. The damping winding may be open-circuited during spark ignition testing since its construction did not meet the requirements, see paragraph 6.2.8.

3. Based on the anlysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.2.33.

6.2.33 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of UL 913(1).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the relay for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 250 v dc before introduction of any test (safety) factor.

The circuits selected for test are described below.

Circuit No.	Test Point	Circuit Description
1	I.S.C. Terms 1 and 2, Figure 1	Relay with no faults introduced.
2	I.S.C. Terms 1 and 2, Figure 1	Short circuit 2500 ohm resistor (no fault), due to short spacings, see paragraph 6.2.11.
3	I.S.C. Terms 1 and 2, Figure 1	Open shunt diode (one fault).
4	I.S.C. Terms 1 and 2, Figure 1	Open coil damping winding (one fault).
5	I.S.C. Terms 1 and 2, Figure 1	Short relay coil (one fault).
6	I.S.C. Terms 1 and 2, Figure 1	Short circuit 2500 ohm resistor (no fault) due to short spacings, see paragraph 6.2.11 and open shunt diode (one fault).
7	I.S.C. Terms 1 and 2, Figure 1	Short circuit 2500 ohm resistor (no fault) due to short spacings, see paragraph 6.2.11 open shunt diode (one fault) and short relay coil (one fault).

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Ma	Results
1	1	0	1.1	1.5	Cadmium	275	82	Note 1
2	2	0	1.1	1.5	Cadmium	275	166	Note 2
3	3	1	1.1	1.5	Cadmium	275	82	Note 2
4	4	1	1.1	1.5	Cadmium	275	82	Note 2
5	5	1	1.1	1.5	Cadmium	275	166	Note 2
6	6	1	1.1	1.5	Cadmium	275	166	Note 2
7	7	2	1.1	1.0	Cadmium	275	Note 3	Note 2

Note -

1. This test was not conducted since this circuit caused ignition of methane air mixture with brass disc and a test (safety) factor of 1.0. See paragraph 5.2.25.

2. Test not conducted since test conditions are more severe than Test No. 1.

3. Current limited only by capacity of source.

The results do not comply with the requirements in UL 913(1) since ignition of the methane-air mixture was obtained.

6.3 ENSIGN ELECTRIC AND MANUFACTURING COMPANY, I.S.R. CONTROL CIRCUIT, PART NO. 6651-004

Product Description

6.3.1 Intrinsically Safe Relay, Part No. 6651-004, manufactured by Ensign Electric Division, Harvey Hubbell, Inc. of Huntington, West Virginia. The device is rated 575 v ac, and the contacts are rated 120 v ac, 10 amp. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe.

6.3.2 Three complete sample devices along with additional component parts were purchased from the manufacturer since a distributor for this device is not available in this area and were subjected to the examination and tests described below.

6.3.3 Instructions covering installation of the device were not supplied as part of the equipment. Instructions were provided upon request. The electrical schematic is shown in Figure 2.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

6.3.4 The Cat. No. A314XBX148 relay cannot be identified as being UL Listed or Recognized.

WIRING TERMINALS AND LEADS

6.3.5 Intrinsically safe terminal No. 9, intended for field wiring the device, consists of a solder terminal on the 100 ohm resistor. This does not comply with paragraphs 113 through 120 of UL 913(7). See Appendix B.

ELECTRICAL SPACINGS

6.3.6 The required spacings for 575 v line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for 120 v line voltage circuits are those indicated in Column 51-300, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

6.3.7 The oversurface spacing between relay socket pin No. 1 (120 v ac) and relay socket pin No. 8 (120 v ac) was measured to be 3/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/8 in.

Intrinsically Safe Electrical Construction

GENERAL, PARAGRAPHS 4.1, 4.3, 4.5-4.8, UL 913(1)

6.3.8 The Relay is not provided with an enclosure. The installation instructions do not specify that the Relay must be provided with means of protection such as an explosion-proof enclosure or that the Relay must be mounted outside of the hazardous location. This does not comply with paragraph 4.5.

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.3.9 Protective Transformer.

6.3.9.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements since it was not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

6.3.10 Shunt Safety Components.

6.3.10.1 The two 1000 ohm wire wound resistors are connected in parallel with the relay coil. It appears that they are intended to be shunt safety components. Since the expected failure mode for a wire wound resistor is open circuit, the resistors are judged not to meet the requirements for shunt safety components. Furthermore, the resistors are connected across the relay coil such that both of the resistors could be disconnected without disconnecting the relay coil at the same time when field wiring the device. This does not comply with paragraphs 3.13 and 5.15.

6.3.10.2 The 1000 ohm wire wound resistor which appears to be intended as a transformer secondary shunt safety component. The expected failure mode for a wire wound resistor is open circuit. This does not comply with paragraphs 3.13 and 5.15.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.3.11 Any spacings, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault under Circuit Fault Analysis, paragraph 6.3.32 unless the spacings are greater than or equal to those given in Table 8.1, UL 913(1) for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.3.12 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined.

6.3.13 Tabulation of Electrical Spacings

	Spacings		Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
2	Relay Socket Pin No. 6 (120 v ac N.O.Contact)	Relay Socket Pin No. 7(+++)	1(++)	1(++)	6	6
2	Relay Socket Pin No. 8 (120 v ac)	Relay Socket Pin No. 7(+++)	2(++)	2(++)	6	8
2	Relay Socket Pin No. 1 (120 v ac)	Relay Socket Pin No. 2 (Secondary Circuit)	1(++)	1(++)	6	8
2	Relay Pin No. 8 (120 v ac)	Relay Pin No. 7(+++)	4(+)	5(+)	6	8
2	Relay Pin No. 1 (120 v ac)	Relay Pin No. 2 (Secondary Circuit)	4(+)	5(+)	6	8

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

(+++) - Intrinsically safe output terminal.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, UL 913(1)

6.3.14 Within the relay the wiring for the 120 v contact circuits intermingles with the wiring of the coil circuit. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, UL 913(1)

6.3.15 The field wiring connection for the intrinsically safe circuit Terminal 9 is located above the field wiring connections for the transformer primary circuit, and is separated by a distance of 46 mm, minimum. This does not comply with the requirements for panel installed equipment in paragraph 11.1 which requires a separation of at least 50 mm. Additionally this construction does not comply with paragraph 10.5 since the field wiring of intrinsically safe and nonintrinsically safe circuits may not be positively separated.

6.3.16 The field wiring connections for the intrinsically safe circuit Terminals 7 and 9 are separated from the line voltage contact circuits by distances of 6 and 25 mm, respectively. This does not comply with the requirements for panel installed equipment in paragraph 11.1 which requires a separation of at least 50 mm. Additionally this construction does not comply with paragraph 10.5 since field wiring of the transformer primary may intermingle with intrinsically safe field wiring, uninsulated secondary conductors and field wiring of contact circuits.

SOURCES OF IGNITION, PARAGRAPH 14.1, UL 913(1)

6.3.17 The type of switch which is intended to be used in the hazardous area was not specified or limited. The use of electronic switches may affect the intrinsic safety of the system. The type of switch to be used would need to be identified in order for this consideration to be made during Circuit Fault Analysis. If only mechanically actuated switches are to be used in the hazardous area then specifying a particular switch would not be necessary, however this information should be indicated in the installation instructions.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913

6.3.18 The Relay is not marked with the designation of the hazardous location in which the intrinsically safe circuit is to be used as required in paragraph 31.4, Item C.

6.3.19 The warning statement given on Figure 2 is not considered as equivalent to the cautionary statement "Caution: Any substitution of components may impair intrinsic safety", given in paragraph 31.5 since any change in the product may affect intrinsic safety. Additionally, this marking was not provided on the Relay in accordance with paragraph 31.5. This marking should be visible after the Relay is installed.

6.3.20 Instructions covering connection of the switch in the field are not given nor is information on the type of device to be used with the Relay provided as required in paragraph 31.8.

6.3.21 The "Intrinsically Safe" terminals on the Relay were not identified. This construction does not comply with paragraph 31.10.

Test Record

6.3.22 The samples and component parts of the device identified in paragraphs 6.3.1 and 6.3.2 were subjected to the following tests.

6.3.23 INPUT-OUTPUT TEST

Test previously conducted with acceptable results. See paragraph 5.3.19.

6.3.24 NORMAL TEMPERATURE TEST

Test previously conducted with acceptable results. See paragraph 5.3.20.

6.3.25 UNDERVOLTAGE AND OVERVOLTAGE TEST

Test previously conducted with acceptable results. See paragraph 5.3.21.

6.3.26 TRANSFORMER OUTPUT TEST

Test previously conducted with acceptable results. See paragraph 5.3.22.

6.3.27 DIELECTRIC WITHSTAND TESTS

METHOD

When in a well heated condition the relay was subjected to these tests. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraph 4.2 and 23.1, UL 913(1), since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to secondary circuits	2200	No breakdown
2	Primary circuits to grounded parts	2200	No breakdown
3	Secondary circuit to grounded parts	500	No breakdown
4	Primary to line voltage contact circuits	2200	No breakdown
5	Line voltage contact circuits to secondary circuits and grounded parts	1250	No breakdown

6.3.28 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

RESULTS

Coil		Direct Current	Inductance at
Type	Part No.	Resistance, Ohms	1 KHz, mh
Relay	A314XBX148	84.46	142.7

6.3.29 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformers was subjected to this test. The sample was connected to a source of supply as indicated. The secondary winding was short-circuited. Each sample was operated continuously until the results noted were observed.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.2, UL 913(1) for a Type 2A transformer since there was emission of flame.

Transformer Insulation Class	Type	Rated V	Rated Hz	Test V	Test Hz	Test Time, Min	Maximum Temperature, Degrees C Ambient	Core	Windings
A	2A	575	60	600	60	10	23	92(+)	169(+)

(+) - Maximum temperature recorded before transformer burst into flames.

6.3.30 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE-WITHSTAND TEST

Test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test, paragraph 6.3.29.

6.3.31 CURRENT LIMITING RESISTOR TESTS

METHOD

Samples of the current limiting resistors indicated were subjected to this test. Each resistor was connected across a variable voltage source of supply. The voltage was applied instantaneously to each resistor. The tests included application to the resistor of a potential of 1.5 times the maximum fault voltage determined during the Circuit Fault Analysis. Each resistor was tested in this manner for 7 hr.

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraph 5.14, UL 913(1).

Sample	Resistor		Rated		1.5 Times Maximum	Test Voltage	Test		Test
No.	Mfg.	P/N	Ohms	Watts	Fault Volts	Volts	Ohms(+)	Amp	Time
1	Ohmite	F210	100	20	55.65	55.7	100.7	0.553	7 hr
2	Dale	HLM-20-10Z	1K	20	55.65	55.7	1018.3	0.055	7 hr

(+) - Calculated at minimum value point during the test - Ohms = volts/amperes.

6.3.32 CIRCUIT FAULT ANAYLSIS

1. Fault analysis was performed to select circuits for spark ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring, and short spacings in accordance with UL 913(1) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the unspecified pilot device is to be located in the hazardous area. The Relay is intended to be either housed in an explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment, it appears that the following components are intended to be protective components.

Component Type	Component Designation	Remarks
Line Voltage Transformer	None Provided	Note 1
100 Ohm Resistor	F210	-
1000 Ohm Transformer Secondary Shunt	HLM-20-10Z	Note 2
1000 Ohm Coil Shunt	HLM-20-10Z	Note 3

Note -

1. The line voltage transformer may be short circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance test, see paragraph 6.3.29. The construction did not meet the applicable construction requirements, see paragraph 6.3.9.1.

2. The resistor may be open-circuited during spark ignition testing since the resistor did not meet the requirements for shunt safety components, see paragraph 6.3.10.2.

3. Both of the resistors may be open-circuited during spark ignition testing since they do not meet the requirements for shunt safety components and since they may be disconnected from the circuit without disconnecting the coil when making the field wiring connections, see paragraph 6.3.10.1. This is counted as one fault, since both resistors are connected to terminal No. 7 with a single wire.

3. Based on the analysis, representative circuits were selected for spark ignition test as noted in paragraph 6.3.33.

6.3.33 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of UL 913(1).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated.

The input voltage to the relay for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v before introduction of any test (safety) factor.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Relay Terminals 7 and 9, Figure 2	No faults introduced.
2	Relay Terminals 7 and 9, Figure 2	Open 1K ohm transformer shunt (one fault).
3	Relay Terminals 7 and 9, Figure 2	Open relay coil shunt resistors (one fault).
4	Relay Terminals 7 and 9, Figure 2	Open 1K ohm transformer shunt (one fault) and open relay coil shunt resistors (one fault).
5	Relay Terminals 7 and 9, Figure 2	Short relay coil (one fault) and open transformer shunt (one fault).
6	Relay Terminals 7 and 9, Figure 2	Short relay coil (one fault) and short transformer primary to secondary (one fault).
7	Relay Terminal 7, Figure 2 to Ground	Short circuit relay socket Terminal 6 or 8 to 7 (intrinsically safe terminal) (no fault) due to short spacings, see paragraph 6.3.13. (+)
8	Relay Terminal 7, Figure 2 to Ground	Short relay socket Terminals 1 to 2 (no fault) due to short spacings, see paragraph 6.3.13. (++)
9	Relay Terminal 9, Figure 2 to Ground	Short transformer primary to secondary (one fault). (+++)

(+) - This condition shorts the 120 v ac contact circuit to the intrinsically safe circuit. Assuming the use of a 120 v, grounded source, arcing of the intrinsically safe circuit to ground arcs the 120 v supply to ground.

(++) - This condition shorts the 120 v ac contact circuit to the transformer secondary circuit at relay socket Terminal 2. Assuming the use of a 120 v grounded source, arcing of the intrinsically safe circuit to ground arcs the 120 v supply to ground through the relay coil.

(+++) - This condition shorts the 575 v ac transformer primary circuit to the transformer secondary circuit at the 100 ohm resistor. Assuming the use of a 575 v grounded source, arcing of the intrinsically safe circuit to ground arcs the 575 v supply to ground through the 100 ohm resistor.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Ma	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles: Before Test	After Test
1	1	0	1.1	1.5*	Cadmium	49.0	165	2	Ignition	1	-
2	1	0	1.1	1.0	Cadmium	40.5	130.8	570	Ignition	9	-
3	2	1	1.1	1.5	Cadmium	-	-	-	Note 1		
4	3	1	1.1	1.5	Cadmium	-	-	-	Note 1		
5	4	2	1.1	1.0	Cadmium	-	-	-	Note 1		
6	5	2	1.1	1.0	Cadmium	-	-	-	Note 1		
7	6	2	1.1	1.0	Cadmium	660 ac	Note 2	-	Note 1		
8	7	0	1.1	1.0	Cadmium	132 ac	-	-	Note 1		
9	8	0	1.1	1.0	Cadmium	132 ac	-	-	Note 1		
10	9	1	1.1	1.0	Cadmium	660 ac	-	-	Note 1		

*Factor applied by increasing relay input voltage.

Note -

1. Test not conducted since test conditions are more severe than Test No. 1.

2. Current limited only by capacity of source.

The results do not comply with the requirements in UL 913(1) since ignition of the methane-air mixture was obtained.

6.4 MSA, MODEL VI METHANE MONITOR

Product Description

6.4.1 Model VI Methane Monitoring System, manufactured by Mine Safety Appliances Company of Pittsburgh, Pennsylvania. The system consists of an AC Power Supply and Contact Driver, Part No. 458175 (Figure 3), a Monitor Part No. 456960 and a Detector Part No. 458120 (Figure 4). Additionally an auxiliary Battery power source Part No. 95554 is available to power the Monitor. The Power Supply is intended to be mounted within an explosion-proof enclosure and has circuits which are connected to the Monitor and the Detector, each claimed to be intrinsically safe. The Power Supply is rated 550 v ac input, the Battery is rated 4 v dc.

6.4.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

6.4.3 Electrical schematics for the equipment are shown in Figures 3 and 4.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

FIELD WIRING TERMINALS

6.4.4 The wire binding screw intended for the connection of the equipment grounding conductor (Terminal No. 1) is not provided with a green-colored head. This does not comply with paragraph 122 of UL 913(7). See Appendix B. The terminal identification is supplied on a wiring diagram in the instruction manual.

INTERNAL WIRING

6.4.5 The orange-colored transformer primary lead has at least 1/64 in. thick insulation with an outer braid. This lead could not be identified as UL Appliance Wiring Material. This does not comply with paragraphs 148-150, of UL 913(7). See Appendix B.

6.4.6 The green, yellow and brown-colored transformer primary lead wires have at least 1/64 in. thick insulation with an outer braid. These leads could be identified as UL Appliance Wiring Material rated 105 C, 300 v maximum. Since these conductors are for use in 550 and 440 v ac circuits they are not considered to be acceptable in accordance with paragraphs 148-150 of UL 913(7). See Appendix B.

ELECTRICAL COMPONENTS

6.4.7 The Part No. A415HXX104 relay in the AC Power Supply and Contact Driver could not be identified as being UL Listed or Recognized.

6.4.8 The AC Power Supply printed wiring board No. 458148 could not be identified as being UL Recognized.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.4.9 Protective Transformer.

6.4.9.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements since it was not constructed with thermal insulation between the input and output windings, including splices and crossover leads as required in paragraph 5.9A.

6.4.10 Shunt Safety Components

6.4.10.1 The relay coil is provided with a single shunt diode (see Figure 3). The diode is mounted to a printed wiring board and connected to the relay coil with separate lead wires. The diode is not duplicated so that the assembly remains safe if one diode becomes defective and it is connected across the coil in such a manner that it may be disconnected from the circuit, leaving the coil in the circuit. This does not comply with paragraph 5.15 and was considered as subject to fault. See Circuit Fault Analysis, paragraph 6.4.41.

OVERCURRENT PROTECTION, PARAGRAPHS 6.1-6.2, UL 913(1)

6.4.11 The intrinsically safe Monitor is supplied with a fuse for overcurrent protection. This does not comply with the exception to paragraph 6.2 since it has been shown by test that the circuit will ignite the hazardous atmosphere of methane. See paragraph 5.4.23. Since the circuit itself is capable of ignition, tests of the fuses were not conducted.

SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.4.12 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault under Circuit Fault Analysis, paragraph 6.4.41, unless the spacings are greater than or equal to those given in Table 8.1 for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.4.13 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. These spacings were in the AC Power Supply and Contact Driver, Figure 3 and in the Monitor, Figure 4.

6.4.14 Tabulation of Electrical Spacings

Fig.	Spacings From	Spacings To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
3	Resistor Rx, Primary Circuit	2 amp fuse, secondary circuit	0(++)	-	10	25
3	2N3055 Reg Term "C", Secondary Circuit	2N3055 Reg Term "E", Secondary Circuit	1/2(++)	1/2(++)	3	3
3	D42C Term "C", Secondary Circuit	D42C Term "B", Secondary Circuit	1/2(++)	1/2(++)	3	3
3	D42C Term "C", Secondary Circuit	D42C Term "B", Secondary Circuit	1/2(++)	1/2(++)	3	3
3	D42C Term "B", Secondary Circuit	Term 8, Intrinsically Safe Terminal	1-1/2(+)	1-1/2(+)	3	3
4	Terminal 3, Monitor	Toroid, Brown Lead Monitor	1/2(++)	1/2(++)	3	3
4	Terminal 10, Monitor	Toroid, Brown Lead Monitor	1/2(++)	1/2(++)	3	3
4	Toroid Red Lead, Monitor	Toroid, Orange Lead, Monitor	1/2(++)	1/2(++)	3	3
4	Toroid, Orange Lead, Monitor	Toroid, Yellow Lead, Monitor	1/2(++)	1/2(++)	3	3
4	Terminal 10, Monitor	Terminal 5, Monitor	1-1/2(+)	1-1/2(+)	3	3
4	Terminal 10, Monitor	Toroid, Blue Lead, Monitor	1(+)	1(+)	3	3
4	Terminal 3, Monitor	Terminal 5, Monitor	1(+)	1(+)	3	3
4	Terminal 3, Monitor	Terminal 8, Monitor	1-1/2(+)	1-1/2(+)	3	3
4	Between all Adjacent Terminals of I.C. No. M789P		1/2(++)	1/2(++)	3	3
4	Between all Adjacent Terminals of Amp No. 1/2 MC1437L		1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

6.4.15 The application of adherent insulating material to the Power Supply and Monitor printed wiring boards was not uniform since some areas were not coated. Also, the insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore can not be relied upon in lieu of spacings in accordance with Footnote b of Table 8.1.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, UL 913(1)

6.4.16 In the Power Supply the internal wiring for the intrinsically safe Terminals 8, 9 and 10 is bunched together for routing with 550 v ac primary transformer wiring and 240 v ac contact wiring. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

6.4.17 In the Power Supply the internal wiring for the 2 amp secondary fuse is routed adjacent to the 550 v ac transformer primary common conductor and 240 v ac contact wiring. This does not comply with paragraph 9.1 since positive separation is not provided between the fuse wiring, which may affect intrinsic safety, and the nonintrinsically safe circuit.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, UL 913(1)

6.4.18 Field wiring conductors for the intrinsically safe circuits may be intermingled with field wiring conductors and factory installed wiring for the line voltage circuits and uninsulated live parts of line voltage circuits since all field wiring is completed on the same terminal block. This does not comply with paragraph 10.5.

BATTERY-OPERATED APPARATUS, PARAGRAPHS 12.1-12.5, UL 913(1)

6.4.19 The Battery available for use with the equipment as an auxiliary power source incorporates an integral device with a bimetalic element soldered in place between the two battery cells. This type of device is not considered equivalent to a current-limiting resistor to limit the maximum current available under short circuit conditions, in accordance with paragraph 12.3, since it will not limit the current when the circuit is initially short-circuited. Therefore the device may be short-circuited during tests. See Circuit Fault Analysis, paragraph 6.4.41.

SOURCES OF IGNITION, PARAGRAPH 14.1, UL 913(1)

6.4.20 Interconnection of the Power Supply and Monitor is accomplished by a seven conductor cable of which only three conductors are used. Additional conductors are provided for connection to an unspecified remote meter and relay which are not supplied with the equipment. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe. The remote meter and relay should be identified so this consideration can be made during Circuit Fault Analysis. Also, when the unspecified remote meter and relay are not used, the uninsulated ends on the conductors may contact uninsulated line voltage parts which may result in transmission of line voltage to the intrinsically safe equipment located in the hazardous area.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913(1)

6.4.21 The Detector is not marked with the manufacturers name and a specific part number. This does not comply with paragraph 31.1. Additionally the marking should identify the Detector as part of the complete system in accordance with paragraph 31.9.

6.4.22 The Monitor is not marked with the cautionary statement "Caution: To prevent ignition of hazardous atmospheres, use one No. 95554, 4 v battery only" in accordance with paragraph 31.3, Item A. This marking should be visible when replacing the Battery.

6.4.23 The rated current and type of replacement fuse were not marked on the Power Supply adjacent to the fuseholder for the primary fuse as required in paragraph 31.4, Item A.

6.4.24 In the Power Supply the intrinsically safe circuits are not identified nor is the product marked with the designation of the hazardous location in which the intrinsically safe circuits are to be used, in accordance with paragraphs 31.4, Item C and 31.4, Item F.

6.4.25 The Monitor and Detector are not marked "Intrinsically Safe" nor are they marked with the designation of the hazardous locations in which they are intended to be used in accordance with paragraphs 31.4, Item C and E.

6.4.26 The Power Supply, Monitor and Detector are not marked with the statement "Caution: Any substitution of components may impair intrinsic safety" or equivalent in accordance with paragraph 31.5.

6.4.27 Clear instructions are not provided concerning connections to remote meter/recording equipment which may affect the intrinsic safety of the whole system as required in paragraph 31.8.

6.4.28 Instructions covering interconnection of component parts of the system should be referenced on the nameplates in accordance with paragraph 31.8.

<u>Test Record</u>

6.4.29 The samples and component parts of the device identified in paragraphs 6.4.1 and 6.4.2 were subjected to the following tests to determine compliance with UL 913(1).

6.4.30 <u>INPUT-OUTPUT TEST</u>

Test was previously conducted with acceptable results. See paragraph 5.4.16.

6.4.31 <u>NORMAL TEMPERATURE TEST</u>

Test was previously conducted with acceptable results. See paragraph 5.4.18.

6.4.32 <u>UNDERVOLTAGE AND OVERVOLTAGE TEST</u>

Test was previously conducted with acceptable results. See paragraph 5.4.19.

6.4.33 <u>TRANSFORMER OUTPUT TEST</u>

Test was previously conducted with acceptable results. See paragraph 5.4.20.

6.4.34 DIELECTRIC WITHSTAND TESTS

METHOD

The Monitor was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1 of UL 913(1) since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to secondary circuits	2200	No breakdown
2	Primary circuits to grounded parts	2200	No breakdown
3	Secondary circuit to grounded parts	500	No breakdown
4	Primary to line voltage contact circuits	2200	No breakdown
5	Line voltage contact circuits to secondary circuits and grounded parts	1500	No breakdown

6.4.35 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

RESULTS

Product	Coil Type	Coil Part No.	Winding	Direct Current Resistance, Ohms	Inductance at 1 KHz, mh
Model VI Power Supply	Relay	626201	-	38.70	101.73
Model VI Monitor	Meter	456467	-	101.06	4.43
Model VI Monitor	Toroidal	454806	Brn/Red	0.36	2.74
Model VI Monitor	Toroidal	454806	Grn/Blu	0.42	0.16
Model VI	Toroidal	454806	Gry/Vio	3.62	59.10

6.4.36 BATTERY RUPTURE TEST

METHOD

The rechargeable Battery was placed in an oven at 90 C (194 F) for a period of 7 hr.

RESULTS

The results comply with the requirements in paragraph 24.1 of UL 913(1) since the Battery did not rupture during the test.

6.4.37 TEST FOR ACCUMULATION OF STATIC ELECTRICITY

METHOD A

Three samples of the rechargeable Battery were conditioned for 48 hr in a room having a temperature of 20 C (68 F) and a relative humidity of 20 percent. The samples were each, in turn, supported on an insulated table in the room and the lights were dimmed. An electrostatic charge was sprayed on nonconductive (plastic) parts of the enclosure using a Van de Graff generator limited to 15,000 v. With each battery electrostaticly charged, a 3/8 in. diameter grounded metal sphere was brought into close proximity with nonconductive parts of the sample under test.

METHOD B

The test was repeated with a 1/16 in. diameter copper wire wrapped around the battery tie down brackets and grounded to simulate mounting the battery in service.

RESULTS A AND B

The results comply with the requirements in paragraph 30.1 of UL 913(1) since there were no sparks observed discharging when the sphere was brought into close proximity with plastic parts in Methods A and B above. Discharge sparks were seen at metal parts of the batteries in Method A only.

6.4.38 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformer was subjected to this test. The sample was connected to a source of supply as indicated. The secondary winding was short-circuited. The sample was operated continuously until the results noted were observed.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.1 of UL 913(1) for Type 2A transformer since there was emission of flame.

Transformer			Rated		Test		Test Time,	Maximum Temperature Degrees C		
Mfr.	P/N	Type	V	Hz	V	Hz	Hr	Ambient	Core	Winding
MSA	95646-4	76222A	550	60	600	60	1/4	23	74(+)	153(+)

(+) - Maximum temperature recorded before transformer burst into flame.

6.4.39 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test, paragraph 6.4.38.

6.4.40 PROTECTIVE DIODE ABNORMAL TESTS

METHOD

The diode indicated was connected to a variable direct current source of supply. Then the current was adjusted to equal that which would exist if the diode short-circuited in the circuit under consideration. The test was continued for 7 hr.

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraph 5.16 of UL 913(1) since the diode was able to carry the test current without opening.

Diode		Rated		Current, Amp		Ambient Temperature,	Test Time,	
Mfg.	Type	V	Amp	Short Circuit	Test	Degrees C	Hr	Results
ITT	1N4001	50	1	3	3	21	7	Diode remained shorted after 7 hr

6.4.41 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring and short spacings in accordance with UL 913(1), were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Monitor and Detector are to be located in the hazardous area. The AC Power Supply and Contact Driver are intended to be housed in an explosion-proof enclosure.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Equipment	Component		
Part No.	Type	Designation	Remarks
458175	Transformer	MSA956-4 7622	Note 1
458175	Diode	1N4001	Note 2
95554	Bi-Metal Switch	-	Note 3

Note -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance tests, see paragraph 6.4.38.

2. The diode may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 6.4.10.1. The diode did meet the applicable performance test, see paragraph 6.4.40.

3. The Bi-metalic switch may be short-circuited during spark ignition testing since it did not meet the requirements for current limiting devices, see paragraph 6.4.19.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.4.42 and representative components were selected for thermal ignition tests.

6.4.42 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of UL 913(1), using copper wires 0.008 in. diameter to replace the tungsten wires when test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

When batteries were used during the test, four trials with fresh or fully charged batteries, two for each polarity, were used for each test circuit.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable position so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply Terminals 9 and 10, Figure 3	No faults introduced. (+)
2	Battery Terminals	A single battery with bimetallic switch shorted (no fault). (++)
3	Power Supply Terminals 9 and 10, Figure 3	Short 2N3055 "C" to "E" (no fault) due to short spacings, see paragraph 6.4.14. (+)
4	Power Supply Terminals 8 and 9, Figure 3	Short D42C "C" to "B" (no fault) and short 200 ohm resistor (one fault) both due to short spacings, see paragraph 6.4.14 and short relay coil, (one fault).
5	Power Supply Terminal 9, Figure 3 and Ground	Short transformer primary to secondary (one fault). (+++)
6	Power Supply Terminal 10, Figure 3	Short 2N3055 "C" to "E" (no fault) above and short primary Resistor RX to Transistor 2N3055 "C" terminal, (no fault) both due to short spacings, see paragraph 6.4.14. (++++)

(+) - Circuit was simulated due to damage sustained to Power Supply during tests conducted previously. See paragraph 5.4.23.

(++) - Circuit was simulated using Sorensen Model DCR40-70B power supply rated 40 v, 70 amp dc maximum. Initial circuit before introduction of the safety factor was 4.99 v dc, 42 amp, representing maximum battery output determined during Battery Output Test. See paragraph 5.4.17.

(+++) - This condition shorts the 550 v ac line circuit to the intrinsically safe Terminal 9 through Resistor RX. Assuming the use of a 550 v grounded source, arcing the intrinsically safe circuit to ground arcs the 550 v supply to ground.

(++++) - This condition shorts the 550 v ac line circuit to the intrinsically safe Terminal 10 through Resistor RX. Assuming the use of a 550 v grounded source, arcing the intrinsically safe circuit to ground arcs the 550 v supply to ground.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revo-lutions	Results	Spart Test Mechanism Calibration Cycles Before Test	After Test
1	1	0	1.1	1.5*	Cadmium	4.40	6.11	400	No Ignition	46	16
2	2	0	1.1	1.5**	Cadmium	6.72	57	13	Ignition	11	-
3	3	0	1.1	1.5***	Cadmium	12.80	12.35	-	Note 1	-	-
4	4	2	1.1	1.0	Cadmium	12.80	12.35	-	Note 2		
5	5	1	1.1	1.0	Cadmium	660	-	-	Note 2		
6	6	0	1.1	1.0	Cadmium	660	-	-	Note 2		

*Factor applied by decreasing the value of limiting resistance.

**Factor applied by increasing the voltage by 1.225 per paragraph 12.2, UL 913(1).

*** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0. See paragraph 5.4.23.

2. Test not conducted since test conditions are more severe than Test No. 2.

The results do not comply with the requirements in UL 913(1), since ignition of the methane air mixture was obtained.

6.4.43 Transistor Thermal Runaway, Component Overload and Strand of Wire Tests were not conducted since test results in paragraph 6.4.42 indicate that circuits which extend into the hazardous location are not intrinsically safe.

6.5 SERVICE MACHINE COMPANY, B-742-001 POWER SUPPLY

Product Description

6.5.1 Intrinsically Safe Power Supply, Part No. B-742-001, manufactured by Service Machine Company of Huntington, West Virginia. The Supply is rated 115 v, 60 Hz input, 5 through 12 v dc, in 1 v increments, output. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe, intended to operate unspecified horns, buzzers, solenoids or relays.

6.5.2 A complete sample of the device along with additional component parts were purchased from the manufacturer, since a distributor for this device is not available in this area, and were subjected to the examination and test described below.

6.5.3 Schematic diagram and instructions covering installation of the devices were not supplied as part of the equipment. Instructions were provided upon request. The schematic diagram is shown in Figure 5.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

ELECTRICAL SPACINGS

6.5.4 The required spacings for line voltage circuits are those indicated in Column 51-300, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

6.5.5 The through air spacing between the uninsulated fuse terminals and grounded parts of the 7.5 ohm resistor can be reduced to zero since the fuseholder was not prevented from rotating. This does not comply with paragraph 196 and Table 6 of UL 913(7) which require a 1/16 in. through air spacing.

Intrinsically Safe Electrical Construction

GENERAL, PARAGRAPHS 4.1, 4.3, 4.5-4.8, UL 913(1)

6.5.6 The Power Supply is not provided with an enclosure. The installation instructions do not specify that the Power Supply must be provided with means of protection such as an explosion-proof enclosure or that the Power Supply must be mounted outside of the hazardous location. This does not comply with paragraph 4.5.

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.5.7 Protective Transformer.

6.5.7.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is a grounded screen between the windings, it may be considered as having Type 2B construction. The transformer is judged not to comply with the applicable construction requirements for Type 2B transformers since the screen is placed between the windings but the splices and crossover leads are not included (paragraph 5.9B), since only one and not two grounding leads are provided (paragraph 5.9B-2), since the screen consists of one layer and not two layers of windings as required (paragraph 5.9B-3), and since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg.

6.5.7.2 The Type 2B transformer does not require a Protective Transformer Abnormal Operation Test. A Type 2B transformer which complies with all the construction features except is provided with only one grounding lead and is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction. Transformers having Type 3 construction are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted per paragraph 6.5.29.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.5.8 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 6.5.31 unless the spacings are greater than or equal to those given in Table 8.1, UL 913(1) for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.5.9 The electrical spacings recorded in the following table are those that were measured to be less than required on the sample examined.

6.5.10 TABULATION OF ELECTRICAL SPACINGS

	Spacings		Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
5	AC Rectifier Terms	Ground	1-1/2(+)	1-1/2(+)	3	3
5	Capacitor "+" Lead	Ground	1-1/2(+)	-	3	3
5	Regulator Term "B"	Regulator Case	1/2(++)	1/2(++)	3	3
5	Regulator Term "E"	Regulator Case	1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, UL 913(1)

6.5.11 The internal wiring from the transformer secondary circuit contacts the lead wires for the 7.5 ohm resistor, zener diodes and capacitor. This does not comply with paragraph 9.1 since positive separation is not provided between nonintrinsically safe and intrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, UL 913(1)

6.5.12 The field wiring connections for the transformer primary circuit are separated from bare live parts of the intrinsically safe circuits (at the diode heat sink) by a distance of 17 mm. This does not comply with the requirements for panel installed equipment in paragraph 11.1 which requires a separation of at least 50 mm. Additionally, this construction does not comply with paragraph 10.5 since field wiring of the transformer primary may intermingle with intrinsically safe wiring and transformer secondary wiring.

SOURCES OF IGNITION, PARAGRAPH 14.1, UL 913(1)

6.5.13 The type of horn, buzzer, solenoid or relay which is intended to be used in the hazardous area is not specified or limited. The device used may affect the intrinsic safety of the system. The type of device must be identified so this consideration can be made during Circuit Fault Analysis.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913(1)

6.5.14 The Power Supply was not marked with the designation of the hazardous location in which the intrinsically safe circuit is to be used as required in paragraph 31.4, Item C.

6.5.15 The intrinsically safe circuit is identified as "I.S." on the wiring diagram (Figure 5). This is not considered to be sufficient marking as required in paragraph 31.4, Item F.

6.5.16 The Power Supply is not marked "Caution: Any substitution of components may impair intrinsic safety," or equivalent as required in paragraph 31.5. This marking would need to be provided on the Power Supply in accordance with paragraph 31.5, and would need to be visible after the Power Supply is installed.

6.5.17 Instructions covering connection of the horn, buzzer, solenoid or relay in the field are not given nor is information on the type of device to be used with the Power Supply provided, as required in paragraph 31.8.

6.5.18 The device to be used with the Power Supply would need to be permanently marked to indicate that it is part of the system. In this case the device was not provided and compliance with paragraph 31.9 cannot be determined.

6.5.19 The "Intrinsically Safe" terminals on the Power Supply were not identified. This does not comply with paragraph 31.10.

6.5.20 The polarity of the DC output terminals was not marked on the Power Supply as required in paragraph 31.12.

Test Record

6.5.21 The samples and component parts of the device identified in paragraphs 6.5.1 and 6.5.2 were subjected to the following tests.

6.5.22 INPUT-OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.5.18.

6.5.23 NORMAL TEMPERATURE TEST

Test previously conducted with acceptable results, see paragraph 5.5.19.

6.5.24 UNDERVOLTAGE AND OVERVOLTAGE TESTS

Not applicable.

6.5.25 TRANSFORMER OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.5.20.

6.5.26 DIELECTRIC WITHSTAND TESTS

METHOD

The Power Supply was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1, UL 913(1), since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to secondary circuits	1500	No breakdown
2	Primary circuits to grounded parts	1250	No breakdown
3	Secondary circuit to grounded	500	No breakdown

6.5.27 CURRENT LIMITING RESISTOR TESTS

METHOD

A sample of the current limiting resistors was subjected to this test. The resistor was connected across a variable voltage source of supply. The voltage was applied to the resistor either gradually until reaching the value indicated. The test included application to the resistor of a potential of 1.5 times the maximum fault voltage determined during the Circuit Fault Analysis. The resistor was tested in this manner for 7 hr.

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraph 5.14 of UL 913(1).

	Resistor		Rated	Maximum	Test Voltage	Test		Test
Mfg.	Part No.	Ohms	Watts	Fault Volts	Volts	Ohms(+)	Amp	Time
Dale	RH-50	7.5	50	15.61	23.4	5.85	4	7 hr

(+) - Calculated at minimum value point during the test - Ohms = Volts/Amperes.

6.5.28 PROTECTIVE DIODE ABNORMAL TESTS

Samples of the protective diode indicated were subjected to these tests.

METHOD A

The diode was connected to a variable direct current source of supply. The diode current and voltage were monitored continuously. The voltage was increased until diode breakdown occurred. The breakdown voltage and the current through the diode immediately after breakdown were recorded.

METHOD B

The diode was connected to a variable direct current source of supply. The voltage was increased until diode breakdown occurred. Then the current was adjusted to equal that which would exist if the diode short-circuited in the circuit under consideration (times a factor of 1.5). The test was continued for 7 hr.

RESULTS A AND B

The results are recorded in the following tabulation.

The results comply with the requirements in paragraph 5.19B of UL 913 (1) since the diodes were able to carry the test current without opening.

Sample No.	Diode Mfg.	Diode Type	Rated V	Rated W	Breakdown V	Breakdown Amp	Current, ma Short Circuit	Current, ma Test	Ambient Temperature, Degrees C	Test Time, Hr	Results
1	IR	IN3314A	15	50	16.9	3.8					Diode shorted.
2	IR	IN3314A	15	50	-	-	3.1	4.7	21	7	Diode shorted and remained shorted after test.

6.5.29 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformer was subjected to this test. The sample was connected to a source of supply as indicated. The secondary winding was short-circuited. The sample was operated continuously until the results noted were observed.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.3 of UL 913 (1) for Type 3 transformer since there was emission of flame.

	Transformer		Rated		Test		Test Time,	Maximum Temperature, Degrees C			
	Part No.	Type	V	Hz	V	Hz	Min	Ambient	Core	Primary	Secondary
1	TR12463	3	115	60	120	60	15	22	86(+)	292(+)	216(+)

(+) - Maximum temperatures measured before transformer burst into flame.

6.5.30 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

This was not conducted since transformer did not comply with the performance requirements of the Abnormal Operation Test, paragraph 6.5.29.

6.5.31 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests. In the anlaysis, two simultaneous independent faults of components (except protective components) field wiring, and short spacings in accordance with UL 913(1), were considered.

2. In the analysis, consideration was given to the following items:

A. Only the unspecified horn, buzzer, solenoid or relay is to be located in the hazardous area. The Power Supply is intended to be housed in an explosion-proof enclosure.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Equipment Part No.	Component Type	Component Designation	Remarks
B-742-001	Transformer	TR12463	Note 1
B-742-001	Resistor	RH-50	
B-742-001	Diode	IN3314A	

Note -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance tests, see paragraphs 6.5.29 and 6.5.30. The construction did not meet the applicable construction requirements, see paragraph 6.5.7.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.5.37.

6.5.32 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of UL 913(1), using copper wires 0.008 in. diameter to replace the tungsten wires when test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 120 v ac, before introduction of any test (safety) factor.

The fuses which could have interrupted interrupt the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply Terminals 1 and 3, Figure 5	No faults introduced. (+)
2	Power Supply Terminals 1 and 3, Figure 5	Short regulator MLM309K from Terminal E to B, (no fault) due to short spacings, see paragraph 6.5.10. (+)
3	Power Supply Terminal 3, Figure 5 to Ground	Short AC rectifier term from transformer Terminal X2 to ground (one fault) due to short spacings, see paragraph 6.5.10.
4	Power Supply Terminal 1 and 3, Figure 5	A 1.005 mh, 0.126 ohm coil connected in series with Terminals 1 and 3 and the test mechanism. The coil was used to simulate an unspecified field connected device.
5	Power Supply Terminals 2 and 3, Figure 5	Open range Resistor RX (one fault) and short Regulator MLM309K from Terminals B to C (no fault) due to short spacings, see paragraph 6.5.10.(+)
6	Power Supply Terminal 3, Figure 5 to Ground	Short transformer primary to secondary (one fault) and short Rectifier "X1" Terminal to "-DC" Terminal (one fault). (++)

(+) - Circuit was simulated since the test (safety) factor could not be introduced on the test sample.

(++) - This condition shorts the 120 v line circuit to the intrinsically safe Terminal 3. Assuming the use of a 120 v grounded source, arcing the intrinsically safe circuit to ground arcs the 120 v supply to ground.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revo-lutions	Results	Spark Test Mechanism Calibration Cycles Before Test	After Test
1	1	0	1.1	1.5*	Cadmium	12.36	2.85	400	No Ignition	93	70
2	2	0	1.1	1.5**	Cadmium	14.62	3.57	400	No Ignition	1	56
3	3	1	1.1	1.0	Cadmium	23.5	15.5	1	Ignition	93	-
4	4	0	1.1	1.5***	Cadmium	14.62	1.56	-	Note 1	-	-
5	5	1	1.1	1.5**	Cadmium	19.82	2.81	400	No Ignition	86	8
6	6	2	1.1	1.0	Cadmium	132	Note 2	-	Note 3	-	-

* Factor applied by decreasing the value of limiting resistance.

** Factor applied by increasing the voltage by 1.225.

*** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

Notes -

1 - Test not conducted since this circuit caused igntion of methane air mixture with a brass disc and a test (safety) factor of 1.0. See paragraph 5.5.22.

2 - Current limited only by capacity of voltage source.

3 - Test not conducted since test conditions are more severe than Test No. 3.

The results do not comply with the requirements in UL 912(1) since ignition of the methane air mixture was obtained.

6.6 GENERAL MONITORS, MODEL 420 METHANE MONITOR, ITEM 2

Product Description

6.6.1 Model 420 Methane Monitoring System, manufactured by General Monitors Inc. of Costa Mesa, California. The system consists of a Power Supply/Cutoff Relay, Serial No. 8080-4008 (Figure 6), Control Indicator Unit, Part No. 18-00-810-1 (Figure 7) and a Remote Sensing Head, Part No. 18-00-823-1 (Figure 7). The Power Supply/Cutoff Relay is intended to be mounted within an explosion-proof enclosure and has circuits to provide power to the Control Indicator Unit. The Control Indicator Unit is provided with an explosion-proof enclosure and has circuits claimed to be intrinsically safe which are connected to the Sensor Head. The Power Supply is rated 550 v, 60 Hz maximum input.

6.6.2 A complete sample system along with additional component parts were purchased through the National Mine Service Company of Nashville, Illinois, a local distributer for the equipment. The samples were subjected to the examination and tests described below.

6.6.3 Electrical schematics for the equipment are shown in Figures 6 and 7. The ground symbol used in Figure 7 is actually the circuit common. It is not grounded to the enclosure.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

ELECTRICAL COMPONENTS

6.6.4 The Part No. PM-1191 relay could not be identified as being UL Listed or Recognized.

CORROSION PROTECTION

6.6.5 The Power Supply base is a steel plate. The plate is not painted or plated to resist corrosion. This does not comply with paragraph 99 of UL 913(7). See Appendix B.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.6.6 Protective Transformer.

6.6.6.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen of copper foil between the windings, it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements for a Type 2A transformer since it is not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

6.6.7 Shunt Safety Components

6.6.7.1 The 10 ohm wire wound resistor appears to be intended as a relay coil (K1) shunt safety component. The expected failure mode for a wire wound resistor is open circuit and the resistor is not duplicated so that the assembly remains safe if one resistor becomes defective. This does not comply with paragraphs 3.13 and 5.15.

SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.6.8 Any spacing including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 6.6.33 unless the spacings are greater than or equal to those given in Table 8.1 for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being a fault.

6.6.9 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined.

6.6.10 <u>Tabulation of Electrical Spacings</u>

Fig.	Spacings From	Spacings To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
7	Printed wiring for Term 1, TB2 Control Indicator Unit, Sec. Circuit	Printed wiring for Term 6, TB2 Control Indicator Unit, Sec. Circuit	1/2 (++)	1/2 (++)	3	3
7	Printed Wiring for Pin 14, I.C. A2 Control Indicator Unit, Sec. Circuit	Printed wiring for Term 6, TB2 Control Indicator Unit, Sec Circuit	1/2 (++)	1/2 (++)	3	3
7	Printed Wiring for Term 4, TB2 Control Indicator Unit, Sec. Circuit	Printed Wiring for Term 6, TB2 Control Indicator Unit, Sec. Circuit	1/2 (++)	1/2 (++)	3	3
7	Relay Coil Circuits Terminals	Relay N.O. Contact Circuits, Line Volts	-	14 (+)	10	25
6	Relay N.C. Contact Term, Line Volts Connected to Term 3 Circuit	Relay N.C. Contact Term, Sec. Circuit Connected to Term 5 Circuit	4-1/2 (+)	10 (+)	10	25
6	Relay N.O. Contact Term, Line Volts Connected to Term 3 Circuit	Relay N.O. Contact Term, Sec. Circuit Connected to Term 5 Circuit	7 (+)	10 (+)	10	25
6	Relay Contact Wiper Term, Line Volts Connected to Term 3 Circuit	Relay Contact Wiper Term, Sec. Circuit Connected to Term 5 Circuit	6 (+)	10 (+)	10	25
6	Relay Contact Wiper, Line Volts Connected to Term 3 Circuit	Relay Contact Wiper, Sec. Circuit Connected to Term 5 Circuit	8 (+)	11 (+)	10	25
6	Relay N.C. Contact Term, Line Volts Connected to Term 3 Circuit	Relay N.C. Contact Term, Sec. Circuit Connected to 11.5 v Transformer Lead	6 (+)	10 (+)	10	25

6.6.10 Tabulation of Electrical Spacings (Cont'd)

Fig.	Spacings: From	Spacings: To	Provided, MM: Through Air	Provided, MM: Over Surface	Required, MM: Through Air	Required, MM: Over Surface
6	Relay N.O. Contact Term, Line Volts Connected to Term 3 Circuit	Relay N.O. Contact Term, Sec. Circuit Connected to 11.5 v Transformer Lead	8 (+)	10 (+)	10	25
6	Relay Contact Wiper Term, Line Volts Connected to Term 3 Circuit	Relay Contact Wiper Term, Sec. Circuit Connected to 11.5 v Transformer Lead	6 (+)	10 (+)	10	25
6	Relay Contact Wiper, Line Volts Connected to Term 3 Circuit	Relay Contact Wiper, Sec Circuit Connected to 11.5 v Transformer Lead	8 (+)	11 (+)	10	25

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

6.6.11 The application of adherent insulating material to the Control Indicator Unit printed wiring board was not uniform since some areas were not coated. The insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore cannot be relied upon in lieu of spacings in accordance with footnote b of Table 8.1.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, UL 913(1)

6.6.12 In the Power Supply, the internal wiring of the line voltage relay contact circuit is intermingled with transformer secondary conductors. This does not comply with paragraph 9.1 since positive separation is not provided between nonintrinsically safe circuits and circuits which may affect intrinsic safety.

6.6.13 The unused, uninsulated transformer primary wiring tap leads may contact transformer secondary wiring or uninsulated conductive parts of secondary circuits. This does not comply with paragraph 9.1 since positive separation is not provided between nonintrinsically safe circuits and circuits which may affect intrinsic safety.

6.6.14 The intrinsically safe wiring in the Control Indicator Unit is intermingled with wiring of other secondary circuits. This does not comply with paragraph 9.1 since positive separation is not provided between intrinsically safe circuits and nonintrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.6 AND 11.1-11.2, UL 913(1)

6.6.15 Field wiring conductors for the intrinsically safe circuits may be intermingled with field wiring conductors for line voltage circuits and uninsulated live parts of line voltage circuits since all field wiring is completed on the same terminal block. This does not comply with paragraph 10.5.

SOURCES OF IGNITION, PARAGRAPH 14.1, UL 913(1)

6.6.16 Interconnection of the Power Supply to the Control Indicator Unit is accomplished by means of a five conductor cable of which only three conductors are used. The additional conductors provided may be connected to unspecified auxiliary equipment which is not supplied with the system. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe. The auxiliary equipment should be identified so this consideration can be made during Circuit Fault Analysis. Additionally, when the auxiliary equipment is not used, the uninsulated ends of these conductors may contact uninsulated transformer primary wiring or uninsulated relay coil contact circuit wiring in the Power Supply and uninsulated intrinsically safe wiring in the Control Indicator Unit.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913(1)

6.6.17 The Power Supply and Sensor are not marked with the name of the manufacturer and a specific part number. This does not comply with paragraph 31.1. Additionally, the marking should identify the Power Supply and Sensor as part of the complete system in accordance with paragraph 31.9.

6.6.18 In the Control Indicator Unit, the intrinsically safe circuits are not identified, nor is the designation of the hazardous location in which the intrinsically safe circuits are to be used, in accordance with paragraphs 31.4, Item C and 31.4, Item F.

6.6.19 The Sensor is not marked "Intrinsically Safe," nor is it marked with the designation of the hazardous location in which it is to be used, in accordance with paragraphs 31.4, Item C and Item E.

6.6.20 The Power Supply, Control Indicator Unit and Sensor are not marked with the statement "Caution: Any substitution of components may impair intrinsic safety," or equivalent in accordance with paragraph 31.5.

6.6.21 Clear instructions are not provided concerning connections to auxiliary equipment which may affect the intrinsic safety of the whole system as required in paragraph 31.8.

6.6.22 The Power Supply/Cutoff Relay is not marked with the relay contact ratings in accordance with paragraph 31.4, Item D.

6.6.23 Instructions covering interconnection of component parts of the system should be referenced on the nameplates in accordance with paragraph 31.8.

Test Record

6.6.24 The samples and component parts of the device identified in paragraphs 6.6.1 and 6.6.2 were subjected to the following tests to determine compliance with UL 913(1).

6.6.25 INPUT-OUTPUT TEST

Test was previously conducted with acceptable results. See paragraph 5.6.17.

6.6.26 NORMAL TEMPERATURE TEST

Test was previously conducted with acceptable results. See paragraph 5.6.18.

6.6.27 UNDERVOLTAGE AND OVERVOLTAGE TEST

Test was previously conducted with acceptable results. See paragraph 5.6.19.

6.6.28 TRANSFORMER OUTPUT TEST

Test was previously conducted with acceptable results. See paragraph 5.6.20.

6.6.29 DIELECTRIC WITHSTAND TESTS

METHOD

The Monitor was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1 of UL 913(1) since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to secondary circuits	2200	No breakdown
2	Primary circuits to grounded parts	2200	No breakdown
3	Secondary circuit to grounded parts	500	No breakdown
4	Primary to relay contact circuits	2200	No breakdown
5	Relay contact circuits to secondary circuits and grounded parts	2200	No breakdown

6.6.30 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

RESULTS

Product	Coil		Direct Current Resistance, Ohms	Inductance at 1 KHz, mh
	Type	Part No.		
Control Indicator Unit	Relay	945-002	12.96	24.84

6.6.31 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformer was subjected to this test. The sample was connected to a source of supply as indicated. The secondary windings were short-circuited. The sample was operated continuously until the results noted were observed.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The result are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.1 of UL 913(1) for a Type 2A transformer since there was emission of flame.

Transformer		Rated		Test		Maximum Temperature, Degrees C		
Part No.	Type	V	Hz	V	Hz	Ambient	Core	Windings
1209-1	2A	580	60	600	60	16	102+	300+

\+ - Maximum temperature recorded before transformer burst into flame.

6.6.32 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

This was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test, paragraph 6.6.31.

6.6.33 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components) and field wiring, and short spacings in accordance with UL 913(1), were considered.

2. In the analysis, consideration was given to the following items:

A. Only the remote Sensing Head is to be located in the hazardous area. The Power Supply/Cutoff Relay is intended to be housed in an explosion-proof enclosure. The Control Indicator unit is housed in an explosion-proof enclosure.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Equipment Part No.	Component Type	Component Designation	Remarks
8080-4008	Transformer	1209-1	Note 1
18-00-810-1	Resistor	R8	Note 2

Note -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance tests, see paragraphs 6.6.31 and 6.6.32 and the construction did not meet the applicable construction requirements, see paragraph 6.6.6.1.

2. The resistor may be open-circuited during spark ignition testing since the resistor did not meet the requirements for shunt safety components, see paragraph 6.6.7.1.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.6.34 and representative components were selected for thermal ignition tests.

6.6.34 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of UL 913(1) using copper wires 0.008 in. diameter to replace the tungsten wires when test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

V, DC	Inductive Current: Current	Inductive Current: Inductor, mh
24	110	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v ac before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit	Test Point	Circuit Description
1	Control Indicator Unit, Terminals 6 and 8, TB2, Figure 7	Open Circuit Resistor R8 (one fault).
2	Control Indicator Unit, Terminals 6 and 8, TB2 Figure 7	Terminal 6, TB2 shorted to Terminal 1, TB2 (no fault) due to short spacings, see paragraph 6.6.10.
3	Control Indicator Unit, Terminals 6 and 8, TB2, Figure 7	Terminal 4, TB2 shorted to Terminal 6, TB2 (no fault), due to short spacings, see paragraph 6.6.10.
4	Control Indicator Unit, Terminal 6, Figure 7 and Ground	Terminal 6, TB2 shorted to Terminal 1, TB2 (no fault) due to short spacings, see paragraph 6.6.10 and short transformer primary to secondary (one fault). (+)

(+) - This condition shorts the 550 v ac line circuit to the intrinsically safe Terminal 6. Assuming the use of a 550 v ac grounded source, arcing the intrinsically safe circuit to ground arcs the 550 v ac supply to ground.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revo-lutions	Results	Spark Test Mechanism Calibration Cycles: Before Test	Spark Test Mechanism Calibration Cycles: After Test
1	1	1	1.1	1.5*	Cadmium	26.6	0.957	2	Ignition	5	-
2	2	0	1.1	1.5*	Cadmium	22.0	28.9	1	Ignition	5	-
3	3	0	1.1	1.5*	Cadmium	17.00	0.479	10	Ignition	7	-
4	4	1	1.1	1.0	Cadmium	660	Note 2	-	Note 1	-	-

* Factor applied by increasing input voltage.

Note -

1 - Test not conducted since test conditions are more severe than Test No. 1.

2 - Current limited only by capacity of source.

The results do not comply with the requirements in UL 913(1) since ignition of the methane air mixture was obtained.

6.6.35 Component Overload and Strand of Wire Tests were not conducted since results in paragraph 6.6.34 indicate that circuits which extend into the hazardous location are not intrinsically safe.

6.7 BENDIX METHANE DETECTION SYSTEM, PART NO. 2417032, ITEM 4

Product Description

6.7.1 Methane Monitoring System, Part No. 2417032-1000, manufactured by the Bendix Corporation, Environmental Science Division in Baltimore, Maryland. The System consists of a Control Assembly, Series 2415899, provided with an explosion-proof housing (Figures 8 and 9), a Relay Assembly, Part No. 2417030 intended to be mounted in an explosion-proof enclosure and Detector Assembly Part No. 2415905-0003. The Control Assembly incorporates the Power Converter Control and Readout Circuitry. The Control Assembly has circuits claimed to be intrinsically safe (Terminals 1, 2 and 3, Figure 9) which are connected to the Detector Assembly, claimed to be intrinsically safe. The Detector Assembly houses a sensing cell intended to sense the presence of methane in air.

6.7.2 A complete sample system along with additional component parts were purchased through the Preiser Mine Company in St. Albans, West Virginia, a distributer for the equipment in this area. The samples were subjected to the examination and tests described below.

6.7.3 Electrical schematics for the equipment are shown in Figures 8 and 9.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

GENERAL

6.7.4 The Inductors L1 and L3 are mounted to the bottom plate of the Power Converter by means of epoxy. One of the inductors was loose in the sample received. This does not comply with paragraph 26 of UL 913(7). See Appendix B.

INTERNAL WIRING

6.7.5 The wiring material used in the Control Assembly has 1/64 in. thick insulation and cannot be identified as being UL Recognized Appliance Wiring Material. Additionally there is intermingling of conductors of primary circuits and secondary circuits. This does not comply with paragraphs 148-150 of UL 913(7), which requires the use of UL Recognized wiring material with at least 1/32 in. thick insulation. See Appendix B.

ELECTRICAL COMPONENTS

6.7.6 The Power Converter and Readout Circuitry printed wiring boards could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

6.7.7 The required spacings for circuits in the transformer primary are those shown in Column 301-600 v, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those shown in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

6.7.8 The over surface spacing between the 550 v, Pin 17 on the printed wiring board and a grounded mounting screw was measured to be 9/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of 3/8 in.

6.7.9 The over surface spacing between the 550 v, Pin 18 on the printed wiring board and a grounded mounting screw was measured to be 3/16 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of 3/8 in.

6.7.10 The through air spacing between 550 v live parts of the terminal board and the enclosure were measured to be 5/16 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of 1/2 in.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.7.11 Protective Transformers.

6.7.11.1 The transformers (Coils L2, L3 and L4) employed in the device were examined to determine if they could be considered protective components. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings in each sample examined, they may be considered as having Type 2A construction. The transformers are judged not to comply with applicable construction requirements for Type 2A construction since they were not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

6.7.12 Shunt Safety Components.

6.7.12.1 The Relay K1 coil is provided with a single shunt diode (see Figure 9). The diode is mounted to the Readout Circuitry printed wiring board adjacent to the relay. The diode is not duplicated so that the assembly remains safe if one diode becomes defective. This does not comply with paragraph 5.15 and was considered as subject to fault. See Circuit Fault Analysis paragraph 6.7.34.

SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.7.13 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 6.7.34 unless the spacings are greater than or equal to those given in Table 8.1 for the specific potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.7.14 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. All of these spacings were in the Power Converter Control Assembly, Figure 8, and in the Readout Circuitry, Figure 9.

6.7.15 Tabulation of Electrical Spacings

Fig.	From	To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
9	Printed Wiring for Pin 5, I.C. U7 in readout circuitry (R.C.)	Printed Wiring for Pin 11, I.C. U7 in R.C.	1/2(++)	1/2(++)	3	3
9	Printed Wiring for Wiring Station 21 in. R.C.	Printed Wiring for Pin 9, I.C. U2 in R.C.	1/2(++)	1/2(++)	3	3
9	Printed Wiring for Wiring Station 21 in. R.C.	Printed Wiring for Pin 7, I.C. U2 in R.C.	1/2(++)	1/2(++)	3	3
9	Terminal C, Trans. Q2 in R.C.	Ground	1(+)	1(+)	3	3
9	Terminal C, Trans. Q3 in R.C.	Ground	1-1/2(+)	1-1/2(+)	3	3
9	Terminal C, Trans. Q4 in R.C.	Ground	1/2(++)	1/2(++)	3	3
9	Terminal C, Trans. Q6 in R.C.	Ground	1(+)	1(+)	3	3
9	Terminal C, Trans. Q8 in R.C.	Ground	1(+)	1(+)	3	3
9	Between all adjacent Terminals of I.C. U1		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U2		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U3		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U4		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U5		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U6		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U7		1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

6.7.15 Tabulation of Electrical Spacings (Cont'd)

Fig.	From	To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
8	Printed Wiring for Term C, Trans. Q5 in Power Converter (PC),	Printed Wiring for Term. 1A, in PC, Board A1, Secondary	6-1/2(+)	2-1/2(++)	10	25
8	Term. C, Trans. Q5 in PC, Board A1, Primary	Term. "+", Cap. C8 in PC, Board A1, Secondary	4-1/2(+)	6(++)	10	25
8	Printed Wiring for Fuse F1 in PC, Board A1, Primary	Printed Wiring for Term. 1A in PC, Board A1, Secondary	-	17(+)	10	25
8	Diode CR11 in PC, Board A2, Primary	Term. 1A in PC, Board A1 Secondary	3(++)	-	10	25
8	Printed Wiring for Term. E, Trans. Q5 in PC, Board A1, Primary	Printed Wiring for Term. 1A in PC, Board A1, Secondary	-	5-1/2(++)	10	25
8	Printed Wiring for Term. B, Trans. Q5 in PC, Board A1, Primary	Printed Wiring for Term. 1A in PC, Board A1, Secondary	-	18-1/2(+)	10	25
8	Printed Wiring for Pin 13 in PC, Board A1, Primary	Printed Wiring for Fuse F2 in PC, Board A1, Secondary	-	2-1/2(++)	10	25
8	Printed Wiring for Pin 6 in PC, Board A1, Primary	Printed Wiring for Fuse F2 in PC, Board A1, Secondary	-	3(++)	10	25
8	Term. C, Trans. Q5 in PC, Board A1, Primary	Term. 2A in PC, Board A1, Secondary	-	12-1/2(+)	10	25

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

6.7.15 Tabulation of Electrical Spacings (Cont'd)

Fig.	From	To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
8	Term. C, Trans. Q5 in PC, Board A1, Primary	Pin 19 in PC, Board A1, Secondary	5(+)	5(+)	10	25
8	Term. C, Trans. Q5 in PC, Board A1, Primary	Fuse F3 in PC, Board A1, Secondary	5-1/2(+)	5-1/2(++)	10	25
8	Pin 13 in PC, Board A1, Primary	Cap. C7 in PC, Board A1, Secondary	-	9(+)	10	25
8	Resist. R5 in PC, Board A1, Primary	Cap. C7 in PC, Board A1, Secondary	-	14(+)	10	25
8	Pin 6 in. PC, Board A1, Primary	Cap. C7 in PC, Board A1, Secondary	-	11-1/2(+)	10	25
8	Cap. C5 in PC, Board A2, Primary	Term. 2A in PC, Board A1, Secondary	6-1/2(+)	-	10	25
8	Pin 14 in PC, Board A2, Primary	Term. 1A in PC, Board A1, Secondary	6-1/2(+)	-	10	25
8	Diode CR8 in PC, Board A2, Primary	Cap. C8 in PC, Board A1, Secondary	9-1/2(+)	-	10	25
8	Term. C, Trans. Q2 in PC, Board A2, Primary	Cap. C8 in PC, Board A1, Secondary	9-1/2(+)	-	10	25
-	Relay Jumper Wire, Relay Assy.	Relay Coil Term., Relay Assy.	0(++)	0(++)	6	15

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

6.7.16 The application of adherent insulating material to the Power Converter and Readout Circuitry printed wiring boards was not uniform since some areas were not coated. Also, the insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore cannot be relied upon in lieu of spacings in accordance with footnote b of Table 8.1.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5; UL 913(1)

6.7.17 The internal intrinsically safe conductors are routed together with nonintrinsically safe conductors. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe conductors.

6.7.18 In the power cable assembly for the device, the conductors for the primary power are routed with the conductors for the relay assembly coil. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe conductors and conductors which may affect intrinsic safety.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, UL 913(1)

6.7.19 In the Relay Assembly the field wiring conductors of line voltage relay contact circuits may be intermingled with field wiring conductors, factory-installed wiring and uninsulated live parts of secondary circuits which may affect intrinsic safety since all field wiring is completed on the same terminal block. This does not comply with paragraph 10.5.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913(1)

6.7.20 The Detector and Relay Assemblies are not marked with the manufacturer's name or part numbers. This does not comply with paragraph 31.1. Additionally the marking should identify this equipment as part of the complete system in accordance with paragraph 31.9.

6.7.21 The rated current and type of replacement fuse was not marked on the Power Converter adjacent to the fuseholder for the primary fuse as required in paragraph 31.4, Item (A).

6.7.22 In the Control Assembly the intrinsically safe circuits are not identified nor is the designation of the hazardous location in which the intrinsically safe circuits are to be used, in accordance with paragraph 31.4, Item C and Item F.

6.7.23 The Detector Assembly is not marked "Intrinsically Safe" nor is it marked with the designation of the hazardous location in which it is intended to be used in accordance with paragraphs 31.4, Item C and Item E.

6.7.24 The Control and Detector Assemblies are not marked with the statement "Caution: Any substitution of components may impair intrinsic safety" or equivalent in accordance with paragraph 31.5.

6.7.25 Instructions covering interconnection of component parts of the system should be referenced on the nameplates in accordance with paragraph 31.8.

Test Record

6.7.26 The samples and component parts of the device identified in paragraphs 6.7.1 and 6.7.2 were subjected to the following tests to determine compliance with UL 913(1).

6.7.27 INPUT-OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.7.22.

6.7.28 NORMAL TEMPERATURES TEST

Test previously conducted with acceptable results, see paragraph 5.7.23.

6.7.29 UNDERVOLTAGE AND OVERVOLTAGE TEST

Test previously conducted with acceptable results, see paragraph 5.7.24.

6.7.30 DIELECTRIC WITHSTAND TESTS

METHOD

The Detector System was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1, UL 913(1), since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to secondary circuits	2200	No breakdown
2	Primary circuits to grounded parts	2200	No breakdown
3	Secondary circuit to grounded parts	500	No breakdown
4	Primary to line voltage contact circuits	2200	No breakdown
5	Contact circuits to secondary circuits and grounded parts	1600	No breakdown

6.7.31 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

RESULTS

Coil		Direct Current	Inductance at
Type	Part No.	Resistance, Ohms	1 KHz, mh
Relay	PR7DY	19.0	53.64

6.7.32 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

Samples of the protective transformers were subjected to this test. Each sample Power Converter rated 550 v ac, consisting of Coils L2, L3, and L4, was connected to a 600 v, 60 Hz source of supply at Terminals 7 and 9. The secondary windings for each coil, in turn, were shorted together until temperatures were constant. The test was repeated with the secondary winding of each coil shorted together at the same time. Each sample was operated continuously for 7 hr.

Temperatures on the coils were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.2, UL 913(1) since the temperature of the insulation on Samples L2 and L4 exceeded the allowable 65 C rise limit for Class A insulation. There was no emission of flame or molten metal.

Sample	Transformer			Test Time,	Maximum Temperature, Degrees C			
No.	Mfr.	Part No.	Type	Hr	Ambient	Core	Primary	Secondary
L2	(+)	1584123D	2A	7	21	80	96	97
L3	(+)	1584124D	2A	7	21	68	68	68
L4	(+)	1584175C	2A	7	21	114	119	140

(+) - H-H Toroidal Winding Company

6.7.33 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

METHOD

Immediately after the Protective Transformer Abnormal Operation Test, a 60 Hz potential was applied between the circuits of the Power Converter indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

System Part No.	Potential V	Test Time, Min	Results: Primary(+) to Secondary(++)	Primary to Ground	Secondary to Ground
2417032-1000	2500	1	OK	-	-
2417032-1000	1100	1	-	OK	OK

OK - No electrical breakdown.

(+) - Primary taken to be power converter Terminals 7 and 9.

(++) - Secondary taken to be power converter Terminals 1A, 2A, 3A, and 4A.

The results comply with the requirements in paragraph 22.1 of UL 913(1) since the spacings and insulation in the transformers were such as to withstand the application of the specified potential for 1 min without breakdown.

6.7.34 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring and short spacings in accordance with UL 913(1) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Detector Assembly is to be located in the hazardous area. The remaining parts of the system including Control Assembly and Relay Assembly are housed in explosion-proof enclosures.

B. From examination of the equipment, it appears that the following components are intended to be protective components.

Equipment Part No.	Component Type	Component Designation	Remarks
2415899	Transformers (Isolation Coils)	L2, L3 and L4	Note 1
2415899	Diode	5A2	Note 2

Notes -

1. The Power Converter isolation coils may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable construction requirements, see paragraph 6.7.11.1. The transformers did not meet the applicable performance test, see paragraph 6.7.32.

2. The diode may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 6.7.12.

C. In the Power Converter, the conductor marked with the conventional symbol for ground, was not grounded to the enclosure.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.7.35 and representative components were selected for thermal ignition tests.

6.7.35 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of UL 913(1), using copper wires 0.008 in. in diameter to replace the tungsten wires when test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the control assembly for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v ac before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable position so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Control Assembly Terminals 1 and 3, Figure 9	No faults introduced. (+)
2	Control Assembly Terminals 1 and 3, Figure 9	Short I.C.U3 Pin 11 to Pin 3 (one fault). (+)
3	Control Assembly Terminals 1 and 3, Figure 9	Short I.C.U3, Pins 12 to 3 (one fault) and short I.C.U1, Pins 12 to 3 (one fault).
4	Control Assembly Terminals 1 and 3, Figure 9	Short Resistor R2 (no fault), due to short spacings between wiring Station 21 to Pin 7 of I.C.U2 and Short U7, Pins 3 to 4 (no fault) due to short spacings, see paragraph 6.7.15.
5	Control Assembly Terminals 1 and 3, Figure 9	Short I.C.U1, Pin 12 to Pin 3 (one fault), and short I.C.U7, Pin 11 to Pin 4 (no fault) due to short spacing between Pin 11 to Pin 5 to 4 of U7, see paragraph 6.7.15. (+)
6	Control Assembly Terminal 3 to Ground Figure 9	Short Terminal C of Transistor Q4 to ground (no fault), due to short spacings, open Diode CR9 (one fault) and open Transistor Q4 collector (one fault).
7	Control Assembly Terminals 1 and 3, Figures 8 and 9	Short Diode CR11 to Terminal 1A (no fault) due to short spacings, and in the control assembly readout circuitry Short I.C.U1, Pin 12 to 3 (one fault) and Short I.C.U7, Pin 11 to Pin 4 (no fault) due to short spacings between Pin 11 to 5 to 4 of U7, see paragraph 6.7.15.

(+) - Circuit was simulated to enable introduction of the test (safety) factor.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	After Test
1	1	0	1.1	1.5*	Cadmium	2.37	2.85	400	No Ignition	10	2
2	2	1	1.1	1.5*	Cadmium	6.3	30.15	400	No Ignition	3	2
3	3	2	1.1	1.0	Cadmium	20.6	2.36	3	Ignition	94	-
4	4	0	1.1	1.5**	Cadmium	20.6	2.36	-	Note 1	-	-
5	5	1	1.1	1.5**	Cadmium	20.6	2.36		Note 1	-	-
6	6	2	1.1	1.0	Cadmium	-	-	-	Note 2	-	-
7	7	1	1.1	1.0	Cadmium	660 ac	Note 3	-	Note 4	-	-

* Factor applied by increasing the test current.

** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

Notes -

1. Test not conducted since this circuit is the same as that which caused ignition in Test 3, with a test (safety) factor of 1.0.

2. Test not conducted since the Readout Assembly was damaged during fault analysis.

3. Current limited only by capacity of source.

4. Test not conducted since test conditions are more severe than Test No. 3.

The results do not comply with the requirements in UL 913(1) since ignition of the methane-air mixture was obtained.

6.7.36 Strand of Wire and Component Burnout Tests were not conducted since results in paragraph 6.7.35 indicate that the circuits which extend into the hazardous location are not intrinsically safe.

6.8 APPALACHIAN, MODEL 102A METHANE MONITOR, ITEM 7

Product Description

6.8.1 Model 102A Methane Monitoring System, manufactured by Appalachian Electronic Instruments, Inc. of Ronceverte, West Virginia. The System consists of an AC Power Supply/Shutdown Relay Unit, Part No. 7163 (Figure 16), an Amplifier Readout Unit, Part No. 7158, and Detector, Part No. 7162. The AC Power Supply/Shutdown Relay Unit intended to be mounted within an explosion-proof enclosure has circuits claimed to be intrinsically safe which are connected to the Amplifier Readout Unit and Detector, each claimed to be intrinsically safe. The AC Power Supply is rated 575 v ac input maximum.

6.8.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

INTERNAL WIRING

6.8.3 The transformer primary lead wires have 1/64 in. thick insulation with an outer braid. These leads were identified as UL Recognized Appliance Wiring Material rated 105 C, 300 v maximum. The 300 v rated leads are not considered to be acceptable since one of the leads may be connected to 575 and 480 v and since all of the leads are bunched together for routing. All of the leads are required to be insulated for the maximum voltage of 600 v in accordance with paragraphs 148-150 of UL 913(7). See Appendix B.

6.8.4 The internal wiring from the transformer primary fuse to the field wiring terminal for the transformer neutral has 1/64 in. thick insulation. This lead could not be identified as UL Recognized Appliance Wiring Material. This does not comply with paragraphs 148-150 of UL 913(7), which require that this lead be insulated for the maximum voltage of 600 v. See Appendix B.

6.8.5 The internal wiring between the relay contact circuits and the field wiring terminal block has 1/64 in. thick insulation. These leads could not be identified as UL Recognized Appliance Wiring Material. It is assumed that the contact circuits are rated for the same maximum voltage as the transformer, 600 v, since the voltage rating was not provided. This does not comply with paragraphs 148-150 of UL 913(7), which require that these leads be insulated for the maximum voltage of 600 v since the contact circuits may be rated 600 v and since the conductors are routed with 600 v transformer primary conductors. See Appendix B.

ELECTRICAL COMPONENTS

6.8.6 The AC Power Supply printed wiring board could not be identified as being UL Recognized.

6.8.7 The fuseholder Cat. No. 342 72 could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

6.8.8 The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). For the purposes of measuring electrical spacings of the Shutdown Relay contact circuits, it was assumed that the relay contacts have the same voltage rating as the AC Power Supply, since the ratings were not provided. See Appendix B.

6.8.9 The through air spacing between the uninsulated, line voltage terminal on the Shutdown Relay contact circuit and the grounded metal frame was measured to be 5/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require 3/16 in. minimum. It should be noted that in the event that the relay contact circuit ratings exceed 2 kva, the through air spacing required would be 3/8 in. minimum.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.8.10 Protective Transformer.

6.8.10.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings, it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements since it was not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

6.8.11 Shunt Safety Components.

6.8.11.1 The relay coil is provided with two shunt diodes, see Figure 16. The diodes are mounted to a printed wiring board and connected to the coil with separate lead wires. The diodes are connected across the coil in such a manner that they may be disconnected from the circuit leaving the coil in the circuit. This does not comply with paragraph 5.15 and was considered as subject to fault. See Circuit Fault Analysis paragraph 6.8.32.

SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6,8.12 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 6.8.32 unless the spacings are greater than or equal to those given in Table 8.1 for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.8.13 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. These spacings were all located in the Power Supply, Figure 16.

6.8.14 Tabulation of Electrical Spacings

			Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
16	Rectifier "+" Terminal	Ground	1-1/2(+)	1-1/2(+)	3	3
16	Rectifier "+" Terminal	LM-340-12 Terminal "E"	-	1-1/2(+)	3	3
16	Primary Fuse F1	Secondary Fuse	3-1/2(+)	-	10	25
16	Relay Coil Contact Circuit	Relay Coil Circuit	7(+)	8(++)	10	25
16	Transistor TP55 Terminal "C"	Transistor TP55, Terminal "B"	1(+)	1(+)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, UL 913(1)

6.8.15 The internal wiring for the coil shunt diodes is bunched together and held with wire ties, with line voltage conductors for relay contacts, for routing. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe circuits and the secondary circuits which may affect intrinsic safety.

6.8.16 The internal wiring for the neutral wire in the transformer primary circuit is routed with transformer secondary conductors. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe circuits and secondary circuits which may affect intrinsic safety.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, UL 913(1)

6.8.17 The wiring terminals for intrinsically safe and nonintrinsically safe circuits are separated by a distance of at least 50 mm. This complies with the requirements for panel installed equipment. However, clear installation instructions regarding wire routing and field connections are not provided. This does not comply with paragraph 11.1.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913(1)

6.8.18 In the Power Supply the intrinsically safe circuits are not identified nor is the designation of the hazardous location in which the intrinsically safe circuits are to be used in accordance with paragraphs 31.4, Item C and Item F.

6.8.19 The Amplifier Readout Unit and the Detector are not marked "Intrinsically Safe" nor are they marked with the designation of the hazardous location in which they are intended to be used in accordance with paragraphs 31.4, Item C and Item E.

6.8.20 The Power Supply, Amplifier Readout Unit and Detector are not marked with the statement "Caution: Any substitution of components may impair intrinsic safety" or equivalent in accordance with paragraph 31.5.

6.8.21 Instructions covering interconnection of component parts and the system should be referenced on the nameplates in accordance with paragraph 31.8.

6.8.22 The Power Supply was not marked with the Shutdown Relay contact ratings as required in paragraph 31.4, Item D.

Test Record

6.8.23 The samples and component parts of the device identified in paragraphs 6.8.1 and 6.8.2 were subjected to the following tests to determine compliance with UL 913(1).

6.8.24 INPUT-OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.8.18.

6.8.25 NORMAL TEMPERATURE TEST

Test previously conducted with acceptable results, see paragraph 5.8.19.

6.8.26 UNDERVOLTAGE AND OVERVOLTAGE TEST

Test previously conducted with acceptable results, see paragraph 5.8.20.

6.8.27 TRANSFORMER OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.8.21.

6.8.28 DIELECTRIC WITHSTAND TESTS

METHOD

The Monitoring System was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1 of UL 912(1) since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to secondary circuits	2200	No breakdown
2	Primary circuits to grounded parts	2200	No breakdown
3	Secondary circuit to grounded parts	500	No breakdown
4	Primary to line voltage contact circuits	2200	No breakdown
5	Line voltage contact circuits to secondary circuits and grounded parts	1500	No breakdown

6.8.29 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

Coil		Direct Current	Inductance at
Type	Part No.	Resistance, Ohms	1 KHz, mh
Relay	99BX-8	74	231.4

6.8.30 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformer was subjected to this test. The sample was connected to a source of supply as indicated. The secondary winding was short-circuited. The sample was operated continuously for 7 hr.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.1 of UL 913(1) since the temperature of the transformer insulation exceeded the allowable 65 C rise limit for Class A insulation. There was no emission of flame or molten metal.

Transformer			Rated		Test		Test Time,	Maximum Temperature Degrees C			
Mfr.	Part No.	Type	V	Hz	V	Hz	Hr	Ambient	Core	Pri	Sec
Raeco Inc.	XD-690A	2A	575	60	600	60	3	21	87	300	265

6.8.31 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

METHOD

Immediately after the Protective Transformer Abnormal Operation Test, a 60 Hz potential was applied between circuits indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min unless a breakdown occurred sooner.

Transformer		Potential,	Test Time,	Results		
Mfr.	Part No.	V	Min	Pri to Sec	Pri to Gnd	Sec to Gnd
Raeco Inc.	XD-690A	2500	-	450 (+)	-	-
Raeco Inc.	XD-690A	1200	1	-	OK	OK

(+) - Breakdown.

OK - No electrical breakdown.

The results do not comply with the requirements in paragraph 22.1 of UL 913(1) since the transformers did not withstand the application of the specified potential for 1 min without breakdown.

6.8.32 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous indepandant faults of components (except protective components), field wiring and short spacings in accordance with the Standard UL 913(1) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Amplifier Readout Unit and Detector are to be located in the hazardous area. The remaining part of the system (associated equipment), the AC Power Supply/Shutdown Relay Unit is intended to be housed in an explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Equipment Part No.	Component Type	Component Designation	Remarks
7163, Power Supply	Transformer	DX-690A	Note 1
7163, Power Supply	Diodes	1N4937	Note 2

Notes -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable construction requirements, see paragraph 6.8.10 The transformer did not meet the applicable performance test, see paragraph 6.8.30.

2. The diodes may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 6.8.11.1.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.8.33 and representative components were selected for thermal ignition tests.

6.8.33 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of the Standard UL 913(1) using copper wires 0.008 in. diameter to replace the tungsten wires when test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply Terminals 1 and 3, Figure 16	No faults introduced. (+)
2	Power Supply Terminals 1 and 3, Figure 16	Short regulator LM-340-12 from B to E (one fault).
3	Power Supply Terminals 1 and 3, Figure 16	Short regulator LM-340-15 from B to E (one fault).
4	Power Supply Terminals 1 and 3, Figure 16	Short rectifier "+" term to regulator LM-340-12 Terminal E (one fault) due to short spacings, see paragraph 6.8.14.
5	Power Supply Terminal 3 and Ground, Figure 16	Short rectifier "+" term to ground (one fault) due to short spacings, see paragraph 6.8.14.
6	Power Supply Terminal 3 and Ground, Figure 16	Short transformer primary to secondary (one fault) due to short spacings, see paragraph 6.8.14.
7	Power Supply Terminal 1 and Ground, Figure 16	Short relay contact circuit to coil (no fault) due to short spacings, see paragraph 6.8.14.
8	Power Supply Terminals 2 and 3, Figure 16	Short rectifier "+" term to regulator LM-340-12 Terminal E (one fault) short transistor TP55C to B (one fault), both due to short spacings, see paragraph 6.8.14 and open one coil shunt diode (no fault).

(+) - Circuit was simulated to introduce test (safety) factor.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	After Test
1	1	0	1.1	1.5*	Cadmium	12.20	3.26	400	No Ignition	20	1
2	2	1	1.1	1.5**	Cadmium	15.43	0.31	-	Note 1	-	-
3	3	1	1.1	1.5**	Cadmium	12.15	0.55	-	Note 1	-	-
4	4	1	1.1	1.5	Cadmium	-	-	-	Note 2	-	-
5	5	1	1.1	1.5	Cadmium	-	-	-	Note 2	-	-
6	6	1	1.1	1.0	Cadmium	660	Note 3	-	Note 2	-	-
7	7	0	1.1	1.0	Cadmium	660	Note 3	-	Note 2	-	-
8	8	2	1.1	1.0	Cadmium	-	-	-	Note 2	-	-

* Factor applied by increasing the value of test current.

** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0, see paragraph 5.8.25.

2. This test was not conducted since test conditions are more severe than Test Nos. 2 and 3.

3. Current limited by capacity of source.

The results do not comply with the requirements in UL 913(1) since ignition of the methane air mixture was obtained.

6.8.34 Component Overload, Transistor Thermal Runaway, Protective Diode Abnormal, and Strand of Wire Tests were not conducted since results in paragraph 6.8.33 indicate that the circuits which extend into the hazardous location are not intrinsically safe.

6.9 BACHARACH, MINNIE METHANE MONITORING SYSTEM, ITEM 6

Product Description

6.9.1 Minnie Monitor System, manufactured by the Bacharach Instrument Company, Division of AMBAC Industries, Inc. of Pittsburgh, Pennsylvania. The System Part No. 23-7582 consists of an AC Power Supply, Part No. 23-7282 (Figure 10), a Readout Enclosure Assembly, Part No. 23-7298, a Detector Head Assembly, Part No. 23-7288 and a Power Cutoff Relay, Part No. 04-5196 (Figure 11). The AC Power Supply and Power Cutoff Relay are mounted together in an explosion-proof housing. The Power Supply has circuits claimed to be intrinsically safe which are connected to the Readout Enclosure Assembly, and Detector Head Assembly each claimed to be intrinsically safe. The Power Supply is rated 550 v, 60 Hz input, 4 v dc output.

6.9.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

6.9.3 Electrical schematics for the equipment are shown in Figures 10 and 11.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

INTERNAL WIRING

6.9.4 The internal wiring of the Power Supply has 1/64 in. thick insulation and could not be identified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148 and 149 of UL 913(7), which requires the use of UL Recognized wiring having at least 1/32 in. thick insulation. See Appendix B.

ELECTRICAL COMPONENTS

6.9.5 The printed wiring board employed in the Power Supply could not be identified as being UL Recognized.

6.9.6 The Part No. PR80060-1 relay could not be identified as being UL Listed or Recognized.

ELECTRICAL SPACINGS

6.9.7 The required spacings for circuits in the transformer primary are those shown in 301-600 v, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those shown in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

6.9.8 The through air spacing between 550 v terminal on the printed wiring board and the enclosure was measured to be 15/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/2 in.

6.9.9 The over surface spacing on the printed wiring board of the power supply between the uninsulated soldered terminal connections for the 550 v and the 480 v line voltage connections was measured to be 5/32 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

6.9.10 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered terminal connections for the 480 v and the 440 v line voltage connections was measured to be 3/16 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

6.9.11 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered terminal connections for the 440 v and the 240 v line voltage connections was measured to be 3/16 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.9.12 Protective Transformer.

6.9.12.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is a grounded screen between the windings, it may be considered as having Type 2B construction. The transformer is judged not to comply with the applicable construction requirements for Type 2B transformers since only one and not two grounding leads are provided (paragraph 5.9B-2) and since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg.

6.9.12.2 The fuses provided in the supply circuit, one in each leg, are interchangeable with fuses having a higher ampere rating. This does not comply with paragraph 5.3 which requires the use of noninterchangeable fuses only.

6.9.12.3 The grounding lead provided was determined to be No. 26 Awg, therefore a special short circuit test is required to determine that the lead can withstand without damage, the current that flows before the fuse operates. The fuses intended to be used with the device are rated 2 amp. The type of fuse used can be interchanged with a fuse having a rating of up to 30 amp. The short circuit test was not conducted since the device was not intended for use with a 30 amp fuse, which would have been used for the test.

6.9.12.4 The Type 2B transformer does not require a Protective Transformer Abnormal Operation Test. A Type 2B transformer which complies with all the construction features except is provided with only one grounding lead and is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction. Transformers having Type 3 constructions are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted as described in paragraph 6.9.35.

6.9.13 Shunt Safety Components.

6.9.13.1 The relay coil is provided with two shunt diodes, connected back-to-back in series (see Figure 11). The diodes are connected directly across the coil terminals with closed loop crimp on connectors. The diodes are not duplicated so that the assembly remains safe if one diode becomes defective (open circuit). This does not comply with paragraph 5.15 and was considered as subject to fault. See Circuit Fault Analysis paragraph 6.9.38.

SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.9.14 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 6.9.38 unless the spacings are greater than or equal to those given in Table 8.1 for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.9.15 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. These spacings were on the Power Supply printed wiring board, Figure 10 and on the Readout Enclosure printed wiring board, Figure 11.

6.9.16 Tabulation of Electrical Spacings

Fig.	Spacings		Provided, MM		Required, MM	
	From	To	Through Air	Over Surface	Through Air	Over Surface
10	Primary Terminal 6	Transistor Q1, Terminal C, Secondary	-	10-1/2(+)	10	25
10	Primary Terminal 1	Transistor Q1, Terminal C, Secondary	-	12(+)	10	25
10	Primary Terminal 5	Transistor Q1, Terminal C, Secondary	2(++)	2(++)	8	18
10	Primary Terminal 4	Transistor Q1, Terminal C, Secondary	7(+)	7(+)	8	18
10	Primary Terminal 3	Transistor Q1, Terminal C, Secondary	5(+)	5(+)	6	10
10	Transistor Q1, Terminal C, Secondary	Ground	1/2(++)	1/2(++)	3	3
10	Transistor Q1, Terminal E, Secondary	"+" 4 V DC Output Terminal Red, Intrinsically Safe	1-1/2(+)	1-1/2(+)	3	3
10	Transistor Q1, Terminal C, Secondary	Transistor Q1, Terminal E, Secondary	1/2(++)	1/2(++)	3	3
10	Transistor Q1, Terminal C, Secondary	Transistor Q1, Terminal B, Secondary	1/2(++)	1/2(++)	3	3
11	Terminal 5A, Readout Enclosure (R.E.)	Pin 2 on Chip A, R.E.	1/2(++)	1/2(++)	3	3
11	Pin 2 on Chip A, R.E.	Pin 13 on Chip A, R.E.	1/2(++)	1/2(++)	3	3
11	Pin 13 on Chip A, R.E.	Pin 15 on Chip A, R.E.	1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

6.9.23 The type of replacement fuse was not marked on the fuse block adjacent to the fuseholders as required in paragraph 31.4, Item A.

6.9.24 In the Power Supply the intrinsically safe circuits are not identified nor is the designation of the hazardous location in which the intrinsically safe circuits are to be used, in accordance with paragraphs 31.4, Item C and Item F.

6.9.25 The Readout Enclosure and Detector are not marked "Intrinsically Safe" nor are they marked with the designation of the hazardous location in which they are intended to be used in accordance with paragraphs 31.4, Item C and Item E.

6.9.26 The Power Supply Readout Enclosure and Detector are not marked with the statement "Caution: Any substitution of components may impair intrinsic safety" or equivalent in accordance with paragraph 31.5.

6.9.27 Clear instructions are not provided concerning connections to remote auxiliary recorder which may affect intrinsic safety of the whole system. Also instructions covering interconnection of component parts of the system were not referenced on the nameplates in accordance with paragraph 31.8.

Test Record

6.9.28 The samples and component parts of the device identified in paragraphs 6.9.1 and 6.9.2 were subjected to the following tests to determine compliance with UL 913(1).

6.9.29 INPUT-OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.9.22.

6.9.30 NORMAL TEMPERATURE TEST

Test previously conducted with acceptable results, see paragraph 5.9.23.

6.9.31 UNDERVOLTAGE AND OVERVOLTAGE TEST

Test previously conducted with acceptable results, see paragraph 5.9.24.

6.9.32 TRANSFORMER OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.9.25.

6.9.33 DIELECTRIC WITHSTAND TESTS

METHOD

The Monitor System was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1, UL 913(1), since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to Secondary Circuits	2200	No breakdown
2	Primary Circuits to Grounded Parts	1250	No breakdown
3	Secondary Circuit to Grounded Parts	500	No breakdown
4	Primary to Line Voltage Contact Circuits	2200	No breakdown
5	Line Voltage Contact Circuits to Secondary Circuits and Grounded Parts	1500	No breakdown

6.9.34 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

RESULTS

Product Part No.	Coil Type	Coil Part No.	Direct Current Resistance, Ohms	Inductance at 1 KHz, mh
23-7263	Relay	04-5196	14.48	49.12
23-7298	Meter	23-1472	55.70	2.33

6.9.35 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformer was subjected to this test. The sample was connected to a source of supply as indicated. The secondary winding was short-circuited. Each sample was operated continuously until the results noted were observed.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.3 of UL 913(1) since there was evidence of emission of flame.

Transformer			Rated		Test		Test Time,	Maximum Temperature, Degrees C			
Mfr.	P/N	Type	V	Hz	V	Hz	Min	Ambient	Core	Winding	Enclosure
GEN Magnetics	211C	3	550	60	600	60	6-1/2	22	115(+)	232(+)	33

(+) - Temperatures measured before emission of heavy smoke from enclosure. Charring of transformer wrap and spattering of varnish noted after test were typical of constructions which burst into flame. Because of enclosure, flames, if any, could not be seen.

6.9.36 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

This test was not conducted since the transformer did not comply with the performance requirements of Abnormal Operation Test, paragraph 6.9.35.

6.9.37 PROTECTIVE DIODE ABNORMAL TESTS

METHOD

The diode was connected to a variable direct current source of supply. Then the current was adjusted to equal that which would exist if the diode short-circuited in the circuit under consideration. The test was continued for 7 hr.

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraph 5.16 of UL 913(1) since the diodes was able to carry the test current without opening.

Diode		Rated		Current, ma		Ambient Temperature	Test Time,	
Mfg.	Type	V	W	Short Circuit	Test	Degrees C	Hr	Results
Motorola	1N5341	6.5	5	1.8	1.8	22	7	Diode operated properly.

6.9.38 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring, and short spacings in accordance with the Standard UL 913(1) were considered.

2. In the analysis, consideration was given to the following items:

A. The Readout Enclosure Assembly and Detector Head Assembly are to be located in the hazardous area. The AC Power Supply and Power Cutoff Relay are housed in an explosion-proof enclosure

B. From examination of the equipment it appears that the following components are intended to be protective components:

Equipment Part No.	Component Type	Component Designation	Remarks
22-7282	Transformer	General Magnetics Part No. 211C	Note 1
04-5196	Diode	1N5341	Note 2

Notes -

1. The transformer may be short-circuited primary to secondary during spark ignition testing since it did not meet the applicable performance test. See paragraphs 6.9.35 and 6.9.36. The transformer did not meet the applicable construction requirements as shown in paragraph 6.9.12.1.

2. The shunt diodes may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 6.9.13.1. The diode did meet the applicable performance test, see paragraph 6.9.37.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.9.39 and representative components selected for thermal ignition tests.

6.9.39 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of the Standard UL 913(1) using copper wires 0.008 in. in diameter to replace the tungsten wires when test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the device for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intronsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply Terminals Red and Orange, Figure 10	No faults introduced. (+)
2	Power Supply Terminals Red and Orange, Figure 10	Open anode on Q3 (one fault).
3	Power Supply Terminal Orange, Figure 10 to Ground	Short transistor Terminal C to ground (no fault) due to short spacings, see paragraph 6.9.16.
4	Power Supply Terminal Red, Figure 10 to Ground	Short transformer Terminal 6 to Transistor Q1, Terminal C (one fault), short Transistor Q1, Terminal C to Terminal E (no fault) and short Resistor R7 (no fault) all due to short spacings, see paragraph 6.9.16.

(+) - Circuit was simulated due to damage sustained to power supply during fault analysis.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	Spark Test Mechanism Calibration Cycles After Test
1	1	0	1.1	1.5*	Cadmium	4.28	1.05	400	No Ignition	43	30
2	2	1	1.1	1.5**	Cadmium	23.8	14.52	-	Note 1	-	-
3	3	1	1.1	1.5**	Cadmium	25.5	20	-	Note 2	-	-
4	4	1	1.1	1.0	Cadmium	660	Note 3	-	Note 2	-	-

* Factor applied by decreasing the amount of limiting resistance.

** Since this circuit was not tested the open circuit volts and short circuit current indicated do not reflect the addition of a test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0, see paragraph 5.9.29.

2. Test not conducted since test conditions are more severe than Test No. 2.

3. Current limited only by capacity of source.

The results do not comply with the requirements in UL 913(1) since ignition of the methane air mixture was obtained.

6.9.40 Component Burnout, Transistor Thermal Runaway, and Strand of Wire Tests were not conducted since results in paragraph 6.9.39 indicate that circuits which extend into the hazardous location are not intrinsically safe.

6.10 BACHARACH, LOW PROFILE METHANOMETER, ITEM 3

Product Description

6.10.1 Methane Monitoring System, Part No. 23-7167, manufactured by the Bacharach Instrument Company, Division of AMBAC Industries, Inc. of Pittsburgh, Pennsylvania. The System consists of a Control Housing, a Remote Meter Housing, Code 23-7157, a Detector Head Assembly, Code 23-7141, and a Power Cutoff Relay, Code 23-1378. The Control Housing incorporates the Power Supply, Code 23-7259 (Figure 12) and the Control Chassis, Code 23-7154 (Figure 13) and is supplied with an explosion-proof enclosure. The Control Housing has circuits, claimed to be intrinsically safe (Terminals R, C and A, Figure 13) which are connected to the Detector Head Assembly claimed to be intrinsically safe. The Remote Meter Housing is provided with an explosion-proof enclosure and is supplied by circuits of the Control Housing. The Power Cutoff Relay is not provided with an enclosure but is intended to be mounted in the mining machine contactor case.

6.10.2 A complete sample system along with additional component parts were purchased from the manufacturer, since a distributer for this device is not available in this area, and were subjected to the examination and tests described below.

6.10.3 Electrical schematics for the equipment are shown in Figures 12 and 13. The Symbol "grd" used in Figure 13 is actually a circuit common. It is not grounded to the enclosure.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

INTERNAL WIRING

6.10.4 The internal wiring of the Power Supply has 1/64 in. thick insulation and could not be identified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148 and 149 of UL 913(7), which require the use of UL Recognized wiring having at least 1/32 in. thick insulation. See Appendix B.

ELECTRICAL COMPONENTS

6.10.5 The Part No. PR-80060-1 relay could not be identified as being UL Listed or Recognized.

6.10.6 The Control Chassis printed wiring board Nos. 23-1987-3 and 23-1245E could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

6.10.7 The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

6.10.8 The Power Supply capacitor is secured in place by a metal bracket, the use of which does not prevent movement along the major axis of the capacitor. The through air electrical spacing between an uninsulated capacitor terminal and an input terminal on the rectifier is reduced to zero with the capacitor in its most unfavorable position. This does not comply with paragraph 196 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.10.9 Protective Transformer.

6.10.9.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is a grounded screen between the windings, it may be considered as having Type 2B construction. The transformer is judged not to comply with the applicable construction requirements for Type 2B transformers since the screen is placed between the windings, but the splices and crossover leads are not included (paragraph 5.9B), since only one and not two grounding leads are provided (paragraph 5.9B-2) and since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg.

6.19.9.2 The transformer primary circuit is provided with a single fuse on the ungrounded side of the line voltage source. If the common side of the line voltage source intended for connection to the power supply is ungrounded this construction does not comply with the requirements in paragraph 5.3 which requires a fuse in each ungrounded conductor.

6.10.9.3 The fuse described in paragraph 6.10.9.2 is interchangeable with fuses having a higher ampere rating. This does not comply with paragraph 5.3 which requires the use of noninterchangeable fuses only.

6.10.9.4 The thickness of the copper foil grounding screen was measured to be 0.003 in. Therefore a special short circuit test is required to determine that in the event of a short circuit between any winding and the screen the screen will withstand, without breakdown, the current that flows until the fuse operates. This test would not be required if the copper foil thickness was at least 0.005 in. The fuses intended to be used with the device range from 0.4 to 1 amp depending on which transformer voltage tap is used. The type of fuse used can be interchanged with a fuse having a rating of up to 30 amp. The short circuit test was not conducted since the device was not intended for use with a 30 amp fuse, which would have been used for the test.

6.10.9.5 The Type 2B transformer does not require a Protective Transformer Abnormal Operation Test. A Type 2B transformer which complies with all the construction features except is provided with only one grounding lead and is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction. Transformers having Type 3 construction are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted as described in paragraph 6.10.30.

SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.10.10 Any spacing including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 6.10.32, unless the spacings are greater than or equal to those given in Table 8.1 for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.10.11 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. All of these spacings were on the Control Chassis Board A1, Figure 13 and in the Power Supply, Figure 12.

6.10.12 Tabulation of Electrical Spacings

	Spacings		Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
13	Transistor Q21 "C" Terminal	Ground	1/2(++)	1/2(++)	3	3
13	Transistor Q21 "C" Terminal	Transistor Q21 "E" Terminal	1/2(++)	1/2(++)	3	3
13	Transistor Q21 "C" Terminal	Transistor Q21 "B" Terminal	1/2(++)	1/2(++)	3	3
13	Terminal V Plus	Terminal 6	2-1/2(+)	2-1/2(+)	3	3
13	Terminal V Plus	Transistor Q21 "B" Terminal	1/2(++)	1/2(++)	3	3
13	Terminal V Plus	Terminal C Plus	1/2(++)	1/2(++)	3	3
13	Terminal V Plus	Terminal PX	1/2(++)	1/2(++)	3	3
13	Terminal PX	Terminal C Plus at R21	1/2(++)	1/2(++)	3	3
13	Terminal 6 at Component A1	Terminal C Plus at Terminals 1 and 2 at Component A1	1/2(++)	1/2(++)	3	3
13	Terminal C Plus	Terminal 5	1/2(++)	1/2(++)	3	3
13	Terminal R	Resistor R6 at R5	1(+)	1(+)	3	3
13	Terminal R	Resistor R9 at R8	1/2(++)	1/2(++)	3	3
12	Wiring Connection No. 2 Primary	Wiring Connection No. 3 Secondary	5(+)	5(++)	10	25

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

6.10.13 The application of adherent insulating material to the control chassis printed wiring boards was not uniform since some areas were not coated. Also the insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore cannot be relied upon in lieu of spacings in accordance with footnote b of Table 8.1.

6.10.14 The control chassis printed wiring boards were provided with an adhesive-backed sponge rubber material approximately 1/8 in. thick attached to the under side of the boards. This construction is not considered as suitable to provide spacings since the insulating material's equivalency to epoxy could not be determined and since this construction may result in air pockets around the printed wiring conductors.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-915, UL 913(1)

6.10.15 In the Control Chassis, the intrinsically safe wiring is intermingled with nonintrinsically safe wiring. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

6.10.16 In the Power Supply the wiring for the Power Cutoff Relay coil is intermingled with the wiring for the transformer primary. This does not comply with paragraph 9.1 since positive separation is not provided between the circuits which may affect intrinsic safety and nonintrinsically safe circuits.

6.10.17 In the cable provided for interconnection of the Control Housing and the transformer power source and Power Cutoff Relay the conductors are bunched together. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe wiring and wiring which may affect intrinsic safety.

Marking

DETAILS PARAGRAPHS 31.1-31.14, UL 913(1)

6.10.18 The Detector Head Assembly is not marked with the manufacturer's name or part number. The Power Cutoff Relay is not marked with the manufacturer's name. The part number on the Relay base does not match the number in the manufacturer's instructions. This does not comply with paragraph 31.1. Additionally the marking should identify the assembly as part of the complete system in accordance with paragraph 31.9.

6.10.19 The rated current and type of replacement fuse to be used was not marked adjacent to the fuseholder as required in paragraph 31.4, Item A.

6.10.20 In the Control Housing the intrinsically safe circuits are not identified nor is the designation of the hazardous location in which the intrinsically safe circuits are to be used, in accordance with paragraphs 31.4, Item C and Item F.

6.10.21 The Detector Head Assembly is not marked "Intrinsically Safe" nor is it marked with the designation of the hazardous location in which it is intended to be used in accordance with paragraphs 31.4, Item C and Item E.

6.10.22 The Control Housing, Remote Meter Housing, Detector Head Assembly and Power Cutoff Relay are not marked with the statement: "Caution: Any substitution of components may impair intrinsic safety," or equivalent in accordance with paragraphs 31.5 and 31.14.

6.10.23 Instructions covering interconnection of component parts of the system should be referenced on the nameplates in accordance with paragraph 31.8.

Test Record

6.10.24 The samples and component parts of the device identified in paragraphs 6.10.1 and 6.10.2 were subjected to the following tests.

6.10.25 INPUT-OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.10.18.

6.10.26 NORMAL TEMPERATURE TEST

Test previously conducted with acceptable results, see paragraph 5.10.19.

6.10.27 UNDERVOLTAGE AND OVERVOLTAGE TEST

Test previously conducted with acceptable results, see paragraph 5.10.20.

6.10.28 TRANSFORMER OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.10.22.

6.10.29 DIELECTRIC WITHSTAND TESTS

METHOD

The Monitoring System was subjected to these tests while in a well heated condition. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1, UL 913(1) since the spacing and insulation in this device were such as to withstand the application of the specified potential for 1 min without breakdown.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to Secondary Circuits	2200	No breakdown
2	Primary Circuits to Grounded Parts	2200	No breakdown
3	Secondary Circuit to Grounded Parts	500	No breakdown
4	Primary to Line Voltage Contact Circuits	2200	No breakdown
5	Line Voltage Contact Circuits to Secondary Circuits and Grounded Parts	2200	No breakdown

6.10.30 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformer was subjected to this test. The sample was connected to a source of supply as indicated. The secondary winding was short-circuited. The sample was operated continuously until the results noted were observed.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.3 of UL 913(1) since there was evidence of emission of flame.

Transformer		Rated		Test		Test Time,	Maximum Temperature, Degrees C			
Part No.	Type	V	Hz	V	Hz	Min	Ambient	Core	Primary	Secondary
23-1294	3	550	60	600	60	10	21	103(+)	288(+)	300(+)

(+) - Maximum temperature recorded before emission of heavy smoke from enclosure. Charring of transformer wrap and spattering of varnish noted after test, were typical of constructions which burst into flame. Because of enclosure, flames, if any, could not be seen.

6.10.31 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

This test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test, see paragraph 6.10.30.

6.10.32 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring and short spacings in accordance with the Standard UL 913(1) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Detector Head Assembly is to be located in the hazardous area. The remaining parts of the system (associated equipment), including Control Housing, Remote Meter Housing, and Power Cutoff Relay are intended to be housed in explosion-proof enclosures.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Equipment Code No.	Component Type	Component Designation	Remarks
23-7259	Transformer	23-1294	Note 1

Note -

1. The transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance test, see paragraph 6.10.30. The transformer was judged not to comply with applicable construction requirements as indicated in paragraph 6.10.9.2.

C. In the Control Chassis, the conductor marked "gnd" (connected to the secondary of the power supply) was not grounded to the enclosure.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.10.33 and representative components were selected for thermal ignition tests.

6.10.33 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of the Standard UL 913 (1), using copper wires 0.008 in. in diameter to replace the tungsten wires when the test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

V, DC	Inductive Circuit	
	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the device for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Control Housing Terminals R and A, Figure 13	No faults introduced. (+)
2	Control Housing Terminals R and A, Figure 13	Short Transistor Q21, Terminal C to Terminal E (no fault) due to short spacings, see paragraph 6.10.12 above. (+)
3	Control Housing Terminals R and A, Figure 13	Short L.C. A1, Pin 8 to Pin 1 (one fault). (+)
4	Control Housing Terminal A, Figure 13 to Ground	Short Transistor Q21, Terminal C to ground (no fault) due to short spacings, see paragraph 6.10.12.
5	Control Housing Terminal R and A, Figure 13	Short Terminal V plus to Terminal 6 (one fault) and Terminal R to Resistor R9 at R8 (no fault) all due to short spacings, see paragraph 6.10.12.
6	Control Housing Terminals R and A, Figure 13	Short Terminal V plus to Terminal C plus (no fault) Terminal C plus to Terminal PX to Terminal PY (no fault) all due to short spacings, see paragraph 6.10.12.
7	Control Housing Terminals R and A, Figure 13	Short Terminal V plus to Terminal PX (no fault) and Terminal PX to Terminal PY (no fault) all due to short spacings, see paragraph 6.10.12.
8	Control Housing Terminals R and A, Figure 13	Short Terminal V plus to Terminal C plus (no fault) Terminal C plus to Terminal 5 (no fault), and Terminal R to Resistor R6 at R5 (one fault) all due to spacings, see paragraph 6.10.12.
9	Control Housing Terminal A, Figure 13 to Ground	Short transformer primary to secondary (one fault) and short rectifier in power supply to "-" dc terminal (one fault).

(+) - The circuit was simulated due to damage sustained to control chasis during fault analysis.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	Spark Test Mechanism Calibration Cycles After Test
1	1	0	1.1	1.5*	Cadmium	4.08	1.80	400	No Ignition	72	43
2	2	0	1.1	1.5*	Cadmium	15.47	4.40	400	No Ignition	5	5
3	3	1	1.1	1.5**	Cadmium	23.50	7.3	-	Note 1	-	-
4	4	0	1.1	1.5**	Cadmium	23.50	15.6	-	Note 2	-	-
5	5	1	1.1	1.5**	Cadmium	23.50	15.6	-	Note 2	-	-
6	6	0	1.1	1.5**	Cadmium	23.50	15.6	-	Note 2	-	-
7	7	0	1.1	1.5**	Cadmium	23.50	15.6	-	Note 2	-	-
8	8	1	1.1	1.5**	Cadmium	23.50	15.6	-	Note 2	-	-
9	9	2	1.1	1.0	Cadmium	660	Note 3	-	Note 2	-	-

* Factor applied by decreasing the amount of limiting resistance.

** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0, see paragraph 5.10.24.

2. Test not conducted since test conditions are more severe than Test No. 3.

3. Current limited only by capacity of source.

The results do not comply with the requirements in UL 913(1) since ignition of the methane air mixture was obtained.

6.10.34 Strand of Wire and Component Burnout Tests were not conducted since results in paragraph 6.10.33 indicate that the circuits which extend into the hazardous location are not intrinsically safe.

6.11 BERTEA, VALVE CONTROL SYSTEM, ITEM 9

Product Description

6.11.1 Intrinsically Safe Valve Control System, for control of electro hydraulic valves, manufactured by Bertea Corporation, Industrial Products Division of Costa Mesa, California. The System consists of an AC Power Supply, Part No. 261861 (Figure 14), Sixteen Pilot Valve Assemblies, Part No. 234912, Sixteen Hand Controllers, Part No. 26436039, two Resistor Terminal Boards, Part No. 2618201 and a Terminal Board, Part No. 261814-1. Interconnection of the system components is depicted schematically in Figure 15. The AC Power Supply, intended to be mounted within an explosion-proof enclosure, has circuits claimed to be intrinsically safe which are connected to the Terminal Boards, Hand Controllers and Pilot Valves. The Hand Controllers and Pilot Valves are claimed to be intrinsically safe. The AC Power Supply is rated 575 v ac, 60 Hz input.

6.11.2 A complete sample of the system along with additional component parts were purchased through Weldon Engineering Company of Des Plaines, Illinois, a local distributor for the equipment. The samples were subjected to the examination and tests described below.

6.11.3 Electrical schematics and instructions covering installation of the system were not supplied as part of the equipment. They were provided upon request. The electrical schematics are shown in Figures 14 and 15.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.4, UL 913(1)

INTERNAL WIRING

6.11.4 The transformer primary leads all have 1/32 in. thick insulation. Seven of the ten leads provided could not be identified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148 and 149 of UL 913(7). See Appendix B.

6.11.5 The internal wiring between the transformer primary circuit field wiring terminals and the transformer primary lead wire connectors has 1/64 in. thick insulation and could not be identified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148-150 of UL 913(7), which requires the use of UL Recognized Wiring having at least 1/32 in. thick insulation. See Appendix B.

ELECTRICAL COMPONENTS

6.11.6 The printed wiring boards employed in the Power Supply could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

6.11.7 The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

6.11.8 The through air spacing between uninsulated 575 v, soldered connector on the terminal board and a grounded metal mounting leg for the terminal board was measured to be 3/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require at least 3/16 in.

6.11.9 The over surface spacing between foil conductor on printed circuit board at "+6 volt" transformer secondary pin No. 1 and pin No. 2 was measured to be 1/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of opposite polarity.

6.11.10 The over surface spacing between foil conductors on printed circuit board at "+6 volt" transformer secondary pin No. 3 and pin No. 2 was measured to be less than 1/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of opposite polarity.

6.11.11 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2 and "-6 volts" transformer secondary pin No. 3 at Diode CR4 was measured to be less than 1/32 in. at two places. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

6.11.12 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 1 and "-6 volts" transformer secondary pin Nos. 2 and 3 were measured to be 1/32 in. and just over 1/32 in., respectively. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

6.11.13 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2, at Capacitor C2 and "-6 volts" transformer secondary pin No. 2 at Capacitors C3 and C6, two places, were measured to be just over 1/32 in. each. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

6.11.14 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2 and "-6 volts" transformer secondary pin No. 1 was measured to be less than 1/32 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

6.11.15 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 3 and "-6 volts" transformer secondary pin Nos. 1 and 2 were measured to be less than 1/32 in. and 1/32 in., respectively. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, UL 913(1)

6.11.16 Protective Transformer.

6.11.16.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound side by side on one leg of the core and separated with insulating material, it may be considered as having Type 1A construction. The transformer is judged not to comply with the applicable construction requirements for Type 1A transformers since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg in accordance with paragraph 5.3.

6.11.16.2 A Type 1A transformer, which complies with all of the construction features except is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction. Transformers having Type 3 construction are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted per paragraph 6.11.33.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, UL 913(1)

6.11.17 Any spacing including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 6.11.36, unless tha spacings are greater than or equal to those given in Table 8.1, UL 913(1) for the specified potential. A spacing not less than one-third of the value in Table 8.1 is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

6.11.18 The electrical spacings recorded in the following table are those that were measured to be less than required on the sample examined. The spacings were on the Power Supply printed wiring board, Figure 14.

6.11.19 Tabulation of Electrical Spacings

Fig.	Spacings: From	Spacings: To	Provided, MM: Through Air	Provided, MM: Over Surface	Required, MM: Through Air	Required, MM: Over Surface
14	Uninsulated Solder Connection of the +6 volts terminal, top board intrinsically safe terminal.	Transformer secondary terminal, bottom board	1(+)	-	3	3
14	Transistor Q1, Terminal C, Bottom Board	Ground	1/2(++)	1/2(++)	3	3
14	Transistor Q2, Terminal C, Bottom Board	Ground	1/2(++)	1/2(++)	3	3
14	Between all Adjacent Pins of I.C. U1, Botton Board		1/2(++)	1/2(++)	3	3
14	Between all Adjacent Pins of I.C. U2, Bottom Board		1/2(++)	1/2(++)	3	3
14	Printed wiring for Transistor Q1, Terminal E, Bottom Board	Ground	2(+)	2(+)	3	3
14	Transistor Q1, Terminal E, Bottom Board	Transistor Q1, Terminal C, Bottom Board	1(+)	1(+)	3	3
14	Printed wiring for Transistor Q2, Terminal E, Bottom Board	Ground	1-1/2(+)	1-1/2(+)	3	3
14	Transistor Q2, Terminal E, Bottom Board	Transistor Q2, Terminal C, Bottom Board	1(+)	1(+)	3	3
14	Printed wiring for Diode CR1, Cathode, Bottom Board	Ground	2(+)	2(+)	3	3
14	Printed wiring for I.C. U1, Pin 13, Bottom Board	Ground	1/2(++)	1/2(++)	3	3
14	Printed wiring for I.C. U1, Pin 10, Bottom Board	Printed wiring for I.C. U1, Pin 12, Bottom Board	1/2(++)	1/2(++)	3	3
14	Printed wiring for I.C. U2, Pin 13, Bottom Board	Ground	1-1/2(+)	1-1/2(+)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, UL 913(1)

6.11.20 The wiring of the transformer secondary contacts printed wiring of the intrinsically safe circuit. This does not comply with paragraph 9.1 since nonintrinsically safe wiring is not positively separated from intrinsically safe wiring.

SOURCES OF IGNITION, PARAGRAPH 14.1, UL 913(1)

6.11.21 The electrical schematic, Figure 15 depicts the use of an optional indicator lamp, an unspecified pilot valve and a function selector switch, not supplied as part of the system. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe. The indicator lamp, pilot valve and selector switch must be identified so this consideration can be made during Circuit Fault Analysis.

Marking

DETAILS, PARAGRAPHS 31.1-31.14, UL 913(1)

6.11.22 The Hand Controllers are not marked with the manufacturers name in accordance with paragraph 31.1.

6.11.23 In the Power Supply, the intrinsically safe circuits are not identified nor is the designation of the hazardous location in which the intrinsically safe circuits are to be used in accordance with paragraphs 31.4, Item C and Item F.

6.11.24 The Terminal Board, Resistor Board, Pilot Valves and Hand Controllers are not marked "Intrinsically Safe" nor are they marked with the designation of the hazardous location in which they are intended to be used in accordance with paragraphs 31.4, Item C and Item F.

6.11.25 The Power Supply, Terminal Board, Resistor Board, Hand Controller and Pilot Valves are not marked with the statement "Caution: Any substitution of components may impair intrinsic safety" or equivalent in accordance with paratraph 31.5. This marking should be visible after the equipment is installed.

6.11.26 Clear instructions covering interconnection of component parts of the system were not referenced on the nameplates in accordance with paragraph 31.8.

Test Record

6.11.27 The samples and component parts of the device identified in paragraphs 6.11.1 and 6.11.2 were subjected to the following tests to determine compliance with UL 913(1).

6.11.28 INPUT-OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.11.27.

6.11.29 NORMAL TEMPERATURE TEST

Test previously conducted with acceptable results, see paragraph 5.11.28.

6.11.30 TRANSFORMER OUTPUT TEST

Test previously conducted with acceptable results, see paragraph 5.11.29.

6.11.31 DIELECTRIC WITHSTAND TESTS

METHOD

When in a well heated condition the Valve Control System was subjected to these tests. The potential was applied between the parts, or circuits, indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min unless a breakdown occurred sooner.

RESULTS

The results comply with the requirements in paragraphs 4.2 and 23.1, UL 913(1), since breakdown occurred.

Test No.	Potential Applied Between	Potential, V	Results
1	Primary to secondary circuits	2200	No breakdown
2	Primary circuits to grounded parts	2200	No breakdown
3	Secondary circuit to grounded parts	500	Breakdown at Transistor Q1 Collector to Ground

6.11.32 ELECTRICAL CHARACTERISTICS OF COILS

METHOD

The characteristics of the coils indicated were measured with suitable meters.

RESULTS

Coil		Direct Current Resistance, Ohms	Inductance at 1 KHz, mh
Type	Part No.		
Solenoid	234912	57.90	24.13

6.11.33 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

METHOD

A sample of the protective transformer was subjected to this test. The sample was connected to a source of supply as indicated. The secondary winding was short-circuited. Each sample was operated continuously until the results noted were observed.

Temperatures on the transformer were measured by means of thermocouples and a suitable measuring instrument.

RESULTS

The results are indicated in the following tabulation.

The results do not comply with the requirements in paragraph 21.3 of UL 913(1) since the temperature of the transformer insulation exceeded the allowed limit for Class A insulation. There was no emission of flame or molten metal.

Transformer P/N	Insulation Class	Type	Rated V	Rated Hz	Test V	Test Hz	Test Time, Min	Maximum Temperature, Degrees C Ambient	Core	Primary	Secondary
261866	A	3	575	60	600	60	3	21	67	185	180

6.11.34 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

METHOD

Immediately after the Protective Transformer Abnormal Operation Test, a 60 Hz potential was applied between circuits indicated. In each case the potential was started at 0 v and gradually increased to the full potential and maintained at that value for 1 min.

RESULTS

Sample No.	Transformer Mfr.	Transformer Part No.	Potential, V	Test Time, Min	Results Primary to Secondary	Primary to Ground	Secondary to Ground
1	-	261866	2500	1	OK	-	-
1	-	261866	1150	1	-	OK	OK

OK - No electrical breakdown.

The results comply with the requirements in paragraph 22.1 of UL 913(1) since the spacings and insulation in the transformers were such as to withstand the application of the specified potential for 1 min without breakdown.

6.11.35 CURRENT LIMITING RESISTOR TESTS

METHOD

Samples of the current limiting resistor indicated were subjected to this test. Each resistor was connected across a variable voltage source of supply. The voltage was applied to each resistor either gradually or instantaneously until reaching the value indicated. The tests included application to the resistor a potential of 1.5 times the maximum fault voltage determined during the Circuit Fault Analysis. Each resistor was tested in this manner until ultimate conditions were reached.

RESULTS

The results are recorded in the following tabulation.

The results comply with the requirements in paragraph 5.14 of UL 913(1).

Sample	Resistor		Rated		1.5 Times Maximum	Test Voltage		Test		Test	
No.	Mfg.	Part No.	Ohms	Watts	Fault Volts	Volts	Applied(++)	Ohms(+)	Ampere	Time	Remarks
1	Ohmite	21J39R	39	1	36.75	36.75	I	36.8	1.0	5 Sec	Open
2	Ohmite	21J39R	39	1	36.75	22	G	32.6	0.675	20 Min	Open
3	Ohmite	21J39R	39	1	36.75	20	G	31.0	0.645	20 Min	Open
4	Ohmite	21J39R	39	1	36.75	22	G	34.2	0.644	20 Min	Open

(+) - Calculated at minimum value point - Ohms = Volts/Amperes.

(++) - I - Instantaneously.
G - Gradual.

6.11.36 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring and short spacings in accordance with the Standard UL 913(1) were considered.

2. In the analysis, consideration was given to the following items:

A. The Terminal Board, Resistor Board, Pilot Valves and Hand Controllers are to be located in the hazardous area. The Power Supply is intended to be housed in explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Equipment	Component		
Part No.	Type	Designation	Remarks
261861	Transformer	261866	Note 1
2618201	Resistor	39 ohm, 1 w, W.W.	

Notes -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance test, see paragraph 6.11.33.

2. The current limiting 30 ohm resistor may be short-circuited during spark ignition testing due to field wiring faults.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 6.11.37 and representative components were selected for thermal ignition tests.

6.11.37 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive methane gas in mixture with air. The test mechanism used is described in Section 19 of the Standard UL 913(1) using copper wires 0.008 in. in diameter to replace the tungsten wires when the test current exceeded 3 amp.

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	110 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the device for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply, Terminals +6 and -6, Figure 14	No faults introduced. (+)
2	Power Supply, Terminals +6 and -6, Figure 14	Short I.C.U1, Pin 12 to Pin 4 (one fault). (+)
3	Power Supply, Terminals +6 and -6, Figure 14	Short I.C.U1, Pin 12 to Pin 4 (one fault). (+)
4	Power Supply, Terminal 0, Figure 14 and Ground	Short Diode CR1 to ground (one fault) due to short spacings, see paragraph 6.11.19.
5	Power Supply, Terminal 0, Figure 14 and Ground	Short I.C.U1, Pin 13 to ground (no fault) and Pin 14 to Pin 13 both due to short spacings, see paragraph 6.11.19.
6	Power Supply, Terminals +6 and -6, Figure 14	Spark mechanism in series with pilot valve and 39 ohm resistor. Short out 30 ohm resistor (one fault), short -6 v field wiring terminal to ground (no fault), and disconnect and short to ground field wiring lead from pilot valve to 0 v terminal (no fault) all due to field wiring faults.
7	Power Supply, Terminal 0, Figure 14 and Ground	Short transformer primary to secondary. (++)

(+) - Circuit was simulated due to damage sustained to Power Supply during fault analysis.

(++) - This condition shorts the 575 v ac line circuit to the intrinsically safe Terminal 0. Assuming the use of a 575 v grounded source, arcing the intrinsically safe circuit to ground arcs the 575 v supply to ground.

RESULTS

Test No.	Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	After Test
1	1	0	1.1	1.5*	Cadmium	12.05	1.83	400	No Ignition	110	20
2	2	1	1.1	1.5**	Cadmium	30.0	2.5	10	Ignition	2	-
3	3	1	1.1	1.5**	Cadmium	22.7	4.53	7	Ignition	7	-
4	4	1	1.1	1.5***	Cadmium	18.51	-	-	Note 1	-	-
5	5	0	1.1	1.5***	Cadmium	18.51	-	-	Note 1	-	-
6	6	1	1.1	1.5**	Cadmium	13.80	0.233	207	Ignition	1	-
7	7	1	1.1	1.0	Cadmium	660	Note 2	-	Note 1	-	-

* Factor applied by decreasing the amount of limiting resistance.

** Factor applied by increasing the input voltage.

*** Since this circuit was not tested, the open circuit voltage and short circuit current indicated do not reflect the addition of a test (safety) factor.

Notes -

1. Test not conducted since test conditions are more severe than Test No. 3.

2. Current limited by capacity of source.

The results do not comply with the requirements in UL 913(1) since ignition of the methane air mixture was obtained.

6.11.38 Component Burnout and Strand of Wire Tests were not conducted since results in paragraph 6.11.37 indicate that circuits which extend into the hazardous location are not intrinsically safe.

CHAPTER 7

EXAMINATION AND TESTING OF METHANE MONITORING SYSTEMS AND MACHINE CONTROL CIRCUITS IN ACCORDANCE WITH "MESAP"(9)

7.1 GENERAL

7.1.1 The equipment described in the following Sections was examined and tested to determine compliance with the requirements in "Test Requirements for Instruments or Apparatus to be considered for M.E.S.A. Intrinsically Safe Certification (tentative)" ("MESAP")(9) as interpreted by the authors, except for paragraphs 4.2, 4.5, 5.3, 5.22B or 9.5. See Appendix A.

7.1.2 Paragraph 4.2 of "MESAP"(9) requires that the equipment comply with requirements for similar equipment for use in ordinary, nonhazardous locations. The examination and testing of the equipment included all applicable ordinary location construction and performance requirements of UL, except for reliability and accuracy of operation of gas monitors. The examination and tests were based on the requirements of Part I of UL 913(7), First Edition, which are included in Appendix B. All test methods and results are included in this Report; but only construction features not in compliance with the UL requirements are reported. If not reported as not in compliance with UL requirements, the construction was judged in compliance with UL requirements. Tests include one or more of the following: Input-Output, Normal Temperature, Undervoltage and Overvoltage, Transformer Output, and Dielectric Withstand Tests. These tests were previously conducted and reported in Chapters 5 and 6.

7.1.3 Paragraphs 4.5, 5.3, 5.22B and 9.5 of "MESAP"(9) require that components comply with the requirements for that component. Some component construction and performance, e.g., printed wiring boards, wiring material, etc., can not be readily evaluated when they are parts of an assembled product and such evaluation was not conducted. Some components, e.g., relays, can be examined and tested for compliance with the ordinary location UL requirements in accordance with paragraph 7.1.2 and such evaluation was conducted when appropriate. If wiring material, or other component, is UL Listed or Component Recognized and is used as intended, such part meets the UL requirements. Components which should meet the requirements but could not be identified as UL Listed or Component Recognized are identified in this Report.

7.1.4 Some features need to comply with both intrinsically safe and electrical construction requirements. In such cases where a feature was not in compliance with either of the requirements, such as spacings, it is reported as not in compliance with the requirements affecting intrinsic safety.

7.1.5 Some of the associated circuits and equipment were provided with explosion-proof enclosures. Evaluation of the explosion-proof features of construction is not included in this Report. The method of installation of cable- or cord-connected equipment for use in mines was not evaluated since the "MESAP"(9) does not identify specific requirements and the UL requirements only cover permanent equipment installations in accordance with the National Electrical Code (NEC), NFPA No. 70-1978.

7.1.6 The results indicate that none of the Methane Monitoring Systems and Machine Control Circuits comply with "MESAP"(9). Examination of each device disclosed features of construction which do not comply with the requirements, and testing of each device caused ignition of the explosive gas-air mixture specified in the test records.

7.2 ENSIGN ELECTRIC AND MANUFACTURING COMPANY, I.S.R. CIRCUIT PART NO. 6651-005, ITEM 10

Product Description

7.2.1 Intrinsically Safe Relay, Part No. 6651-005, manufactured by Ensign Electric Division, Harvey Hubbell, Inc., of Huntington, West Virginia. The coil is rated 230 v dc, shunt duty and the contacts are rated 250 v dc, 2 amp. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe, which may extend into the hazardous area of the underground mine.

7.2.2 Three complete sample devices along with additional component parts were purchased from the manufacturer since a distributor for this device is not available in this area, and were subjected to the examination and tests described below.

7.2.3 Instructions covering installation of the device were not supplied as part of the equipment. Instructions were provided upon request. The electrical schematic is shown in Figure 1.

Ordinary Location Electrical Construction, Paragraphs 4.2 and 4.5 "MESAP"(9)

7.2.4 The wiring terminals provided on the device extend both above and below the mounting base. This, coupled with the lack of adequate installation instructions, make it difficult to insure that electrical spacings to grounded parts will be maintained after installation. Also, the size and shape of the mounting screws may result in inadequate spacings.

ELECTRICAL COMPONENTS

7.2.5 The Part No. 162HXH101 relay could not be identified as being UL Listed or Recognized.

Intrinsically Safe Electrical Construction

GENERAL, PARAGRAPHS 4.1, 4.3, 4.4, 4.6-14.10, "MESAP"(9)

7.2.6 The Relay is not provided with an enclosure. The installation instructions do not specify that the Relay must be provided with means of protection such as an explosion-proof enclosure or that the Relay must be mounted outside of the hazardous location. This does not comply with paragraph 4.7.

PASSIVE PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.2.7 Shunt Safety Components.

7.2.7.1 The coil is provided with a single shunt diode, see Figure 1. The diode is connected across the coil with separate crimped connectors at the wiring terminals used for field-installed wiring. The diode is not duplicated so that the assembly remains safe if one diode becomes defective and it is connected across the coil in such a manner that it may be disconnected from the circuit, leaving the coil in the circuit, while making the field wiring connections. This does not comply with paragraph 5.16, and is to be considered as subject to fault. See Circuit Fault Analysis paragraph 7.2.23.

7.2.8 Damping Winding.

7.2.8.1 The coil is provided with a damping winding consisting of two layers of copper wire wound over the coil bobbin. The ends of the windings are soldered together. Since the windings are not continuously short-circuited together by soldering or equivalent means in accordance with paragraph 5.13 it is to be considered as subject to fault. See Circuit Fault Analysis paragraph 7.2.23.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.2.9 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault under Circuit Fault Analysis, paragraph 7.2.23, unless the spacings are greater than or equal to those given in Table 8.1A for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1 may be considered as connected without being counted as a fault.

7.2.10 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined.

7.2.11 Tabulation of Electrical Spacings

Fig.	Spacings		Provided, MM		Required, MM	
	From	To	Through Air	Over Surface	Through Air	Over Surface
1	N.O. Contact, "+" Terminal (250 v dc)	Grounded Mounting Plate (+++)	4-1/2(+)	-	6	10
1	"+" Terminal (250 v dc)	Ungrounded Diode Bracket	0(++)	9(+)	6	10
1	"1" Terminal	Ungrounded Diode Bracket	0(++)	9(+)	6	10
1	Ungrounded Diode Bracket	Grounded Mounting Plate	1(++)	-	6	10
1	Diode Terminals (250 v dc)	Ungrounded Diode Bracket	-	7-1/2(+)	6	10
1	"-" Terminal, Diode (250 v dc)	"1" Terminal	3-1/2(+)	-	6	10

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

(+++) - A grounded mounting plate was not provided as part of the equipment. It was assumed that the relay may be mounted on a grounded mounting plate, or surface.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.2.12 The internal wiring between the 2500 ohm resistor and the line voltage "+" terminal contacts the wiring between the intrinsically safe "1" terminal and the resistor. This does not comply with paragraph 9.1, since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

7.2.13 The internal wiring between the coil shunt diode and the line voltage "-" terminal contacts the wiring between the intrinsically safe "2" terminal and the diode. This does not comply with paragraph 9.1, since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, "MESAP"(9)

7.2.14 The wiring terminals for intrinsically safe and nonintrinsically safe circuits are separated by a distance of at least 50 mm. This complies with the requirements for panel installed equipment. However, clear installation instructions regarding wire routing and field connections are not provided. This does not comply with paragraph 11.1.

SOURCES OF IGNITION, PARAGRAPH 14.1, "MESAP"(9)

7.2.15 The type of pilot device which is intended to be used in the hazardous area was not specified or limited. The pilot device used may affect the intrinsic safety of the system. The pilot device is required to be identified so this consideration can be made during Circuit Fault Analysis.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.2.16 Instructions covering connection of the pilot device in the field are not given. The instructions give neither minimum resistance, maximum inductance nor identification of a specific apparatus. This does not comply with paragraph 30.2.

7.2.17 The relay is not marked with the MESA logo and the approval or certification number as required in paragraph 30.3.

7.2.18 The relay is not marked with the warning statement: "Any substitution of components may impair intrinsic safety", or with reference to specific installation requirements, such as installation instructions, as required in paragraph 30.6.

7.2.19 The intrinsically safe terminals are not marked "Intrinsically Safe" as required in paragraph 30.7.

Test Record

7.2.20 DIELECTRIC WITHSTAND TEST

Test previously conducted with acceptable results, see paragraph 6.2.28.

7.2.21 CURRENT LIMITING RESISTOR TESTS

Test previously conducted with acceptable results, see paragraph 6.2.31.

7.2.22 PROTECTIVE DIODE ABNORMAL TESTS

Test previously conducted with acceptable results, see paragraph 6.2.30.

7.2.23 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring, and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the unspecified pilot device is to be located in the hazardous area. The Relay is intended to be either housed in an explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Component Type	Designation	Remarks
Diode	SD-0606	Note 1
Resistor	F423	Note 2
Damping Winding	-	Note 3

Notes -

1. The coil shunt diode may be open-circuited during spark ignition testing since the diode is not duplicated nor is it reliably connected in the circuit, see paragraph 7.2.7. The diode did meet the applicable performance test, see paragraph 6.2.30.

2. The resistor may be short-circuited during spark ignition testing without its being counted as a fault since adequate electrical spacings are not provided, see paragraph 7.2.11. The resistor did meet the applicable performance test, see paragraph 6.2.31.

3. The damping winding may be open-circuited during spark ignition testing since its construction did not meet the requirements, see paragraph 7.2.8.

3. Based on the analysis, representative circuits were selected for spark ignition tests.

7.2.24 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

V, DC	Inductive Circuit	
	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The Input voltage to the relay for the tests was adjusted by the appropriate voltage factor indicated based on a rating of 250 v dc before introduction of a test (safety) factor.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	I.S.C. Terminals 1 and 2, Figure 1	Relay with no faults introduced.
2	I.S.C. Terminals 1 and 2, Figure 1	Short circuit 2500 ohm resistor (no fault), due to short spacings, see paragraph 7.2.11.
2	I.S.C. Terminals 1 and 2, Figure 1	Open shunt diode (one fault).
4	I.S.C. Terminals 1 and 2, Figure 1	Open coil damping winding (one fault).
5	I.S.C. Terminals 1 and 2, Figure 1	Short relay coil (one fault).
6	I.S.C. Terminals 1 and 2, Figure 1	Short circuit 2500 ohm resistor (no fault) due to short spacings, see paragraph 7.2.11 and open shunt diode (one fault).
7	I.S.C. Terminals 1 and 2, Figure 1	Short circuit 2500 ohm, resistor (no fault) due to short spacings, see paragraph 7.2.11, open shunt diode (one fault) and short relay coil (one fault).

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Results
1	0	1.1	1.5	Cadmium	275	82	Note 1
2	0	1.1	1.5	Cadmium	275	166	Note 2
3	1	1.1	1.5	Cadmium	275	82	Note 2
4	1	1.1	1.5	Cadmium	275	82	Note 2
5	1	1.1	1.5	Cadmium	275	166	Note 2
6	1	1.1	1.5	Cadmium	275	166	Note 2
7	2	1.1	1.0	Cadmium	275	Note 3	Note 2

Notes -

1. This test was not conducted since this circuit caused ignition of methane-air mixture with a brass disc and a test (safety) factor of 1.0, see paragraph 5.2.25.

2. Test not conducted since test conditions are more severe than Test No. 1.

3. Current limited only by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition of the gas-air mixture was obtained.

7.3 ENSIGN ELECTRIC & MFG. COMPANY, I.S.R. CONTROL CIRCUIT, PART NO. 6651-004, ITEM 11

Product Description

7.3.1 Intrinsically Safe Relay, Part No. 6651-004, manufactured by Ensign Electric Division, Harvey Hubbell, Inc. of Huntington, West Virginia. The device is rated 575 v ac, and the contacts are rated 120 v ac, 10 amp. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe.

7.3.2 Three complete sample devices along with additional component parts were purchased from the manufacturer since a distributor for this device is not available in this area, and were subjected to the examination and tests described below.

7.3.3 Instructions covering installation of the device were not supplied as part of the equipment. Instructions were provided upon request. The electrical schematic is shown in Figure 2.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP"(9)

ELECTRICAL COMPONENTS

7.3.4 The Cat. No. A314XBX148 relay cannot be identified as being UL Listed or Recognized.

WIRING TERMINALS AND LEADS

7.3.5 Intrinsically safe terminal No. 9, intended for field wiring the device, consists of a solder terminal on the 100 ohm resistor. This does not comply with paragraphs 113 through 120 of UL 913(7). See Appendix B.

ELECTRICAL SPACINGS

7.3.6 The required spacings for 575 v line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for 120 v line voltage circuits are those indicated in Column 51-300, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

7.3.7 The over surface spacing between relay socket pin No. 1 (120 v ac) and relay socket pin No. 8 (120 v ac) was measured to be 3/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/8 in.

Intrinsically Safe Electrical Construction

GENERAL, PARAGRAPHS 4.1, 4.3, 4.4, 4.6-4.10, "MESAP"(9)

7.3.8 The Relay is not provided with an enclosure. The installation instructions do not specify that the Relay must be provided with means of protection such as an explosion-proof enclosure or that the Relay must be mounted outside of the hazardous location. This does not comply with paragraph 4.7.

PASSIVE PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.3.9 Protective Transformers.

7.3.9.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements since it was not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

7.3.10 Shunt Safety Components.

7.3.10.1 The two 1000 ohm wire wound resistors are connected in parallel with the relay coil. It appears that they are intended to be shunt safety components. Since the expected failure mode for a wire wound resistor is open circuit, the resistors are judged not to meet the intent of the requirements for shunt safety components. Furthermore, the resistors are connected across the relay coil such that both of the resistors could be disconnected without disconnecting the relay coil at the same time when field wiring the device. This does not comply with paragraphs 3.14 and 5.16.

7.3.10.2 The 1000 ohm wire wound resistor which appears to be intended as a transformer secondary shunt safety component. The expected failure made for a wire wound resistor is open circuit. This does not comply with paragraphs 3.14 and 5.16.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.3.11 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault under Circuit Fault Analysis, paragraph 7.3.26, unless the spacings are greater than or equal to those given in Table 8.1A for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being a fault.

7.3.12 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined.

7.3.13 Tabulation of Electrical Spacings

Fig.	Spacings: From	Spacings: To	Provided, MM: Through Air	Provided, MM: Over Surface	Required, MM: Through Air	Required, MM: Over Surface
2	Relay Socket Pin No. 6 (120 v ac N.O. Contact)	Relay Socket Pin No. 7 (+++)	1(++)	1(++)	6	8
2	Relay Socket Pin No. 8 (120 v ac)	Relay Socket Pin No. 7 (+++)	2(++)	2(++)	6	8
2	Relay Socket Pin No. 1 (120 v ac)	Relay Socket Pin No. 2 (Secondary circuit)	1(++)	1(++)	6	8
2	Relay Pin No. 8 (120 v ac)	Relay Pin No. 7 (+++)	4(+)	5(+)	6	8
2	Relay Pin No. 1 (120 v ac)	Relay Pin No. 2 (Secondary circuit)	4(+)	5(+)	6	8

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

(+++) - Intrinsically safe output terminal.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.3.14 Within the relay the wiring for the 120 v contact circuits intermingles with the wiring of the coil circuit. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, "MESAP"(9)

7.3.15 The field wiring connection for the intrinsically safe circuit Terminal 9 is located above the field wiring connections for the transformer primary circuit, and is separated by a distance of 46 mm, minimum. This does not comply with the requirements for panel installed equipment in paragraph 11.1 which requires a separation of at least 50 mm. Additionally this construction does not comply with paragraph 10.5 since the field wiring of intrinsically safe and nonintrinsically safe circuits may not be positively separated.

7.3.16 The field wiring connections for the intrinsically safe circuit Terminals 7 and 9 are separated from the line voltage contact circuits by distances of 6 and 25 mm, respectively. This does not comply with the requirements for panel installed equipment in paragraph 11.1 which requires a separation of at least 50 mm. Additionally this construction does not comply with paragraph 10.5 since field wiring of the transformer primary may intermingle with intrinsically safe field wiring, uninsulated secondary conductors and field wiring of contact circuits.

SOURCES OF IGNITION, PARAGRAPH 14.1, "MESAP"(9)

7.3.17 The type of switch which is intended to be used in the hazardous area was not specified or limited. The use of electronic switches may affect the intrinsic safety of the system. The type of switch to be used would need to be identified in order for this consideration to be made during Circuit Fault Analysis. If only mechanically actuated switches are to be used in the hazardous area then specifying a particular switch would not be necessary, however this information should be indicated in the installation instructions.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.3.18 Instructions covering connection of the switch in the field are not given. The instructions give neither minimum resistance, maximum inductance nor identification of a specific apparatus. This does not comply with paragraph 30.2.

7.3.19 The relay is not marked with the MESA logo and the approval or certification number as required in paragraph 30.3.

7.3.20 The relay is not marked with the warning statement: "Any substitution of components may impair intrinsic safety," or with reference to specific installation requirements such as installation instructions as required in paragraph 30.6.

7.3.21 The intrinsically safe terminals are not marked "Intrinsically Safe" as required in paragraph 30.7.

Test Record

7.3.22 DIELECTRIC WITHSTAND TEST

Test previously conducted with acceptable results, see paragraph 6.3.27.

7.3.23 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test previously conducted with unacceptable results, see paragraph 6.3.29

7.3.24 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test was not conducted since transformer did not comply with the performance requirements of the Abnormal Operation Test, see paragraph 6.3.30.

7.3.25 CURRENT LIMITING RESISTOR TESTS

Test previously conducted with acceptable results, see paragraph 6.3.31.

7.3.26 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring, and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the unspecified pilot device is to be located in the hazardous area. The Relay is intended to be either housed in an explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment, it appears that the following components are intended to be protective components.

Component		
Type	Designation	Remarks
Line Voltage Transformer	None Provided	Note 1
100 Ohm Resistor	F210	-
1000 Ohm Transformer Secondary Shunt	HLM-20-10Z	Note 2
1000 Ohm Coil Shunt	HLM-20-10Z	Note 3

Notes -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance test, see paragraph 6.3.29. The transformer did not meet the applicable construction requirements, see paragraph 7.3.9.1.

2. The resistor may be open-circuited during spark ignition testing since the resistor did not meet the requirements for shunt safety components, see paragraph 7.3.10.2.

3. Both of the resistors may be open-circuited during spark ignition testing since they do not meet the requirements for shunt safety components and since they may be disconnected from the circuit without disconnecting the coil when making the field wiring connections, see paragraph 7.3.10.1 This is counted as one fault, since both resistors are connected to terminal No. 7 with a single wire.

3. Based on the analysis, representative circuits were selected for spark ignition test as noted in paragraph 7.3.27.

7.3.27 <u>SPARK IGNITION TEST</u>

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated.

The input voltage to the relay for the tests was adjusted by the appropriate voltage factor indicated based on a test voltage of 600 v before introduction of any test (safety) factor.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Relay Terminals 7 and 9, Figure 2	No faults introduced.
2	Relay Terminals 7 and 9, Figure 2	Open 1K ohm transformer shunt (one fault).
3	Relay Terminals 7 and 9, Figure 2	Open relay coil shunt resistors (one fault).
4	Relay Terminals 7 and 9, Figure 2	Open 1K ohm transformer shunt (one fault) and open relay coil shunt resistors (one fault).
5	Relay Terminals 7 and 9, Figure 2	Short relay coil (one fault) and open transformer shunt (one fault).
6	Relay Terminals 7 and 9, Figure 2	Short relay coil (one fault) and short transformer primary to secondary (one fault).
7	Relay Terminal 7, Figure 2 to Ground	Short circuit relay socket Terminal 6 or 8 to 7 (intrinsically safe terminal) (no fault) due to short spacings, see paragraph 7.3.13. (+)
8	Relay Terminal 7, Figure 2 to Ground	Short relay socket Terminals 1 to 2 (no fault) due to short spacings, see paragraph 7.3.13. (++)
9	Relay Terminal 9, Figure 2 to Ground	Short transformer primary to secondary (one fault). (+++)

(+) - This condition shorts the 120 v ac contact circuit to the intrinsically safe circuit. Assuming the use of a 120 v, grounded source, arcing of the intrinsically safe circuit to ground arcs the 120 v supply to ground.

(++) - This condition shorts the 120 v ac contact circuit to the transformer secondary circuit at relay socket Terminal 2. Assuming the use of a 120 v grounded source, arcing of the intrinsically safe circuit to ground arcs the 120 v supply to ground through the relay coil.

(+++) - This condition shorts the 575 v ac transformer primary circuit to the transformer secondary circuit at the 100 ohm resistor. Assuming the use of a 575 v grounded source, arcing of the intrinsically safe circuit to ground arcs the 575 v supply to ground through the 100 ohm resistor.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Results
1	0	1.1	1.5*	Cadmium	49.0	165	Note 1
2	1	1.1	1.5	Cadmium	-	-	Note 2
3	1	1.1	1.5	Cadmium	-	-	Note 2
4	2	1.1	1.5	Cadmium	-	-	Note 2
5	2	1.1	1.5	Cadmium	-	-	Note 2
6	2	1.1	1.0	Cadmium	600 AC	Note 3	Note 2
7	0	1.1	1.0	Cadmium	132 AC	Note 3	Note 2
8	0	1.1	1.0	Cadmium	132 AC	Note 3	Note 2
9	1	1.1	1.0	Cadmium	660 AC	Note 3	Note 2

*Factor applied by increasing relay input voltage.

Notes -

1. Test not conducted since this test circuit caused ignition of methane air mixture, see paragraph 5.3.24.

2. Test not conducted since test conditions are more severe than Test No. 1.

3. Current limited only by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition of the gas air mixture was obtained.

7.4 MSA, MODEL VI METHANE MONITOR

Product Description

7.4.1 Model VI Methane Monitoring System, manufactured by Mine Safety Appliances Company of Pittsburgh, Pennsylvania. The system consists of an AC Power Supply and Contact Driver, Part No. 458175 (Figure 3), a Monitor Part No. 456960 and a Detector Part No. 458120 (Figure 4). Additionally an auxiliary Battery power source Part No. 95554 is available to power the Monitor. The Power Supply is intended to be mounted within an explosion-proof enclosure and has circuits which are connected to the Monitor and the Detector, each claimed to be intrinsically safe. The Power Supply is rated 550 v ac input, the Battery is rated 4 v dc.

7.4.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

7.4.3 Electrical schematics for the equipment are shown in Figures 3 and 4.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP" (9)

FIELD WIRING TERMINALS

7.4.4 The wire binding screw intended for the connection of the equipment grounding conductor (Terminal No. 1) is not provided with a green-colored head. This does not comply with paragraph 122 of UL 913(7). See Appendix B. The terminal identification is supplied on a wiring diagram in the instruction manual.

INTERNAL WIRING

7.4.5 The orange-colored transformer primary lead has at least 1/64 inch thick insulation with an outer braid. This lead could not be identified as UL Appliance Wiring Material. This does not comply with paragraphs 148-150 of UL 913(7). See Appendix B.

7.4.6 The green, yellow and brown-colored transformer primary lead wires have at least 1/64 inch thick insulation with an outer braid. These leads could be identified as UL Appliance Wiring Material rated 105 C, 300 v maximum. Since these conductors are for use in 550 and 440 v ac circuits they are not considered to be acceptable in accordance with paragraphs 148-150 of UL 913(7), see Appendix B.

ELECTRICAL COMPONENTS

7.4.7 The Part No. A415HXX104 relay in the AC Power Supply and Contact Driver could not be identified as being UL Listed or Recognized.

7.4.8 The AC Power Supply printed wiring board No. 458148 could not be identified as being UL Recognized.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.4.9 Protective Transformer.

7.4.9.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements since it was not constructed with thermal insulation between the input and output windings, including splices and crossover leads as required in paragraph 5.9A.

7.4.10 Shunt Safety Components.

7.4.10.1 The relay coil is provided with a single shunt diode (see Figure 3). The diode is mounted to a printed wiring board and connected to the relay coil with separate lead wires. The diode is not duplicated so that the assembly remains safe if one diode becomes defective and it is connected across the coil in such a manner that it may be disconnected from the circuit, leaving the coil in the circuit. This does not comply with paragraph 5.16 and was considered as subject to fault. See Circuit Fault Analysis, paragraph 7.4.34.

OVERCURRENT PROTECTION, PARAGRAPHS 6.1-6.2, "MESAP"(9)

7.4.11 The intrinsically safe Monitor is supplied with a fuse for overcurrent protection. This does not comply with the exception to paragraph 6.2 since it has been shown by test that the circuit will ignite the hazardous atmosphere of methane. See paragraph 5.4.23. Since the circuit itself is capable of ignition, tests of the fuses were not conducted.

SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.4.12 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault under Circuit Fault Analysis, paragraph 7.4.34, unless the spacings are greater than or equal to those given in Table 8.1A for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being counted as a fault.

7.4.13 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. These spacings were in the AC Power Supply and Contact Driver, Figure 3 and in the Monitor, Figure 4.

7.4.14 Tabulation of Electrical Spacings

Fig.	Spacings: From	Spacings: To	Provided, MM: Through Air	Provided, MM: Over Surface	Required, MM: Through Air	Required, MM: Over Surface
3	Resistor RX, Primary Circuit	2 amp fuse, secondary circuit	0(++)	-	10	25
3	2N3055 Reg Terminal "C", Secondary Circuit	2N3055 Reg Terminal "E", Secondary Circuit	1/2(++)	1/2(++)	3	3
3	D42C Terminal "C", Secondary Circuit	D42C Terminal "B", Secondary Circuit	1/2(++)	1/2(++)	3	3
3	D42C Terminal "C", Secondary Circuit	D42C Terminal "B", Secondary Circuit	1/2(++)	1/2(++)	3	3
3	D42C Terminal "B", Secondary Circuit	Terminal 8, Intrinsically Safe Terminal	1-1/2(+)	1-1/2(+)	3	3
4	Terminal 3, Monitor	Toroid, Brown Lead Monitor	1/2(++)	1/2(++)	3	3
4	Terminal 10, Monitor	Toroid, Brown Lead Monitor	1/2(++)	1/2(++)	3	3
4	Toroid Red Lead, Monitor	Toroid, Orange Lead, Monitor	1/2(++)	1/2(++)	3	3
4	Toroid, Orange Lead, Monitor	Toroid, Yellow Lead, Monitor	1/2(++)	1/2(++)	3	3
4	Terminal 10, Monitor	Terminal 5, Monitor	1-1/2(+)	1-1/2(+)	3	3
4	Terminal 10, Monitor	Toroid, Blue Lead, Monitor	1(+)	1(+)	3	3
4	Terminal 3, Monitor	Terminal 5, Monitor	1(+)	1(+)	3	3
4	Terminal 3, Monitor	Terminal 8, Monitor	1-1/2(+)	1-1/2(+)	3	3
4	Between all Adjacent Terminals of I.C. No. M789P		1/2(++)	1/2(++)	3	3
4	Between all Adjacent Terminals of AMP No. 1/2 MC1437L		1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

7.4.15 The application of adherent insulating material to the Power Supply and Monitor printed wiring boards was not uniform since some areas were not coated. Also, the insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore can not be relied upon in lieu of spacings in accordance with Footnote b of Table 8.1A.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.4.16 In the Power Supply the internal wiring for the intrinsically safe Terminals 8, 9 and 10 is bunched together for routing with 550 v ac primary transformer wiring and 240 v ac contact wiring. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

7.4.17 In the Power Supply the internal wiring for the 2 amp secondary fuse is routed adjacent to the 550 v ac transformer primary common conductor and 240 v ac contact wiring. This does not comply with paragraph 9.1 since positive separation is not provided between the fuse wiring, which may affect intrinsic safety, and the nonintrinsically safe circuit.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, "MESAP"(9)

7.4.18 Field wiring conductors for the intrinsically safe circuits may be intermingled with field wiring conductors and factory installed wiring for the line voltage circuits and uninsulated live parts of line voltage circuits since all field wiring is completed on the same terminal block. This does not comply with paragraph 10.5.

BATTERY-OPERATED APPARATUS, PARAGRAPHS 12.1-12.5, "MESAP"(9)

7.4.19 The Battery available for use with the equipment as an auxiliary power source incorporates an integral device with a bimetalic element soldered in place between the two battery cells. This type of device is not considered equivalent to a current-limiting resistor to limit the maximum current available under short circuit conditions, in accordance with paragraph 12.3, since it will not limit the current when the circuit is initially short-circuited. Therefore the device may be short-circuited during tests. See Circuit Fault Analysis, paragraph 7.4.34.

SOURCES OF IGNITION, PARAGRAPH 14.1, "MESAP"(9)

7.4.20 Interconnection of the Power Supply and Monitor is accomplished by a seven conductor cable of which only three conductors are used. Additional conductors are provided for connection to an unspecified remote meter and relay which are not supplied with the equipment. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe. The remote meter and relay should be identified so this consideration can be made during Circuit Fault Analysis. Also, when the unspecified remote meter and relay are not used, the uninsulated ends on the conductors may contact uninsulated line voltage parts which may result in transmission of line voltage to the intrinsically safe equipment located in the hazardous area.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.4.21 Clear instructions covering connection of the remote meter/recording device are not given. The instructions give neither minimum resistance, maximum inductance nor identification of a specific apparatus. This does not comply with paragraph 30.2.

7.4.22 The Detector is not marked with the MESA logo, the approval or certification number, and the part number as required in paragraph 30.3.

7.4.23 The Monitor and Detector are not marked with the statement "Any substitution of components may impair intrinsic safety" as required in paragraph 30.5.

7.4.24 The Power Supply is not marked with the statement "Any substitution of components may impair intrinsic safety" nor is it marked with requirements covering its installation as required in paragraph 30.6.

7.4.25 The intrinsically safe terminals and the output plug of the Power Supply, the Battery plug, the input and output receptacles of the Monitor and the Detector plug are not marked "Intrinsically Safe" as required in paragraph 30.7.

7.4.26 The Monitor is not marked to indicate the type, voltage, and size of Battery to be used in the equipment as required in paragraph 30.8.

7.4.27 The polarity of the Power Supply output terminals is not marked as required in paragraph 30.9.

Test Record

7.4.28 DIELECTRIC WITHSTAND TEST

Test was previously conducted with acceptable results. See paragraph 6.4.34.

7.4.29 BATTERY RUPTURE TEST

Test was previously conducted with acceptable results. See paragraph 6.4.36.

7.4.30 TEST FOR ACCUMULATION OF STATIC ELECTRICITY

Test was previously conducted with acceptable results. See paragraph 6.4.37.

7.4.31 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test was previously conducted with unacceptable results. See paragraph 6.4.38.

7.4.32 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test. See paragraph 6.4.38.

7.4.33 PROTECTIVE DIODE ABNORMAL TESTS

Test was previously conducted with acceptable results. See paragraph 6.4.40.

7.4.34 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring, and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Monitor and Detector are to be located in the hazardous area. The AC Power Supply and Contact Driver are intended to be housed in the explosion-proof enclosure.

B. From examination of the equipment it appears that the following components are intended to be protective components.

Component		
Type	Designation	Remarks
Transformer	MSA956-4 7622	Note 1
Diode	1N4001	Note 2
Bimetalic Switch	--	Note 3

Notes -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance tests, see paragraph 6.4.38.

2. The diode may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 7.4.10.1. The diode did meet the applicable performance test, see paragraph 6.4.40.

3. The Bimetalic switch may be short-circuited during spark ignition testing since it did not meet the requirements for current limiting devices, see paragraph 7.4.19.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.4.35 and representative components were selected for thermal ignition tests.

7.4.35 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

When batteries were used during the test, four trials with fresh or fully charged batteries, two for each polarity, were used for each test circuit.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable position so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Battery Terminals	A single battery with bimetallic switch shorted (no fault). (++)
2	Power Supply Terminals 9 and 10, Figure 3	Short 2N3055 "C" to "E" (no fault) due to short spacings, see paragraph 7.4.14. (+)
3	Power Supply Terminals 8 and 9, Figure 3	Short D42C "C" to "B" (no fault) and short 200 ohm resistor (one fault) both due to short spacings, see paragraph 7.4.14 and short relay coil, (one fault).
4	Power Supply Terminal 9, Figure 3 and Ground	Short transformer primary to secondary (one fault). (+++)
5	Power Supply Terminal 10, Figure 3 and Ground	Short 2N3055 "C" to "E" (no fault) above and short primary Resistor RX to Transistor 2N3055 "C" terminal, (no fault) both due to short spacings, see paragraph 7.4.14. (++++)

(+) - Circuit was simulated due to damage sustained to the Power Supply during tests conducted previously. See paragraph 5.4.23.

(++) - Circuit was simulated. Initial circuit before introduction of the test (safety) factor was 4.99 v dc, 42 amp, representing the maximum battery output determined during the Battery Output Test. See paragraph 5.4.17.

(+++) - This condition shorts the 550 v ac line circuit to the intrinsically safe Terminal 9 through Resistor RX. Assuming the use of a 550 v grounded source, arcing the intrinsically safe circuit to ground arcs the 550 v supply to ground.

(++++) - This condition shorts the 550 v ac line circuit to the intrinsically safe Terminal 10 through Resistor Rx. Assuming the use of a 550 v grounded source, arcing the intrinsically safe circuit to ground arcs the 550 v supply to ground.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Amp	Results
1	0	1.1	1.5*	Cadmium	6.72	57	Note 1
2	0	1.1	1.5**	Cadmium	12.80	12.35	Note 2
3	2	1.1	1.5**	Cadmium	12.80	12.35	Note 3
4	1	1.1	1.0	Cadmium	660	-	Note 3
5	0	1.1	1.0	Cadmium	660	-	Note 3

* Factor applied by increasing the voltage by 1.22.

** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of a test (safety) factor.

Notes -

1. Test not conducted since this test circuit previously caused ignition of methane air mixture, see paragraph 6.4.42.

2. Test was not conducted since this circuit previously caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0. See paragraph 5.4.23.

3. Test was not conducted since test conditions are more severe than Test No. 3.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition of the gas air mixture was obtained.

7.4.36 Transistor Thermal Runaway, Component Overload and Strand of Wire tests were not conducted since test results in paragraph 7.4.35 indicate that circuits which extend into the hazardous location are not intrinsically safe.

7.5 SERVICE MACHINE COMPANY, B-742-001 POWER SUPPLY, ITEM 8

Product Description

7.5.1 Intrinsically Safe Power Supply, Part No. B-742-001, manufactured by Service Machine Company of Huntington, West Virginia. The Supply is rated 115 v, 60 Hz input, 5 through 12 v dc, in 1 v increments, output. The device is intended for panel installation and has a circuit which is claimed to be intrinsically safe, intended to operate unspecified horns, buzzers, solenoids or relays.

7.5.2 A complete sample of the device along with additional component parts were purchased from the manufacturer, since a distributor for this device is not available in this area, and were subjected to the examination and test described below.

7.5.3 The schematic diagram and instructions covering installation of the devices were not supplied as part of the equipment. Instructions were provided upon request. The schematic diagram is shown in Figure 5.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP"(9)

ELECTRICAL SPACINGS

7.5.4 The required spacings for line voltage circuits are those indicated in Column 51-300, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

7.5.5 The through air spacing between the uninsulated fuse terminals and grounded parts of the 7.5 ohm resistor can be reduced to zero since the fuseholder was not prevented from rotating. This does not comply with paragraph 196 and Table 6 of UL 913(7) which require a 1/16 in. through air spacing.

Intrinsically Safe Electrical Construction

GENERAL, PARAGRAPHS 4.1, 4.3, 4.4, 4.6-4.10, "MESAP"(9)

7.5.6 The Power Supply is not provided with an enclosure. The installation instructions do not specify that the Power Supply must be provided with means of protection such as an explosion-proof enclosure or that the Power Supply must be mounted outside of the hazardous location. This does not comply with paragraph 4.7.

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.5.7 Protective Transformer.

7.5.7.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is a grounded screen between the windings, it may be considered as having Type 2B construction. The transformer is judged not to comply with the applicable construction requirements for Type 2B transformers since the screen is placed between the windings but the splices and crossover leads are not included (paragraph 5.9B), since only one and not two grounding leads are provided (paragraph 5.9B-2), since the screen consists of one layer and not two layers of windings as required (paragraph 5.9B-3), and since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg.

7.5.7.2 The Type 2B transformer does not require a Protective Transformer Abnormal Operation Test. A Type 2B transformer which complies with all the construction features except is provided with only one grounding lead and is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction. Transformers having Type 3 construction are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted per paragraph 6.5.29.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.5.8 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 7.5.24, unless the spacings are greater than or equal to those given in Table 8.1A, for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being counted as a fault.

7.5.9 The electrical spacings recorded in the following table are those that were measured to be less than required on the sample examined.

7.5.10 TABULATION OF ELECTRICAL SPACINGS

	Spacings		Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
5	AC Rectifier Terms	Ground	1-1/2(+)	1-1/2(+)	3	3
5	Capacitor "+" Lead	Ground	1-1/2(+)	-	3	3
5	Regulator Term "B"	Regulator Case	1/2(++)	1/2(++)	3	3
5	Regulator Term "E"	Regulator Case	1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.5.11 The internal wiring from the transformer secondary circuit contacts the lead wires for the 7.5 ohm resistor, zener diodes and capacitor. This does not comply with paragraph 9.1 since positive separation is not provided between nonintrinsically safe and intrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, "MESAP"(9)

7.5.12 The field wiring connections for the transformer primary circuit are separated from bare live parts of the intrinsically safe circuits (at the diode heat sink) by a distance of 17 mm. This does not comply with the requirements for panel installed equipment in paragraph 11.1 which requires a separation of at least 50 mm. Additionally, this construction does not comply with paragraph 10.5 since field wiring of the transformer primary may intermingle with intrinsically safe wiring and transformer secondary wiring.

SOURCES OF IGNITION, PARAGRAPH 14.1, "MESAP"(9)

7.5.13 The type of horn, buzzer, solenoid or relay which is intended to be used in the hazardous area is not specified or limited. The device used may affect the intrinsic safety of the system. The type of device must be identified so this consideration can be made during Circuit Fault Analysis.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.5.14 Clear instructions are not provided concerning connection of the horn, buzzer, solenoid, or relay to the Power Supply output terminals. The instructions give neither minimum resistance, maximum inductance nor identification of a specific apparatus. This does not comply with paragraph 30.2.

7.5.15 The Power Supply is not marked with the MESA logo, the approval or certification number, and part number as required in paragraph 30.3.

7.5.16 The Power Supply is not marked with the statement "Any substitution of components may impair intrinsic safety" nor is it marked with specific requirements covering its installation as required in paragraph 30.5.

7.5.17 The intrinsically safe terminals of the Power Supply are not marked "Intrinsically Safe" as required in paragraph 30.7.

7.5.18 The polarity of the output terminals is not marked as required in paragraph 30.9.

7.5.19 DIELECTRIC WITHSTAND TESTS

Test previously conducted with acceptable results, see paragraph 6.5.26.

7.5.20 CURRENT LIMITING RESISTOR TESTS

Test previously conducted with acceptable results, see paragraph 6.5.27.

7.5.21 PROTECTIVE DIODE ABNORMAL TESTS

Test previously conducted with acceptable results, see paragraph 6.5.28.

7.5.22 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test previously conducted with unacceptable results, see paragraph 6.5.29.

7.5.23 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test. See paragraph 6.5.29.

7.5.24 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests. In the analysis, two simultaneous independent faults of components (except protective components) field wiring, and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the unspecified horn, buzzer, solenoid or relay is to be located in the hazardous area. The Power Supply is intended to be housed in an explosion-proof enclosure.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Component		
Type	Designation	Remarks
Transformer	TR12463	Note 1
Resistor	RH-50	
Diode	1N3314A	

Note -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance test, see paragraph 6.5.29. The construction did not meet the applicable construction requirements, see paragraph 7.5.7.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.5.22.

7.5.25 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Falut Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constand head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 120 v ac, before introduction of any test (safety) factor.

The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply Terminals 1 and 3, Figure 5	No faults introduced. (+)
2	Power Supply Terminals 1 and 3, Figure 5	Short regulator MLM309K from Terminal E to B, (no fault) due to short spacings, see paragraph 7.5.10. (+)
3	Power Supply Terminal 3, Figure 5 to Ground	Short AC rectifier term from transformer Terminal X2 to ground (one fault) due to short spacings, see paragraph 7.5.10.
4	Power Supply Terminals 1 and 3, Figure 5	A 1.005 mh, 0.126 ohm coil connected in series with Terminals 1 and 3 and the test mechanism. The coil was used to simulate an unspecified field connected device.
5	Power Supply Terminals 2 and 3, Figure 5	Open range Resistor RX (one fault) and short Regulator MLM309K from Terminals B to C (no fault) due to short spacings, see paragraph 7.5.10. (+)
6	Power Supply Terminal 3, Figure 5 to Ground	Short transformer primary to secondary (one fault) and short Rectifier "X1" Terminal to "-DC" Terminal (one fault). (++)

(+) - Circuit was simulated since the test (safety) factor could not be introduced on the test sample.

(++) - This condition shorts the 120 v line circuit to the intrinsically safe Terminal 3. Assuming the use of a 120 v grounded source, arcing the intrinsically safe circuit to ground arcs the 120 v supply to ground.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Wire Type	Wire Diameter, Mil	Opwn Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	Spark Test Mechanism Calibration Cycles After Test
1	0	1.1	1.5*	Cadmium	Tungsten	8	12.36	2.85	400	No Ignition	3	29
2	0	1.1	1.5*	Cadmium	Copper	8	14.62	3.57	400	No Ignition	17	3
3	1	1.1	1.0	Cadmium	Copper	8	23.5	15.5	-	Note 1	-	-
4	0	1.1	1.5***	Cadmium	-	-	14.62	1.56	--	Note 2	-	-
5	1	1.1	1.5**	Cadmium	Tungsten	8	19.82	2.81	400	No Ignition	15	2
6	2	1.1	1.0	Cadmium	-	-	132	Note 3	-	Note 4		

* Factor applied by decreasing the value of limiting resistance.

** Factor applied by increasing the voltage by 1.225.

*** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of a test (safety) factor.

Notes -

1. Test not conducted since this test circuit previously caused ignition of methane air mixture, see paragraph 6.5.32.

2. Test not conducted since this circuit previously caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0. See paragraph 5.5.22.

3. Current limited only by capacity of source.

4. Test not conducted since test conditions are more severe than test No. 3.

The results do not comply with the requirements in "MESAP"(9) since ignition of gas air mixture was obtained.

7.6 GENERAL MONITORS, MODEL 420 METHANE MONITOR, ITEM 2

Product Description

7.6.1 Model 420 Methane Monitoring System, manufactured by General Monitors, Inc. of Costa Mesa, California. The system consists of a Power Supply/Cutoff Relay, Serial No. 8080-4008 (Figure 6), Control Indicator Unit, Part No. 18-00-810-1 (Figure 7) and a Remote Sensing Head, Part No. 18-00-823-1 (Figure 7). The Power Supply/Cutoff Relay is intended to be mounted within an explosion-proof enclosure and has circuits to provide power to the Control Indicator Unit. The Control Indicator Unit is provided with an explosion-proof enclosure and has circuits claimed to be intrinsically safe which are connected to the Sensor Head. The Power Supply is rated 550 v, 60 Hz maximum input.

7.6.2 A complete sample system along with additional component parts were purchased through the National Mine Service Company of Nashville, Illinois, a local distributer for the equipment. The samples were subjected to the examination and tests described below.

7.6.3 Electrical schematics for the equipment are shown in Figures 6 and 7. The ground symbol used in Figure 7 is actually the circuit common. It is not grounded to the enclosure.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP" (9)

ELECTRICAL COMPONENTS

7.6.4 The Part No. PM-1191 relay could not be identified as being UL Listed or Recognized.

CORROSION PROTECTION

7.6.5 The Power Supply base is a steel plate. The plate is not painted or plated to resist corrosion. This does not comply with paragraph 99 of UL 913(7). See Appendix B.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.6.6 Protective Transformer.

7.6.6.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen of copper foil between the windings, it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements for a Type 2A transformer since it is not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

7.6.7 Shunt Safety Components.

7.6.7.1 The 10 ohm wire wound resistor appears to be intended as a relay coil (K1) shunt safety component. The expected failure mode for a wire wound resistor is open circuit and the resistor is not duplicated so that the assembly remains safe if one resistor becomes defective. This does not comply with paragraphs 3.14 and 5.16.

SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.6.8 Any spacing including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 7.6.25 unless the spacings are greater than or equal to those given in Table 8.1A for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being a fault.

7.6.9 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined.

7.6.10 <u>Tabulation of Electrical Spacings</u>

Fig.	Spacings: From	Spacings: To	Provided, MM: Through Air	Provided, MM: Over Surface	Required, MM: Through Air	Required, MM: Over Surface
7	Printed wiring for Terminal 1, TB2 Control Indicator Unit, Secondary Circuit	Printed wiring for Terminal 6 TB2 Control Indicator Unit, Secondary Circuit	1/2(++)	1/2(++)	3	3
7	Printed wiring for Pin 14, I.C. A2 Control Indicator Unit, Secondary Circuit	Printed wiring for Terminal 6 TB2 Control Indicator Unit, Secondary Circuit	1/2(++)	1/2(++)	3	3
7	Printed wiring for Terminal 4, TB2 Control Indicator Unit, Secondary Circuit	Printed wiring for Terminal 6, TB2 Control Indicator Unit, Secondary Circuit	1/2(++)	1/2(++)	3	3
7	Relay Coil Circuits Terminals	Relay N.O. Contact Circuits, Line Volts	-	14(+)	10	25
6	Relay N.C. Contact Terminal, Line Volts Connected to Terminal 3 Circuit	Relay N.C. Contact Terminal, Secondary Circuit Connected to Terminal 5 Circuit	4-1/2(+)	10(+)	10	25
6	Relay N.O. Contact Terminal, Line Volts Connected to Terminal 3 Circuit	Relay N.O. Contact Terminal, Secondary Circuit Connected to Terminal 5 Circuit	7(+)	10(+)	10	25
6	Relay Contact Wiper Terminal, Line Volts Connected to Terminal 3 Circuit	Relay Contact Wiper Terminal, Secondary Circuit Connected to Terminal 5 Circuit	6(+)	10(+)	10	25
6	Relay Contact Wiper, Line Volts Connected to Terminal 3 Circuit	Relay Contact Wiper, Secondary Circuit Connected to Terminal 5 Circuit	8(+)	11(+)	10	25

7.6.10 Tabulation of Electrical Spacings (Cont'd)

Fig.	Spacings: From	Spacings: To	Provided, MM: Through Air	Provided, MM: Over Surface	Required, MM: Through Air	Required, MM: Over Surface
6	Relay N.C. Contact Terminal, Line Volts Connected to Terminal 3 Circuit	Relay N.C. Contact Terminal, Secondary Circuit Connected to 11.5 v Transformer Lead	6(+)	10(+)	10	25
6	Relay N.O. Contact Terminal, Line Volts Connected to Terminal 3 Circuit	Relay N.O. Contact Terminal, Secondary Circuit Connected to 11.5 v Transformer Lead	8(+)	10(+)	10	25
6	Relay Contact Wiper Terminal, Line Volts Connected to Terminal 3 Circuit	Relay Contact Wiper Terminal, Secondary Circuit Connected to 11.5 v Transformer Lead	6(+)	10(+)	10	25
6	Relay Contact Wiper, Line Volts Connected to Terminal 3 Circuit	Relay Contact Wiper, Secondary Circuit Connected to 11.5 v Transformer Lead	8(+)	11(+)	10	25

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

7.6.11 The application of adherent insulating material to the Control Indicator Unit printed wiring board was not uniform since some areas were not coated. The insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore cannot be relied upon in lieu of spacings in accordance with Footnote b of Table 8.1A.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.6.12 In the Power Supply, the internal wiring of the line voltage relay contact circuit is intermingled with transformer secondary conductors. This does not comply with paragraph 9.1 since positive separation is not provided between nonintrinsically safe circuits and circuits which may affect intrinsic safety.

7.6.13 The unused, uninsulated transformer primary wiring tap leads may contact transformer secondary wiring or uninsulated conductive parts of secondary circuits. This does not comply with paragraph 9.1 since positive separation is not provided between nonintrinsically safe circuits and circuits which may affect intrinsic safety.

7.6.14 The intrinsically safe wiring in the Control Indicator Unit is intermingled with wiring of other secondary circuits. This does not comply with paragraph 9.1 since positive separation is not provided between intrinsically safe circuits and nonintrinsically safe circuits.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.6 AND 11.1-11.2, "MESAP"(9)

7.6.15 Field wiring conductors for the intrinsically safe circuits may be intermingled with field wiring conductors for line voltage circuits and uninsulated live parts of line voltage circuits since all field wiring is completed on the same terminal block. This does not comply with paragraph 10.5.

SOURCES OF IGNITION, PARAGRAPH 14.1, "MESAP"(9)

7.6.16 Interconnection of the Power Supply to the Control Indicator Unit is accomplished by means of a five conductor cable of which only three conductors are used. The additional conductors provided may be connected to unspecified auxiliary equipment which is not supplied with the system. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe. The auxiliary equipment should be identified so this consideration can be made during Circuit Fault Analysis. Additionally, when the auxiliary equipment is not used, the uninsulated ends of these conductors may contact uninsulated transformer primary wiring or uninsulated relay coil contact circuit wiring in the Power Supply and uninsulated intrinsically safe wiring in the Control Indicator Unit.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.6.17 Clear instructions are not provided concerning connections to remote meter/recording terminals. The instructions give neither minimum resistance, maximum inductance nor identification of a specific apparatus. This does not comply with paragraph 30.2.

7.6.18 The Power Supply/Cutoff Relay and Remote Sensing Head are not marked with the MESA logo and the approval or certification number as required in paragraph 30.3.

7.6.19 The Remote Sensing Head is not marked with the statement "Any substitution of components may impair intrinsic safety" as required in paragraph 30.5.

7.6.20 The Power Supply/Cutoff Relay and Control Indicator Unit are not marked with the statement "Any substitution of components may impair intrinsic safety" nor are they marked with specific requirements covering their installation as required in paragraph 30.6.

7.6.21 The intrinsically safe terminals of the Control Indicator Unit and the input connections of the Remote Sensing Head are not marked "Intrinsically Safe" as required in paragraph 30.7.

Test Record

7.6.22 DIELECTRIC WITHSTAND TEST

Test was previously conducted with acceptable results. See paragraph 6.6.29.

7.6.23 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test was previously conducted with unacceptable results. See paragraph 6.6.31.

7.6.24 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test. See paragraph 6.6.31.

7.6.25 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components) and field wiring, and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the remote Sensing Head is to be located in the hazardous area. The Power Supply/Cutoff Relay is intended to be housed in an explosion-proof enclosure. The control Indicator unit is housed in an explosion-proof enclosure.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Component		
Type	Designation	Remarks
Transformer	1209-1	Note 1
Resistor	R8	Note 2

Note -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance tests, see paragraph 6.6.31 and the construction did not meet the applicable construction requirements, see paragraph 7.6.6.1.

2. The resistor may be open-circuited during spark ignition testing since the resistor did not meet the requirements for shunt safety components, see paragraph 7.6.7.1.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.6.26 and representative components were selected for thermal ignition tests.

7.6.26 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Current	
V, DC	Current	Inductor, mh
24	100	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 600 v ac before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit	Test Point	Circuit Description
1	Control Indicator Unit, Terminals 6 and 8, TB2, Figure 7	Open Circuit Resistor R8 (one fault).
2	Control Indicator Unit, Terminals 6 and 8, TB2, Figure 7	Terminal 6, TB2 shorted to Terminal 1, TB2 (no fault) due to short spacings, see paragraph 7.6.10.
3	Control Indicator Unit, Terminals 6 and 8, TB2, Figure 7	Terminal 4, TB2 shorted to Terminal 6, TB2 (no fault), due to short spacings, see paragraph 7.6.10.
4	Control Indicator Unit, Terminal 6, Figure 7 and Ground	Terminal 6, TB2 shorted to Terminal 1, TB2 (no fault) due to short spacings, see paragraph 7.6.10 and short transformer primary to secondary (one fault). (+)

(+) - This condition shorts the 550 v ac line circuit to intrinsically safe Terminal 6. Assuming the use of a 550 v ac grounded source, arcing the intrinsically safe circuit to ground arcs the 550 v ac supply to ground.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Open Circuit, Volts	Short Circuit, Ma	Results
1	1	1.1	1.5*	Cadmium	26.6	0.957	Note 1
2	0	1.1	1.5*	Cadmium	22.0	28.9	Note 1
3	0	1.1	1.5*	Cadmium	17.00	0.479	Note 1
4	1	1.1	1.0	Cadmium	660	Note 3	Note 2

* The open circuit volts and short circuit current indicated reflect the addition of a test (safety) factor.

Note -

1. Test not conducted since this test circuit previously caused ignition of methane air mixture, see paragraph 6.6.34.

2. Test was not conducted since test conditions are more severe than Test Nos. 1, 2 and 3.

3. Current limited by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition of the gas air mixture was obtained.

7.6.27 Component Overload and Strand of Wire Tests were not conducted since results in paragraph 6.6.34 indicate that circuits which extend into the hazardous location are not intrinsically safe.

7.7 BENDIX METHANE DETECTION SYSTEM, PART NO. 2417032, ITEM 4

Product Description

7.7.1 Methane Monitoring System, Part No. 2417032-1000, manufactured by the Bendix Corporation, Environmental Science Division in Baltimore, Maryland. The System consists of a Control Assembly, Series 2415899, provided with an explosion-proof housing (Figures 8 and 9), a Relay Assembly, Part No. 2417030 intended to be mounted in an explosion-proof enclosure and Detector Assembly Part No. 2415905-0003. The Control Assembly incorporates the Power Converter Control and Readout Circuitry. The Control Assembly has circuits claimed to be intrinsically safe (Terminals 1, 2 and 3, Figure 9) which are connected to the Detector Assembly, claimed to be intrinsically safe. The Detector Assembly houses a sensing cell intended to sense the presence of methane in air.

7.7.2 A complete sample system along with additional component parts were purchased through the Preiser Mine Company in St. Albans, West Virginia, a distributer for the equipment in this area. The samples were subjected to the examination and tests described below.

7.7.3 Electrical schematics for the equipment are shown in Figures 8 and 9.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP"(9)

GENERAL

7.7.4 The Inductors L1 and L3 are mounted to the bottom plate of the Power Converter by means of epoxy. One of the inductors was loose in the sample received. This does not comply with paragraph 26 of UL 913(7). See Appendix B.

INTERNAL WIRING

7.7.5 The wiring material used in the Control Assembly has 1/64 in. thick insulation and cannot be identified as being UL Recognized Appliance Wiring Material. Additionally there is intermingling of conductors of primary circuits and secondary circuits. This does not comply with paragraphs 148-150 of UL 913(7), which requires the use of UL Recognized wiring material with at least 1/32 in. thick insulation. See Appendix B.

ELECTRICAL COMPONENTS

7.7.6 The Power Converter and Readout Circuitry printed wiring boards could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

7.7.7 The required spacings for circuits in the transformer primary are those shown in Column 301-600 v, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those shown in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

7.7.8 The over surface spacing between the 550 v, Pin 17 on the printed wiring board and a grounded mounting screw was measured to be 9/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which requires a spacing of 3/8 in.

7.7.9 The over surface spacing between the 550 v, Pin 18 on the printed wiring board and a grounded mounting screw was measured to be 3/16 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which requires a spacing of 3/8 in.

7.7.10 The through air spacing between 550 v live parts of the terminal board and the enclosure were measured to be 5/16 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of 1/2 in.

Intrinsically Safe Electrical Construction

7.7.11 Protective Transformers.

7.7.11.1 The transformers (Coils L2, L3 and L4) employed in the device were examined to determine if they could be considered protective components. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings in each sample examined, they may be considered as having Type 2A construction. The transformers are judged not to comply with applicable construction requirements for Type 2A construction since they were not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

7.7.12 Shunt Safety Components.

7.7.12.1 The Relay K1 coil is provided with a single shunt diode (see Figure 9). The diode is mounted to the Readout Circuitry printed wiring board adjacent to the relay. The diode is not duplicated so that the assembly remains safe if one diode becomes defective. This does not comply with paragraph 5.16 and was considered as subject to fault. See Circuit Fault Analysis paragraph 7.7.27.

SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.7.13 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 7.7.27, unless the spacings are greater than or equal to those given in Table 8.1A for the specific potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being counted as a fault.

7.7.14 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. All of these spacings were in the Power Converter Control Assembly, Figure 8, and in the Readout Circuitry, Figure 9.

7.7.15 Tabulation of Electrical Spacings

	Spacings		Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
9	Printed wiring for Pin 5, I.C. U7 in readout circuitry (R.C.)	Printed wiring for Pin 11, I.C. U7 in R.C.	1/2(++)	1/2(++)	3	3
9	Printed wiring for wiring station 21 in. R.C.	Printed wiring for Pin 9, I.C. U2 in R.C.	1/2(++)	1/2(++)	3	3
9	Printed wiring for wiring station 21 in. R.C.	Printed wiring for Pin 7, I.C. U2 in R.C.	1/2(++)	1/2(++)	3	3
9	Terminal C, Trans. Q2 in R.C.	Ground	1(+)	1(+)	3	3
9	Terminal C, Trans. Q3 in R.C.	Ground	1-1/2(+)	1-1/2(+)	3	3
9	Terminal C, Trans. Q4 in R.C.	Ground	1/2(++)	1/2(++)	3	3
9	Terminal C, Trans. Q6 in R.C.	Ground	1(+)	1(+)	3	3
9	Terminal C, Trans. Q8 in R.C.	Ground	1(+)	1(+)	3	3
9	Between all adjacent Terminals of I.C. U1		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C.U2		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U3		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U4		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U5		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U6		1/2(++)	1/2(++)	3	3
9	Between all adjacent Terminals of I.C. U7		1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

7.7.15 Tabulation of Electrical Spacings (Cont'd)

Fig.	Spacings: From	Spacings: To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
8	Printed wiring for Terminal C, Trans. Q5 in Power Converter (PC), Board A1, Primary	Printed wiring for Terminal 1A, in PC, Board A1, Secondary	6-1/2(+)	2-1/2(++)	10	25
8	Terminal C, Trans. Q5 in PC, Board A1, Primary	Terminal "+", Capacitor C8 in PC, Board A1, Secondary	4-1/2(+)	6(++)	10	25
8	Printed wiring for Fuse F1 in PC Board A1, Primary	Printed wiring for Terminal 1A in PC Board A1, Secondary	-	17(+)	10	25
8	Diode CR11 in PC Board A2, Primary	Terminal 1A in PC Board A1, Secondary	3(++)	-	10	25
8	Printed wiring for Terminal E, Trans. Q5 in PC Board A1, Primary	Printed wiring for Terminal 1A in PC Board A1, Secondary	-	5-1/2(++)	10	25
8	Printed wiring for Terminal B, Trans. Q5 in PC Board A1, Primary	Printed wiring for Terminal 1A PC Board A1, Secondary	-	18-1/2(+)	10	25
8	Printed wiring for Pin 13 in PC Board A1, Primary	Printed wiring for Fuse F2 in PC Board A1 Secondary	-	2-1/2(++)	10	25
8	Printed wiring for Pin 6 in PC Board A1, Primary	Printed wiring for Fuse F2 in PC Board A1, Secondary	-	3(++)	10	25
8	Terminal C, Trans. Q5 in PC Board A1, Primary	Terminal 2A in PC Board A1, Secondary	-	12-1/2(+)	10	25

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

7:7.15 Tabulation of Electrical Spacings (Cont'd)

Fig.	Spacings From	Spacings To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
8	Terminal C, Trans. Q5 in PC Board A1, Primary	Pin 19 in PC Board A1, Secondary	5(+)	5(++)	10	25
8	Terminal C, Trans. Q5 in PC Board A1, Primary	Fuse F3 in PC Board A1, Secondary	5-1/2(+)	5-1/2(++)	10	25
8	Pin 13 in PC Board A1, Primary	Capacitor C7 in PC Board A1, Secondary	-	9(+)	10	25
8	Resistor R5 in PC Board A1, Primary	Capacitor C7 in PC Board A1, Secondary	-	14(+)	10	25
8	Pin 6 in PC Board A1, Primary	Capacitor C7 in PC Board A1, Secondary	-	11-1/2(+)	10	25
8	Capacitor C5 in PC Board A2, Primary	Terminal 2A in PC Board A1, Secondary	6-1/2(+)	-	10	25
8	Pin 14 in PC Board A2, Primary	Terminal 1A in PC Board A1, Secondary	6-1/2(+)	-	10	25
8	Diode CR8 in PC Board A2, Primary	Capacitor C8 in PC Board A1, Secondary	9-1/2(+)	-	10	25
8	Terminal C, Trans. Q2 in PC Board A2, Primary	Capacitor C8 in PC Board A1, Secondary	9-1/2(+)	-	10	25
	Relay jumper wire, relay assy.	Relay coil terminal, relay assy.	0(++)	0(++)	6	15

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

7.7.16 The application of adherent insulating material to the Power Converter and Readout Circuitry printed wiring boards was not uniform since some areas were not coated. Also, the insulating materials equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore cannot be relied upon in lieu of spacings in accordance with Footnote b of Table 8.1A.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.7.17 The internal intrinsically safe conductors are routed together with nonintrinsically safe conductors. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe conductors.

7.7.18 In the power cable assembly for the device, the conductors for the primary power are routed with the conductors for the relay assembly coil. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe conductors and conductors which may affect intrinsic safety.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, "MESAP"(9)

7.7.19 In the Relay Assembly the field wiring conductors of line voltage relay contact circuits may be intermingled with field wiring conductors, factory-installed wiring and uninsulated live parts of secondary circuits which may affect intrinsic safety since all field wiring is completed on the same terminal block. This does not comply with paragraph 10.5.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.7.20 The Detector and Relay are not marked with the MESA logo, the approval or certification number, and the part number as required in paragraph 30.3.

7.7.21 The Detector and Relay are not marked with the statement "Any substitution of components may impair intrinsic safety" as required in paragraph 30.5.

7.7.22 The Control Assembly is not marked with the statement "Any substitution of components may impair intrinsic safety" nor is it marked with specific requirements covering its installation as required in paragraph 30.6.

7.7.23 The Control Assembly output receptacle, the Detector plug, and the Relay terminals are not marked "Intrinsically Safe" as required in paragraph 30.7.

Test Record

7.7.24 DIELECTRIC WITHSTAND TEST

Test previously conducted with acceptable results, see paragraph 6.7.30.

7.7.25 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test previously conducted with acceptable results, see paragraph 6.7.32.

7.7.26 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test previously conducted with acceptable results, see paragraph 6.7.33.

7.7.27 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Detector Assembly is to be located in the hazardous area. The remaining parts of the system including Control Assembly and Relay Assembly are housed in explosion-proof enclosures.

B. From examination of the equipment it appears that the following components are intended to be protective components.

Component		
Type	Designation	Remarks
Transformers (Isolation Coils)	L2, L3, and L4	Note 1
Diode	5A2	Note 2

Notes -

1. The Power Converter isolation coils may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable construction requirements, see paragraph 7.7.11.1. The transformers did not meet the applicable performance test, see paragraph 6.7.32.

2. The diode may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 7.7.12.

C. In the Power Converter, the conductor marked with the conventional symbol for ground, was not grounded to the enclosure.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.7.28.

7.7.28 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the control assembly for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 600 v ac before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable position so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

Circuit No.	Test Point	Circuit Description
1	Control Assembly Terminals 1 and 3, Figure 9	Short I.C.U3 Pin 11 to Pin 3 (one fault). (+)
2	Control Assembly Terminals 1 and 3, Figure 9	Short I.C.U3, Pins 12 to 3 (one fault) and short I.C.U1, Pins 12 to 3 (one fault).
3	Control Assembly Terminals 1 and 3, Figure 9	Short Resistor R2 (no fault) due to short spacings between wiring Station 21 to Pin 7 of I.C.U.2 and Short U7, Pin 3 to 4 (no fault) due to short spacings, see paragraph 7.7.15.
4	Control Assembly Terminals 1 and 3, Figure 9	Short I.C.U3, Pins 12 to 3 (one fault) and short I.C.U7, Pins 11 to 4 (no fault) due to short spacing between Pin 11 to Pin 5 to 4 of U7, see paragraph 7.7.15. (+)
5	Control Assembly Terminal 3 to Ground, Figure 9	Short Terminal C of Transistor Q4 to ground (no fault), due to short spacings, open Diode CR9, (one fault) and open Transistor Q4 collector (one fault).
6	Control Assembly Terminals 1 and 3, Figures 8 and 9	Short Diode CR11 to Terminal 1A (no fault) due to short spacings, and in the control assembly readout circuitry Short I.C.U1, Pin 12 to 3 (one fault) and Short I.C.U7, Pin 11 to Pin 4 (no fault) due to short spacings between Pin 11 to 5 to 4 of U7, see paragraph 7.7.15.

(+) - Circuit was simulated to enable introduction of the test (safety) factor.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Wire Type	Wire Diameter, Mil	Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	Spark Test Mechanism Calibration Cycles After Test
1	1	1.1	1.5*	Cadmium	Copper	8***	6.3	30.15	10	Ignition	20	-
2	2	1.1	1.5**	Cadmium	-	-	20.6	2.36	-	Note 1	-	-
3	0	1.1	1.5**	Cadmium	-	-	20.6	2.36	-	Note 2	-	-
4	1	1.1	1.5**	Cadmium	-	-	20.6	2.36	-	Note 2	-	-
5	2	1.1	1.5	Cadmium	-	-	-	-	-	Note 3	-	-
6	1	1.1	1.0	Cadmium	-	-	660 AC	Note 4	-	Note 2	-	-

* Factor applied by increasing the test current.

** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

*** The test was not conducted using a 4 mil strand of wire since the required 95 percent of the source voltage, at the maximum short circuit, could not be attained per paragraph 19.5 of "MESAP".

1. Test not conducted since this circuit previously caused ignition of methane air mixture, see paragraph 6.7.35.

2. Test not conducted since test conditions are more severe than Test No. 2.

3. Test not conducted since readout assembly was damaged during fault analysis.

4. Current limited only by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition gas-air mixture was obtained.

7.7.29 Strand of wire and component burnout tests were not conducted since results in paragraph 6.7.35 indicate that the circuits which extend into the hazardous location are not intrinsically safe.

7.8 APPALACHIAN, MODEL 102A METHANE MONITOR, ITEM 7

Product Description

7.8.1 Model 102A Methane Monitoring System, manufactured by Appalachian Electronic Instruments, Inc. of Ronceverte, West Virginia. The System consists of an AC Power Supply/Shutdown Relay Unit, Part No. 7163 (Figure 16), an Amplifier Readout Unit, Part No. 7158, and Detector, Part No. 7162. The AC Power Supply/Shutdown Relay unit intended to be mounted within an explosion-proof enclosure has circuits claimed to be intrinsically safe which are connected to the Amplifier Readout Unit and Detector, each claimed to be intrinsically safe. The AC Power Supply is rated 575 v ac input maximum.

7.8.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP"(9)

INTERNAL WIRING

7.8.3 The transformer primary lead wires have 1/64 in. thick insulation with an outer braid. These leads were identified as UL Recognized Appliance Wiring Material rated 105 C, 300 v maximum. The 300 v rated leads are not considered to be acceptable since one of the leads may be connected to 575 and 480 v and since all of the leads are bunched together for routing. All of the leads are required to be insulated for the maximum voltage of 600 v in accordance with paragraphs 148-150 of UL 913(7). See Appendix B.

7.8.4 The internal wiring from the transformer primary fuse to the field wiring terminal for the transformer neutral has 1/64 in. thick insulation. This lead could not be identified as UL Recognized Appliance Wiring Material. This does not comply with paragraphs 148-150 of UL 913(7), which require that this lead be insulated for the maximum voltage of 600 v. See Appendix B.

7.8.5 The internal wiring between the relay contact circuits and the field wiring terminal block has 1/64 in. thick insulation. These leads could not be identified as UL Recognized Appliance Wiring Material. It is assumed that the contact circuits are rated for the same maximum voltage as the transformer, 600 v, since the voltage rating was not provided. This does not comply with paragraphs 148-150 of UL 913(7), which require that these leads be insulated for the maximum voltage of 600 v since the contact circuits may be rated 600 v and since the conductors are routed with 600 v transformer primary conductors. See Appendix B.

ELECTRICAL COMPONENTS

7.8.6 The AC Power Supply printed wiring board could not be identified as being UL Recognized.

7.8.7 The fuseholder Cat. No. 342 72 could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

7.8.8 The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). For the purposes of measuring electrical spacings of the Shutdown Relay contact circuits, it was assumed that the relay contacts have the same voltage rating as the AC Power Supply, since the ratings were not provided. See Appendix B.

7.8.9 The through air spacing between the uninsulated, line voltage terminal on the Shutdown Relay contact circuit and the grounded metal frame was measured to be 5/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require 3/16 in. minimum. It should be noted that in the event that the relay contact circuit ratings exceed 2 kva, the through air spacing required would be 3/8 in. minimum.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.8.10 Protective Transformer.

7.8.10.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is no grounded screen or copper foil between the windings, it may be considered as having Type 2A construction. The transformer is judged not to comply with applicable construction requirements since it was not constructed with thermal insulation between the input and output windings, including splices and crossover leads, as required in paragraph 5.9A.

7.8.11 Shunt Safety Components.

7.8.11.1 The relay coil is provided with two shunt diodes, see Figure 16. The diodes are mounted to a printed wiring board and connected to the coil with separate lead wires. The diodes are connected across the coil in such a manner that they may be disconnected from the circuit leaving the coil in the circuit. This does not comply with paragraph 5.16 and was considered as subject to fault. See Circuit Fault Analysis paragraph 7.8.25.

SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.8.12 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 7.8.25, unless the spacings are greater than or equal to those given in Table 8.1A for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being counted as a fault.

7.8.13 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. These spacings were all located in the Power Supply, Figure 16.

7.8.14 Tabulation of Electrical Spacings

	Spacings		Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
16	Rectifier "+" Terminal	Ground	1-1/2(+)	1-1/2(+)	3	3
16	Rectifier "+" Terminal	LM-340-12 Terminal "E"	-	1-1/2(+)	3	3
16	Primary Fuse F1	Secondary Fuse	3-1/2(+)	-	10	25
16	Relay Coil Contact Circuit	Relay Coil Circuit	7(+)	8(++)	10	25
16	Transistor TP55, Terminal "C"	Transistor TP55, Terminal "B"	1(+)	1(+)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.8.15 The internal wiring for the coil shunt diodes is bunched together and held with wire ties, with line voltage conductors for relay contacts, for routing. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe circuits and the secondary circuits which may affect intrinsic safety.

7.8.16 The internal wiring for the neutral wire in the transformer primary circuit is routed with transformer secondary conductros. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe circuits and secondary circuits which may affect intrinsic safety.

FIELD WIRING CONNECTIONS, PARAGRAPHS 10.1-10.6 AND 11.1-11.2, "MESAP"(9)

7.8.17 The wiring terminals for intrinsically safe and nonintrinsically safe circuits are separated by a distance of at least 50 mm. This complies with the requirements for panel installed equipment. However, clear installation instructions regarding wire routing and field connections are not provided. This does not comply with paragraph 11.1.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.8.18 The Power Supply and Detector are not marked with MESA logo and the approval or certification number as required in paragraph 30.3.

7.8.19 The Amplifier Readout Unit and the Detector are not marked with the statement "Any substitution of components may impair intrinsic safety" as required in paragraph 30.5.

7.8.20 The Power Supply is not marked with the statement "Any substitution of components may impair intrinsic safety" nor is it marked with specific requirements covering its installation as required in paragraph 30.6.

7.8.21 The intrinsically safe terminals of the Power Supply, the input and output connections of the Amplifier Readout Unit, and the input connection of the Detector are not marked "Intrinsically Safe" as required in paragraph 30.7.

Test Record

7.8.22 DIELECTRIC WITHSTAND TEST

Test previously conducted with acceptable results, see paragraph 6.8.28.

7.8.23 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test previously conducted with acceptable results, see paragraph 6.8.30.

7.8.24 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test previously conducted with unacceptable results, see paragraph 6.8.31.

7.8.25 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Amplifier Readout Unit and Detector are to be located in the hazardous area. The remaining part of the system (associated equipment), the AC Power Supply/Shutdown Relay Unit is intended to be housed in an explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Component		
Type	Designation	Remarks
Transformer	DX-690A	Note 1
Diodes	1N4937	Note 2

Notes -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable construction requirements, see paragraph 7.8.10.1. The transformer did not meet the applicable performance test, see paragraph 6.8.31.

2. The diodes may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 7.8.11.1.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.8.26 and representative components were selected for thermal ignition tests.

7.8.26 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the power supply for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply Terminals 1 and 3, Figure 16	No faults introduced. (+)
2	Power Supply Terminals 1 and 3, Figure 16	Short regulator LM-340-12 from B to E (one fault).
3	Power Supply Terminals 1 and 3, Figure 16	Short regulator LM-340-15 from B to E (one fault).
4	Power Supply Terminals 1 and 3, Figure 16	Short rectifier "+" terminal to regulator LM-340-12 Terminal E (one fault) due to short spacings, see paragraph 7.8.14.
5	Power Supply Terminal 3 and Ground, Figure 16	Short rectifier "+" terminal to ground (one fault) due to short spacings, see paragraph 7.8.14.
6	Power Supply Terminal 3 and Ground, Figure 16	Short transformer primary to secondary (one fault) due to short spacings, see paragraph 7.8.14.
7	Power Supply Terminal 1 and Ground, Figure 16	Short relay contact circuit to coil (no fault) due to short spacings, see paragraph 7.8.14.
8	Power supply Terminals 2 and 3, Figure 16	Short rectifier "+" terminal to regulator LM-340-12 Terminal E (one fault) short Transistor TP55C to B (one fault), both due to short spacings, see paragraph 7.8.14 above and open one coil shunt diode (no fault).

(+) - Circuit was simulated to introduce test (safety) factor.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Wire Type	Wire Diameter, Mil	Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	Spark Test Mechanism Calibration Cycles After Test
1	0	1.1	1.5*	Cadmium	Copper	6	12.20	3.26	400	No Ignition	2	2
2	1	1.1	1.5**	Cadmium	-	-	15.43	0.31	-	Note 1	-	-
3	1	1.1	1.5**	Cadmium	-	-	12.15	0.55	-	Note 1	-	-
4	1	1.1	1.5	Cadmium	-	-	-	-	-	Note 2	-	-
5	1	1.1	1.5	Cadmium	-	-	-	-	-	Note 2	-	-
6	1	1.1	1.0	Cadmium	-	-	660	Note 3	-	Note 2	-	-
7	0	1.1	1.0	Cadmium	-	-	660	Note 3	-	Note 2	-	-
8	2	1.1	1.5	Cadmium	-	-	-	-	-	Note 2	-	-

* Factor applied by increasing the value of test current.

** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0, see paragraph 5.8.25.

2. This test was not conducted since test conditions are more severe than Test Nos. 2 and 3.

3. Current limited by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition of the gas air mixture was obtained.

7.8.27 Component Overload, Transistor Thermal Runaway, Protective Diode Abnormal and Strand of Wire Tests were not conducted since results in paragraph 6.8.33 indicate that the circuits which extend into the hazardous location are not intrinsically safe.

7.9 BACHARACH, MINNIE METHANE MONITORING, SYSTEM, ITEM 6

Product Description

7.9.1 Minnie Monitor System, manufactured by the Bacharach Instrument Company, Division of AMBAC Industries, Inc. of Pittsburgh, Pennsylvania. The System Part No. 23-7582 consists of an AC Power Supply, Part No. 23-7282 (Figure 10), a Readout Enclosure Assembly, Part No. 23-7298, a Detector Head Assembly, Part No. 23-7288 and a Power Cutoff Relay, Part No. 04-5196 (Figure 11). The AC Power Supply and Power Cutoff Relay are mounted together in an explosion-proof housing. The Power Supply has circuits claimed to be intrinsically safe which are connected to the Readout Enclosure Assembly, and Detector Head Assembly each claimed to be intrinsically safe. The Power Supply is rated 550 v, 60 Hz input, 4 v dc output.

7.9.2 A complete sample of the system along with additional component parts were purchased from the manufacturer since a distributer for this device is not available in this area, and subjected to the examination and tests described below.

7.9.3 Electrical schematics for the equipment are shown in Figures 10 and 11.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP"(9)

INTERNAL WIRING

7.9.4 The internal wiring of the Power Supply has 1/64 in. thick insulation and could not be identified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148 and 149 of UL 913(7), which requires the use of UL Recognized wiring having at least 1/32 in. thick insulation. See Appendix B.

ELECTRICAL COMPONENTS

7.9.5 The printed wiring board employed in the Power Supply could not be identified as being UL Recognized.

7.9.6 The Part No. PR80060-1 relay could not be identified as being UL Listed or Recognized.

ELECTRICAL SPACINGS

7.9.7 The required spacings for circuits in the transformer primary are those shown in 301-600 v, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those shown in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

7.9.8 The through air spacing between 550 v terminal on the printed wiring board and the enclosure was measured to be 15/64 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/2 in.

7.9.9 The over surface spacing on the printed wiring board of the power supply between the uninsulated soldered terminal connections for the 550 v and the 480 v line voltage connections was measured to be 5/32 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

7.9.10 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered terminal connections for the 480 v and the 440 v line voltage connections was measured to be 3/16 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

7.9.11 The over surface spacing on the printed wiring board of the power supply, between the uninsulated soldered terminal connections for the 440 v and the 240 v line voltage connections was measured to be 3/16 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 3/8 in.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.9.12 Protective Transformer.

7.9.12.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is a grounded screen between the windings, it may be considered as having Type 2B construction. The transformer is judged not to comply with the applicable construction requirements for Type 2B transformers since only one and not two grounding leads are provided (paragraph 5.9B-2) and since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg.

7.9.12.2 The fuses provided in the supply circuit, one in each leg, are interchangeable with fuses having a higher ampere rating. This does not comply with paragraph 5.3 which requires the use of noninterchangeable fuses only.

7.9.12.3 The grounding lead provided was determined to be No. 26 Awg, therefore a special short circuit test is required to determine that the lead can withstand without damage, the current that flows before the fuse operates. The fuses intended to be used with the device are rated 2 amp. The type of fuse used can be interchanged with a fuse having a rating of up to 30 amp. The short circuit test was not conducted since the device was not intended for use with a 30 amp fuse, which would have been used for the test.

7.9.12.4 The Type 2B transformer does not require a Protective Transformer Abnormal Operation Test. A Type 2B transformer which complies with all the construction features except is provided with only one grounding lead and is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction. Transformers having Type 3 constructions are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted as described in paragraph 6.9.35.

7.9.13 Shunt Safety Components.

7.9.13.1 The relay coil is provided with two shunt diodes, connected back-to-back in series (see Figure 11). The diodes are connected directly across the coil terminals with closed loop crimp on connectors. The diodes are not duplicated so that the assembly remains safe if one diode becomes defective (open circuit). This does not comply with paragraph 5.16 and was considered as subject to fault. See Circuit Fault Analysis paragraph 7.9.31.

<u>SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)</u>

7.9.14 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 7.9.31, unless the spacings are greater than or equal to those given in Table 8.1A for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being counted as a fault.

7.9.15 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. These spacings were on the Power Supply printed wiring board, Figure 10 and on the Readout Enclosure printed wiring board, Figure 11.

7.6.16 Tabulation of Electrical Spacings

Fig.	Spacings From	Spacings To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
10	Primary Terminal 6	Transistor Q1, Terminal C, Secondary	-	10-1/2(+)	10	25
10	Primary Terminal 1	Transistor Q1, Terminal C, Secondary	-	12(+)	10	25
10	Primary Terminal 5	Transistor Q1, Terminal C, Secondary	2(++)	2(++)	8	18
10	Primary Terminal 4	Transistor Q1, Terminal C, Secondary	7(+)	7(+)	8	18
10	Primary Terminal 3	Transistor Q1, Terminal C, Secondary	5(+)	5(+)	6	10
10	Transistor Q1, Terminal C, Secondary	Ground	1/2(++)	1/2(++)	3	3
10	Transistor Q1, Terminal E, Secondary	"+" 4 V DC Output Terminal Red, Intrinsically Safe	1-1/2(+)	1-1/2(+)	3	3
10	Transistor Q1, Terminal C, Secondary	Transistor Q1, Terminal E, Secondary	1/2(++)	1/2(++)	3	3
10	Transistor Q1, Terminal C, Secondary	Transistor Q1, Terminal B, Secondary	1/2(++)	1/2(++)	3	3
11	Terminal 5A, Readout Enclosure (R.E.)	Pin 2 on Chip A, R.E.	1/2(++)	1/2(++)	3	3
11	Pin 2 on Chip A, R.E.	Pin 13 on Chip A, R.E.	1/2(++)	1/2(++)	3	3
11	Pin 13 on Chip A, R.E.	Pin 15 on Chip A, R.E.	1/2(++)	1/2(++)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

7.9.17 The application of adherent insulating material to the Power Supply and Readout Enclosure printed wiring boards was not uniform since some areas were not coated. The insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore can not be relied upon in lieu of spacings in accordance with Footnote b of Table 8.1A.

7.9.18 The Power Supply and Readout Enclosure printed wiring boards were provided with an adhesive-backed sponge rubber material approximately 1/8 in. thick attached to the foil side of the boards. This construction is not considered as suitable to provide spacings since the insulating material's equivalency to epoxy could not be determined and since this construction may result in air pockets around the printed wiring conductors.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.9.19 The internal wiring of transformer secondary circuits contacts internal wiring of transformer primary circuits. This does not comply with paragraph 9.1 since positive separation is not provided between the circuits which may affect the intrinsically safety and nonintrinsically safe circuits.

7.9.20 The internal wiring of the intrinsically safe circuits contacts wiring of primary circuit conductors and line voltage relay contact circuits. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

SOURCES OF IGNITION, PARAGRAPH 14.1, "MESAP"(9)

7.9.21 The type of remote auxiliary recorder which is intended to be used with this system is not specified or limited. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe. The remote auxiliary recorder must be identified so this consideration can be made during Circuit Fault Analysis.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.9.22 Clear instructions are not provided concerning connections to remote meter/recording terminals. The instructions give neither minimum resistance, maximum inductance nor identification of a specific apparatus. This does not comply with paragraph 30.2.

7.9.23 The Detector was not marked with the manufacturer's name, MESA logo, the approval or certification number, and the part number as required in paragraph 30.3.

7.9.24 The Readout Enclosure and the Detector are not marked with the statement "Any substitution of components may impair intrinsic safety" as required in paragraph 30.5.

7.9.25 The Power Supply is not marked with the statement "Any substitution of components may impair intrinsic safety" nor is it marked with specific requirements covering its installation as required in paragraph 30.6.

7.9.26 The output receptacle of the Power Supply, the input plug and output receptacle of the Readout Enclosure, and the Detector plug are not marked "Intrinsically Safe" as required in paragraph 30.7.

7.9.27 The polarity of the power supply output terminals is not marked as required in paragraph 30.9.

<u>Test Record</u>

7.9.28 <u>DIELECTRIC WITHSTAND TEST</u>

Test previously conducted with acceptable results, see paragraph 6.9.33.

7.9.29 <u>PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST</u>

Test previously conducted with unacceptable results, see paragraph 6.9.35.

7.9.30 <u>PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST</u>

Test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test. See paragraph 6.9.35.

7.9.31 <u>PROTECTIVE DIODE ABNORMAL TEST</u>

Test previously conducted with acceptable results, see paragraph 6.9.37.

7.9.32 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring, and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. The Readout Enclosure Assembly and Detector Head Assembly are to be located in the hazardous area. The AC Power Supply and Power Cutoff relay are housed in an explosion-proof enclosure.

B. From examination of the equipment it appears that the following components are intended to be protective components.

Component		
Type	Designation	Remarks
Transformer	General Magnetics Part No. 211C	Note 1
Diode	1N5341	Note 2

Notes -

1. The transformer may be short-circuited primary to secondary during spark ignition testing since it did not meet the applicable performance test. See paragraph 6.9.35. The transformer did not meet the applicable construction requirements as shown in paragraph 7.9.12.1.

2. The shunt diodes may be open-circuited during spark ignition testing since the diode assembly did not meet the applicable construction requirements, see paragraph 7.9.13.1. The diode did meet the applicable performance test, see paragraph 6.9.37.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.9.32.

7.9.33 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the device for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply Terminals Red and Orange, Figure 10	No faults introduced. (+)
2	Power Supply Terminals Red and Orange, Figure 10	Open anode on Q3 (one fault).
3	Power Supply Terminal Orange, Figure 10 to Ground	Short transistor Terminal C to ground (no fault) due to short spacings, see paragraph 7.9.16.
4	Power Supply Terminal Red, Figure 10 to Ground	Short transformer Terminal C to Transistor Q1, Terminal C (one fault), short Transistor Q1, Terminal C to Terminal E (no fault) and short Resistor R7 (no fault) all due to short spacings, see paragraph 7.9.16.

(+) - Circuit was simulated due to damage sustained to power supply during fault analysis.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Wire		Open Circuit, Volts	Short Circuit, Amp	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles	
					Type	Diameter, Mil					Before Test	After Test
1	0	1.1	1.5*	Cadmium	Tungsten	8	4.28	1.05	400	No Ignition	19	14
2	1	1.1	1.5**	Cadmium	-	-	23.8	14.52	-	Note 1	-	-
3	1	1.1	1.5**	Cadmium	-	-	25.5	20	-	Note 2	-	-
4	1	1.1	1.0	Cadmium	-	-	660	Note 3	-	Note 2	-	-

* Factor applied by decreasing the amount of limiting resistance.

** Since this circuit was not tested the open circuit volts and short circuit current indicated do not reflect the addition of a test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane-air mixture with a brass disc and a test (safety) factor of 1.0, see paragraph 6.9.39.

2. Test not conducted since test conditions are more severe than Test No. 2.

3. Current limited only by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition of the gas-air mixture was obtained.

7.9.34 Component Burnout, Transistor Thermal Runaway, and Strand of Wire Tests were not conducted since results in paragraph 6.9.39 indicate that circuits which extend into the hazardous location are not intrinsically safe.

7.10 BACHARACH, LOW PROFILE METHANOMETER, ITEM 3

Product Description

7.10.1 Methane Monitoring System, Part No. 23-7167, manufactured by the Bacharach Instrument Company, Division of AMBAC Industries, Inc. of Pittsburgh, Pennsylvania. The System consists of a Control Housing, a Remote Meter Housing, Code 23-7157, a Detector Head Assembly, Code 23-7141, and a Power Cutoff Relay, Code 23-1378. The Control Housing incorporates the Power Supply, Code 23-7259 (Figure 12) and the Control Chassis, Code 23-7154 (Figure 13) and is supplied with an explosion-proof enclosure. The Control Housing has circuits, claimed to be intrinsically safe (Terminals R, C, and A, Figure 13) which are connected to the Detector Head Assembly claimed to be intrinsically safe. The Remote Meter Housing is provided with an explosion-proof enclosure and is supplied by circuits of the Control Housing. The Power Cutoff Relay is not provided with an enclosure but is intended to be mounted in the mining machine contactor case.

7.10.2 A complete sample system along with additional component parts were purchased from the manufacturer, since a distributer for this device is not available in this area, and were subjected to the examination and tests described below.

7.10.3 Electrical schematics for the equipment are shown in Figures 12 and 13. The Symbol "grd" used in Figure 13 is actually a circuit common. It is not grounded to the enclosure.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP"(9)

INTERNAL WIRING

7.10.4 The internal wiring of the Power Supply has 1/64 in. thick insulation and could not be identified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148 and 149 of UL 913(7), which require the use of UL Recognized wiring having at least 1/32 in. thick insulation. See Appendix B

ELECTRICAL COMPONENTS

7.10.5 The Part No. PR-80060-1 relay could not be identified as being UL Listed or Recognized.

7.10.6 The Control Chassis printed wiring board Nos. 23-1987-3 and 23-1245E could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

7.10.7 The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

7.10.8 The Power Supply capacitor is secured in place by a metal bracket, the use of which does not prevent movement along the major axis of the capacitor. The through air electrical spacing between an uninsulated capacitor terminal and an input terminal on the rectifier is reduced to zero with the capacitor in its most unfavorable position. This does not comply with paragraph 196 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.10.9 Protective Transformer.

7.10.9.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound over each other and there is a grounded screen between the windings, it may be considered as having Type 2B construction. The transformer is judged not to comply with the applicable construction requirements for Type 2B transformers since the screen is placed between the windings, but the splices and crossover leads are not included (paragraph 5.9B), since only one and not two grounding leads are provided (paragraph 5.9B-2) and since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg.

7.10.9.2 The transformer primary circuit is provided with a single fuse on the ungrounded side of the line voltage source. If the common side of the line voltage source intended for connection to the power supply is ungrounded this construction does not comply with the requirements in paragraph 5.3 which requires a fuse in each ungrounded conductor.

7.10.9.3 The fuse described in paragraph 7.10.9.2 is interchangeable with fuses having a higher ampere rating. This does not comply with paragraph 5.3 which requires the use of noninterchangeable fuses only.

7.10.9.4 The thickness of the copper foil grounding screen was measured to be 0.003 in. therefore a special short circuit test is required to determine that in the event of a short circuit between any winding and the screen the screen will withstand, without breakdown, the current that flows until the fuse operates. This test would not be required if the copper foil thickness was at least 0.005 in. The fuses intended to be used with the device range from 0.4 to 1 amp depending on which transformer voltage tap is used. The type of fuse used can be interchanged with a fuse having a rating of up to 30 amp. The short circuit test was not conducted since the device was not intended for use with a 30 amp fuse, which would have been used for the test.

7.10.9.5 The Type 2B transformer does not require a Protective Transformer Abnormal Operation Test. A Type 2B transformer which complies with all the construction features except is provided with only one grounding lead and is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction. Transformers having Type 3 construction are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted as described in paragraph 6.10.30.

SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.10.10 Any spacing, including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 7.10.25 below, unless the spacings are greater than or equal to those given in Table 8.1A for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being counted as a fault.

7.10.11 The electrical spacings recorded in the following table are those which were measured to be less than required on the sample examined. All of these spacings were on the Control Chassis Board A1, Figure 13 and in the Power Supply, Figure 12.

7.10.12 Tabulation of Electrical Spacings

	Spacings		Provided, MM		Required, MM	
Fig.	From	To	Through Air	Over Surface	Through Air	Over Surface
13	Transistor Q21 "C" Terminal	Ground	1/2(++)	1/2(++)	3	3
13	Transistor Q21 "C" Terminal	Transistor Q21 "E" Terminal	1/2(++)	1/2(++)	3	3
13	Transistor Q21 "C" Terminal	Transistor Q21 "B" Terminal	1/2(++)	1/2(++)	3	3
13	Terminal V Plus	Terminal 6	2-1/2(+)	2-1/2(+)	3	3
13	Terminal V Plus	Transistor Q21 "B" Terminal	1/2(++)	1/2(++)	3	3
13	Term V Plus	Terminal C Plus	1/2(++)	1/2(++)	3	3
13	Terminal V Plus	Terminal PX	1/2(++)	1/2(++)	3	3
13	Terminal PX	Terminal C Plus at R21	1/2(++)	1/2(++)	3	3
13	Terminal 6 at Component A1	Terminal C Plus at Terminals 1 and 2 at Component A1	1/2(++)	1/2(++)	3	3
13	Terminal C Plus	Terminal 5	1/2(++)	1/2(++)	3	3
13	Terminal R	Resistor R6 at R5	1(+)	1(+)	3	3
13	Terminal R	Resistor R9 at R8	1/2(++)	1/2(++)	3	3
12	Wiring Connection No. 2, Primary	Wiring Connection No. 3, Secondary	5(+)	5(+)	10	25

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

7.10.13 The application of adherent insulating material to the Control Chassis printed wiring boards was not uniform since some areas were not coated. Also the insulating material's equivalency to epoxy could not be determined since information regarding its composition was not available. The coating therefore cannot be relied upon in lieu of spacings in accordance with Footnote b of Table 8.1A.

7.10.14 The Control Chassis printed wiring boards were provided with an adhesive-backed sponge rubber material approximately 1/8 in. thick attached to the under side of the boards. This construction is not considered as suitable to provide spacings since the insulating material's equivalency to epoxy could not be determined and since this construction may result in air pockets around the printed wiring conductors.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.10.15 In the Control Chassis, the intrinsically safe wiring is intermingled with nonintrinsically safe wiring. This does not comply with paragraph 9.1 since positive separation is not provided between the intrinsically safe and nonintrinsically safe circuits.

7.10.16 In the Power Supply the wiring for the Power Cutoff Relay coil is intermingled with the wiring for the transformer primary. This does not comply with paragraph 9.1 since positive separation is not provided between the circuits which may affect intrinsic safety and nonintrinsically safe circuits.

7.10.17 In the cable provided for interconnection of the Control Housing and the transformer power source and Power Cutoff Relay the conductors are bunched together. This does not comply with paragraph 9.1 since positive separation is not provided between the nonintrinsically safe wiring and wiring which may affect intrinsic safety.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.10.18 The Detector is not marked with the manufacturer's name, MESA logo, the approval or certification number, and the part number. The Power Cutoff Relay is not marked with the manufacturer's name, MESA logo, and the approval or certification number. The part number on the Relay Cutoff base does not agree with the number in the manufacturer's instructions. This does not comply with paragraph 30.3.

7.10.19 The Remote Meter, the Detector, and the Power Cutoff Relay are not marked with the statement "Any substitution of components may impair intrinsic safety" as required in paragraph 30.5.

7.10.20 The Control Housing is not marked with the statement "Any substitution of components may impair intrinsic safety" nor is it marked with specific requirements covering its installation as required in paragraph 30.6.

7.10.21 The Control Housing to Detector connecting cable is not marked "Intrinsically Safe" as required in paragraph 30.7.

Test Record

7.10.22 DIELECTRIC WITHSTAND TEST

Test previously conducted with acceptable results, see paragraph 6.10.29.

7.10.23 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test previously conducted with unacceptable results, see paragraph 6.10.30.

7.10.24 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test was not conducted since the transformer did not comply with the performance requirements of the Abnormal Operation Test, see paragraph 6.10.30.

7.10.25 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components, field wiring and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. Only the Detector Head Assembly is to be located in the hazardous area. The remaining parts of the system (associated equipment), including Control Housing, Remote Meter Housing, and Power Cutoff Relay are intended to be housed in explosion-proof enclosures.

B. From examination of the equipment it appears that the following components are intended to be protective components:

Component		
Type	Designation	Remarks
Transformer	23-1294	Note 1

Note -

1. The transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance test, see paragraph 6.10.30. The transformer was judged not to comply with applicable construction requirements as indicated in paragraph 7.10.9.1.

C. In the Control Chassis, the conductor marked "gnd" (connected to the secondary of the power supply) was not grounded to the enclosure.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.10.26 and representative components were selected for thermal ignition tests.

7.10.26 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of operation.

The input voltage to the device for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

For all tests the adjustments were set in their most unfavorable positions so as to provide the maximum outputs to the intrinsically safe circuits. The fuses which could have interrupted the test were short-circuited.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Control Housing Terminals R and A, Figure 13	No faults introduced. (+)
2	Control Housing Terminals R and A, Figure 13	Short Transistor Q21, Terminal C to Terminal E (no fault) due to short spacings, see paragraph 7.10.12. (+)
3	Control Housing Terminals R and A, Figure 13	Short I.C. A1, Pin 8 to Pin 1 (one fault). (+)
4	Control Housing Terminal A, Figure 13 to Ground	Short Transistor Q21 Terminal C to ground (no fault) due to short spacings, see paragraph 7.10.12.
5	Control Housing Terminal R and A, Figure 13	Short Terminal V plus to Terminal 6 (one fault) and Terminal R to Resistor R9 at R8 (no fault) all due to short spacings, see paragraph 7.10.12.
6	Control Housing Terminal R and A, Figure 13	Short Terminal V plus to Terminal C plus (no fault) Terminal C plus to Terminal PX to Terminal PY (no fault) all due to short spacings, see paragraph 7.10.12.
7	Control Housing Terminals R and A, Figure 13	Short Terminal V plus to Terminal PX (no fault) and Terminal PX to Terminal PY (no fault) all due to short spacings, see paragraph 7.10.12.
8	Control Housing Terminals R and A, Figure 13	Short Terminal V plus to Terminal C plus (no fault) Terminal C plus to Terminal 5 (no fault), and Terminal R to Resistor R6 at R5 (one fault) all due to spacings, see paragraph 7.10.12.
9	Control Housing Terminal A, Figure 13 to Ground	Short transformer primary to secondary (one fault) and short rectifier in power supply to "-" dc terminal (one fault).

(+) - The circuit was simulated due to damage sustained to Control Chassis during fault analysis.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Wire Type	Wire Diameter, Mil	Open Circuit, Volts	Short Circuit, Ma	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	Spark Test Mechanism Calibration Cycles After Test
1	0	1.1	1.5*	Cadmium	Tungsten	8	4.08	1.80	400	No Ignition	29	19
2	0	1.1	1.5*	Cadmium	Copper	6	15.47	4.40	400	No Ignition	1	2
3	1	1.1	1.5**	Cadmium	-	-	23.50	7.3	-	Note 1	-	-
4	0	1.1	1.5**	Cadmium	-	-	23.50	15.6	-	Note 2	-	-
5	1	1.1	1.5**	Cadmium	-	-	23.50	15.6	-	Note 2	-	-
6	0	1.1	1.5**	Cadmium	-	-	23.50	15.6	-	Note 2	-	-
7	0	1.1	1.5**	Cadmium	-	-	23.50	15.6	-	Note 2	-	-
8	1	1.1	1.5**	Cadmium	-	-	23.50	15.6	-	Note 2	-	-
9	2	1.1	1.0	Cadmium	-	-	660	Note 3	-	Note 2	-	-

* Factor applied by decreasing the amount of limiting resistance.

** Since this circuit was not tested, the open circuit volts and short circuit current indicated do not reflect the addition of the test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane air mixture with a brass disc and a test (safety) factor of 1.0, see paragraph 5.10.42.

2. Test not conducted since test conditions are more severe than Test No. 3.

3. Current limited only by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9) since ignition of the gas air mixture was obtained.

7.10.27 Strand of wire and component burnout tests were not conducted since results in paragraph 5.10.24 indicate that the circuits which extend into the hazardous location are not intrinsically safe.

7.11 BERTEA, VALVE CONTROL SYSTEM, ITEM 9

Product Decription

7.11.1 Intrinsically Safe Valve Control System, for control of electro hydraulic valves, manufactured by Bertea Corporation, Industrial Products Division of Costa Mesa, California. The System consists of an AC Power Supply, Part No. 261861 (Figure 14), Sixteen Pilot Valve Assemblies, Part No. 234912, Sixteen Hand Controllers, Part No. 26436039, two Resistor Terminal Boards, Part No. 2618201 and a Terminal Board, Part No. 261814-1. Interconnection of the system components is depicted schematically in Figure 15. The AC Power Supply, intended to be mounted within an explosion-proof enclosure, has circuits claimed to be intrinsically safe which are connected to the Terminal Boards, Hand Controllers and Pilot Valves. The Hand Controllers and Pilot Valves are claimed to be intrinsically safe. The AC Power Supply is rated 575 v ac, 60 Hz input.

7.11.2 A complete sample of the System along with additional component parts were purchased through Weldon Engineering Company of Des Plaines, Illinois, a local distributor for the equipment. The samples were subjected to the examination and tests described below.

7.11.3 Electrical schematics and instructions covering installation of the system were not supplied as part of the equipment. They were provided upon request. The electrical schematics are shown in Figures 14 and 15.

Ordinary Locations Electrical Construction, Paragraphs 4.2 and 4.5, "MESAP"(9)

INTERNAL WIRING

7.11.4 The transformer primary leads all have 1/32 in. thick insulation. Seven of the ten leads provided could not be identified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148 and 149 of UL 913(7). See Appendix B.

7.11.5 The internal wiring between the transformer primary circuit field wiring terminals and the transformer primary lead wire connectors has 1/64 in. thick insulation and could not be idengified as UL Recognized Appliance Wiring Material. This wiring does not comply with paragraphs 148-150 of UL 913(7), which requires the use of UL Recognized Wiring having at least 1/32 in. thick insulation. See Appendix B.

7.11.6 The printed wiring boards employed in the Power Supply could not be identified as being UL Recognized.

ELECTRICAL SPACINGS

7.11.7 The required spacings for line voltage circuits are those indicated in Column 301-600, 2 kva maximum of Table 6 of UL 913(7). The required spacings for circuits in the transformer secondary are those indicated in Column 0-50, 2 kva maximum of Table 6 of UL 913(7). See Appendix B.

7.11.8 The through air spacing between uninsulated 575 v, soldered connector on the terminal board and a grounded metal mounting leg for the terminal board was measured to be 3/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require at least 3/16 in.

7.11.9 The over surface spacing between foil conductors on printed circuit board at "+6 volt" transformer secondary pin No. 1 and pin No. 2 was measured to be 1/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of opposite polarity.

7.11.10 The over surface spacing between foil conductors on printed circuit board at "+6 volt" transformer secondary pin No. 3 and pin No. 2 was measured to be less than 1/32 in. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of opposite polarity.

7.11.11 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2 and "-6 volts" transformer secondary pin No. 3 at Diode CR4 was measured to be less than 1/32 in. at two places. This does not comply with paragraph 195 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

7.11.12 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 1 and "-6 volts" transformer secondary pin Nos. 2 and 3 were measured to be 1/32 in. and just over 1/32 in., respectively. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

7.11.13 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2, at Capacitor C2 and "-6 volts" transformer secondary pin No. 2 at Capacitors C3 and C6, two places, were measured to be just over 1/32 in. each. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

7.11.14 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 2 and "-6 volts" transformer secondary pin No. 1 was measured to be less than 1/32 in. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

7.11.15 The over surface spacing between foil conductors on printed circuit board at "+6 volts" transformer secondary pin No. 3 and "-6 volts" transformer secondary pin Nos. 1 and 2 were measured to be less than 1/32 in. and 1/32 in., respectively. This does not comply with paragraph 197 and Table 6 of UL 913(7) which require a spacing of at least 1/16 in. between uninsulated live parts of different circuits.

Intrinsically Safe Electrical Construction

PROTECTIVE COMPONENTS, PARAGRAPHS 5.1-5.27, "MESAP"(9)

7.11.16 Protective Transformer.

7.11.16.1 The line voltage transformer employed in the device was examined to determine if it could be considered a protective component. Since the windings are wound side by side on one leg of the core and separated with insulating material, it may be considered as having Type 1A construction. The transformer is judged not to comply with the applicable construction requirements for Type 1A transformers since the transformer primary circuit was not provided with a noninterchangeable fuse in each ungrounded leg in accordance with paragraph 5.3.

7.11.16.2 A Type 1A transformer, which complies with all of the construction features except is not provided with a noninterchangeable fuse in each ungrounded leg of the transformer primary circuit may be considered as having Type 3 construction.

Transformers having Type 3 construction are subjected to the Protective Transformer Abnormal Operation Test. This test was conducted, see paragraph 6.11.33.

ELECTRICAL SPACINGS, PARAGRAPHS 8.1-8.6, "MESAP"(9)

7.11.17 Any spacing including spacings to ground, that can affect adversely the intrinsic safety of the equipment is considered subject to fault, under Circuit Fault Analysis, paragraph 7.11.30, unless the spacings are greater than or equal to those given in Table 8.1A, for the specified potential. A spacing not less than one-third of the value in Table 8.1A is considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A may be considered as connected without being counted as a fault.

7.11.18 The electrical spacings recorded in the following table are those that were measured to be less than required on the sample examined. The spacings were on the Power Supply printed wiring board, Figure 14.

7.11.19 <u>Tabulation of Electrical Spacings</u>

Fig.	Spacings From	Spacings To	Provided, MM Through Air	Provided, MM Over Surface	Required, MM Through Air	Required, MM Over Surface
14	Uninsulated Solder Connection of the +6 volts terminal, top board intrinsically safe terminal	Transformer secondary terminal bottom board	1(+)	-	3	3
14	Transistor Q1, Terminal C, Bottom Board	Ground	1/2(++)	1/2(++)	3	3
14	Transistor Q2, Terminal C, Bottom Board	Ground	1/2(++)	1/2(++)	3	3
14	Between all Adjacent Pins of I.C. U1, Botton Board		1/2(++)	1/2(++)	3	3
14	Between all Adjacent Pins of I.C. U2, Bottom Board		1/2(++)	1/2(++)	3	3
14	Printed wiring for Transistor Q1, Terminal E, Bottom Board	Ground	2(+)	2(+)	3	3
14	Transistor Q1, Terminal E, Bottom Board	Transistor Q1, Terminal C, Bottom Board	1(+)	1(+)	3	3
14	Printed wiring for Transistor Q2, Terminal E, Bottom Board	Ground	1-1/2(+)	1-1/2(+)	3	3
14	Transistor Q2, Terminal E, Bottom Board	Transistor Q2, Terminal C, Bottom Board	1(+)	1(+)	3	3
14	Printed wiring for Diodde CR1, Cathode, Bottom Board	Ground	2(+)	2(+)	3	3
14	Printed wiring for I.C. U1, Pin 13, Bottom Board	Ground	1/2(++)	1/2(++)	3	3
14	Printed wiring for I.C.U1, Pin 10, Bottom Board	Printed wiring for I.C. U1, Pin 12, Bottom Board	1/2(++)	1/2(++)	3	3
14	Printed wiring for I.C. U2, Pin 13, Bottom Board	Ground	1-1/2(+)	1-1/2(+)	3	3

(+) - Less than required, but not less than 1/3.

(++) - Less than 1/3 required.

SEPARATION OF INTERNAL WIRING, PARAGRAPHS 9.1-9.5, "MESAP"(9)

7.11.20 The wiring of the transformer secondary contacts printed wiring of the intrinsically safe circuit. This does not comply with paragraph 9.1 since nonintrinsically safe wiring is not positively separated from intrinsically safe wiring.

SOURCES OF IGNITION, PARAGRAPH 14.1, "MESAP"(9)

7.11.21 The elctrical schematic, Figure 15 depicts the use of an optional indicator lamp, an unspecified pilot valve and a function selector switch, not supplied as part of the system. The connection of unknown electrical equipment to the system may result in the whole system not being intrinsically safe. The indicator lamp, pilot valve and selector switch must be identified so this consideration can be made during Circuit Fault Analysis.

Marking

DETAILS, PARAGRAPHS 30.1-30.12, "MESAP"(9)

7.11.22 The Hand Controllers are not marked with the manufacturer's name, the MESA logo and the approval or certification number. The Power Supply Pilot Valves, and Terminal Boards are not marked with the MESA logo and the approval or certification number. This does not comply with paragraph 30.3.

7.11.23 The Pilot Valves, Terminal Boards and Hand Controllers are not marked with the statement "Any substitution of components may impair intrinsic safety" as required in paragraph 30.5.

7.11.24 The Power Supply is not marked with the statement "Any substitution of components may impair intrinsic safety," nor is it marked with specific requirements covering its installation as required in paragraph 30.6.

7.11.25 The intrinsically safe terminals of the Power Supply, Hand Coltrollers Pilot Valves and Terminal Boards are not marked "Intrinsically Safe".

Test Record

7.11.26 DIELECTRIC WITHSTAND TESTS

Test previously conducted with unacceptable results, see paragraph 6.11.31.

7.11.27 PROTECTIVE TRANSFORMER ABNORMAL OPERATION TEST

Test previously conducted with unacceptable results, see paragraph 6.11.33.

7.11.28 PROTECTIVE TRANSFORMER DIELECTRIC VOLTAGE WITHSTAND TEST

Test previously conducted with acceptable results, see paragraph 6.11.34.

7.11.29 CURRENT LIMITING RESISTOR TESTS

Test previously conducted with acceptable results, see paragraph 6.11.35.

7.11.30 CIRCUIT FAULT ANALYSIS

1. Fault analysis was performed to select circuits for spark ignition tests and to select components for thermal ignition tests. In the analysis, two simultaneous independant faults of components (except protective components), field wiring, and short spacings in accordance with "MESAP"(9) were considered.

2. In the analysis, consideration was given to the following items:

A. The Terminal Board, Resistor Board, Pilot Valves and Hand Controllers are to be located in the hazardous area. The Power Supply is intended to be housed in explosion-proof enclosure or located in the nonhazardous area.

B. From examination of the equipment it appears that the following components are intended to be protective components.

Component		
Type	Designation	Remarks
Transformer	261866	Note 1
Resistor	39 ohm 1 w, W.W.	Note 2

Notes -

1. The line voltage transformer may be short-circuited primary to secondary during spark ignition testing since the transformer did not meet the applicable performance test, see paragraph 6.11.33.

2. The current limiting 30 ohm resistor may be short-circuited during spark ignition testing due to field wiring faults.

3. Based on the analysis, representative circuits were selected for spark ignition tests as noted in paragraph 7.11.31.

7.11.31 SPARK IGNITION TEST

METHOD

The circuits selected during the Circuit Fault Analysis were tested in explosive propane gas in mixture with air. The test mechanism used is described in Section 19 of "MESAP"(9).

The explosive gas-air mixture of uniform concentration was prepared by means of flow meters operating in conjunction with constant head regulators. The gas used was supplied under pressure in the usual commercial cylinders.

The most easily ignitable explosive concentration of the gas, percent by volume, in mixture with air was verified both before and after each test by a test circuit of known inductance and current. The verification circuit had the following characteristics:

	Inductive Circuit	
V, DC	Current	Inductor, mh
24	100 ma	95

In turn, each circuit was connected to the test mechanism at the test point indicated. The test mechanism was operated to make and break the circuit for the number of revolutions indicated. For direct current circuits the polarity was reversed after not less than 200 cy of opration.

The input voltage to the device for the tests was adjusted by the appropriate voltage factor indicated as based on a test voltage of 600 v ac, before introduction of any test (safety) factor.

The circuits selected for test are described below:

Circuit No.	Test Point	Circuit Description
1	Power Supply, Terminals +6 and -6, Figure 14	No faults introduced. (+)
2	Power Supply, Terminals +6 and -6, Figure 14	Short I.C.U1, Pin 12 to Pin 4 (one fault). (+)
3	Power Supply, Terminals +6 and -6, Figure 14	Short I.C.U1, Pin 12 to Pin 4 (one fault). (+)
4	Power Supply Terminal 0, Figure 14 and Ground	Short Diode CR1 to ground (one fault) due to short spacings, see paragraph 7.11.19.
5	Power Supply, Terminal 0, Figure 14 and Ground	Short I.C.U1, Pin 13 to ground (no fault) and Pin 14 to Pin 13 both due to short spacings, see paragraph 7.11.19.
6	Power Supply, Terminals +6 and -6, Figure 14	Spark mechanism in series with pilot valve and 39 ohm resistor. Shortout 30 ohm resistor (one fault), short -6 v field wiring terminal to ground (no fault), and disconnect and short to ground field wiring lead from pilot valve to 0 v terminal (no fault) all due to field wiring faults.
7	Power Supply, Terminal 0, Figure 14 and Ground	Short transformer primary to secondary. (++)

(+) - Circuit was simulated due to damage sustained to Power Supply during fault analysis.

(++) - This condition shorts the 575 v ac line circuit to the intrinsically safe Terminal 0. Assuming the use of a 575 v grounded source, arcing the intrinsically safe circuit to ground, arcs the 575 v supply to ground.

RESULTS

Circuit No.	Number of Faults	Voltage Factor	Test (Safety) Factor	Disc Type	Wire Type	Wire Diameter, Mil	Open Circuit, Volts	Short Circuit, Ma	Number of Revolutions	Results	Spark Test Mechanism Calibration Cycles Before Test	Spark Test Mechanism Calibration Cycles After Test
1	0	1.1	1.5*	Cadmium	Tungsten	8	12.05	1.83	400	No Ignition	44	4
2	1	1.1	1.5***	Cadmium	-	-	30.0	2.5	-	Note 1	-	-
3	1	1.1	1.5***	Cadmium	-	-	22.7	4.53	-	Note 1	-	-
4	1	1.1	1.5**	Cadmium	-	-	18.51	-	-	Note 2	-	-
5	0	1.1	1.5**	Cadmium	-	-	18.51	-	-	Note 2	-	-
6	1	1.1	1.5***	Cadmium	-	-	13.80	0.233	-	Note 1	-	-
7	1	1.1	1.0	Cadmium	-	-	660	Note 3	-	Note 2	-	-

* Factor applied by decreasing the amount of limiting resistance.

** Since this circuit was not tested, the open circuit voltage and short circuit current indicated do not reflect the addition of a test (safety) factor.

*** The open circuit voltage and short circuit current indicated reflect the addition of a test (safety) factor.

Notes -

1. This test was not conducted since this circuit caused ignition of methane air mixture, see paragraph 6.11.37.

2. Test not conducted since test conditions are more severe than Test No. 3.

3. Current limited by capacity of source.

The results do not comply with the requirements in Section 19 of "MESAP"(9).

7.11.32 Component Burnout and Strand of Wire Tests were not conducted since results in paragraph 6.11.37 indicate that circuits which extend into the hazardous location are not intrinsically safe.

CHAPTER 8

8. COMPARISON OF INDIVIDUAL REQUIREMENTS

8.1 As shown by Tables I, II and III in Chapter 1, certain requirements of CFR Title 30(8), UL 913(1) and "MESAP"(9) were not met by most of the equipment investigated. In the following, these individual requirements are compared for the three standards, and their impact on certification suitability of the equipment is discussed. Other requirements, which were either not applicable or were met by most of the equipment are not specifically discussed.

8.2 ELECTRICAL SPACINGS

8.2.1 In examining the items of equipment for electrical spacings (clearances) between uninsulated parts in accordance with CFR Title 30(8), UL used a level of adequacy based on requirements in UL 913(7), since specific dimensional requirements are not provided in Title 30(8). All of the items examined had electrical spacings less than those required.

8.2.2 The electrical spacings given in Table 8.1B of "MESAP"(9) are suggested as a guide for Category B associated apparatus. Since the spacings are not required by the document, they were not applied in the investigation of the items described in Chapter 7.

8.2.3 If less severe spacing requirements were applied in the investigation of the items according to Title 30(8), some of the items may be in compliance with Title 30 requirements. However, Items 1, 3, 8 and 10 would not comply with any spacing requirements since they have construction which may result in spacings being reduced to zero.

8.3 AUXILIARY COMPONENTS

8.3.1 According to requirements in UL 913(1) and "MESAP"(9), items of intrinsically safe and associated electrical equipment which are intended to be used in conjunction with other pieces of electrical equipment or auxiliary equipment would be investigated with the specific equipment since intrinsic safety is evaluated for a complete system. This is because the use of other types of equipment not anticipated at the time of the investigation may affect the intrinsic safety of the system as a whole. Items 8, 10 and 11 are intended to be used with unidentified electrical equipment and Items 1, 2, 6, and 9 are intended to be used with unspecified auxiliary equipment. These constructions do not comply with either UL 913(1) or "MESAP"(9).

8.3.2 Since this consideration is not a part of CFR Title 30(8), the use of unspecified auxiliary equipment in conjunction with certified devices appears to be in compliance with requirements in Title 30(8).

8.4 SPARK IGNITION TESTS

8.4.1 The requirements in UL 913(1) and "MESAP"(9) provide construction details of the spark test apparatus and the procedure employed to calibrate the specific test mixture, both before and after the test. Experience has shown that small changes in the apparatus can have a significant effect on the test results. For example, the use of a cadmium disc produces a more sensitive test than does the use of a brass disc for a particular test mixture and therefore increases the likelihood of ignition during the test. As a consequence, a circuit which meets the test requirements with a brass disc may not meet the test requirements when a cadmium disc is used in the apparatus. Calibration of the test mixture is important since it verifies that the particular gas-air mixture being used is the most easily ignitable mixture. In spark ignition tests conducted according to UL 913(1) and "MESAP"(9), the spark test apparatus employed a cadmium disc.

8.4.2 Circuits subjected to spark ignition tests according to UL 913(1) and "MESAP"(9) are selected during Circuit Fault Analysis where one and two faults of components (except protective components) are used with an appropriate test (safety) factor. The requirements in paragraph 13.1 of "MESAP"(9) specify introduction of a power or energy factor of 1.5 with two faults. This is more severe than requirements in UL 913(1) which specifies the introduction of a factor of 1.5 with one fault and a factor of 1.0 with two faults. Faults may be introduced where electrical spacings are less than required in UL 913(1) and "MESAP"(9).

8.4.3 Requirements in paragraph 4.6 of "MESAP"(9) specify that for devices having conductors or conductor strands smaller than No. 30 B&S, the spark test apparatus is to be modified before testing unless the conductors or conductor strands are encapsulated. According to paragraph 19.8 of "MESAP"(9), the modifications include the use of wires of the type found in the device being tested, having a size not exceeding 80 percent of the diameter of the smallest conductor or strand. This produces a more severe condition than the requirements in UL 913(1), since it takes into account the heating of the small wires in the spark test apparatus. None of the items of equipment met the requirements of the Spark Ignition Test in either UL 913(1) or "MESAP"(9).

8.4.4 The requirements in CFR Title 30(8) for spark ignition testing are nonspecific. They do not identify the type of apparatus or methodology to be used. Calibration of the test mixture both before and after the test is not specified in Title 30(8). The type of test apparatus used for spark ignition testing in accordance with CFR Title 30(8) is described in UL 913(7). See Appendix B. This apparatus employs a brass disc. The circuits selected for test according to Part 18 of Title 30(8) may be subjected to a single component fault, including protective components. Test (safety) factors are not introduced into the circuit under test. The spark ignition tests conducted according to Part 27 of Title 30(8) use circuits with no faults introduced and a voltage test (safety) factor of 1.25. None of the items of equipment met the requirements of the Spark Ignition Test conducted per Title 30(8) as described above except for Item 4.

8.5. PROTECTIVE COMPONENTS

8.5.1 In UL 913(1) and "MESAP"(9), some components (e.g., transformers, resistors, diodes) which affect intrinsic safety and which meet specified performance and construction requirements designed to verify their reliability may be considered as protective components not subject to fault during fault analysis.

8.5.2 In CFR Title 30(8), components which affect intrinsic safety are not required to be subjected to performance tests. For example the testing of resistors which are intended to limit the current to an intrinsically safe circuit does not include a determination of whether or not the resistors will short-circuit and therefore result in loss of protection, when subjected to the maximum voltage available under fault conditions. Also, the testing of a line voltage transformer does not include a determination of whether or not the transformer will effectively isolate a high voltage primary from a low voltage secondary circuit when subjected to conditions such as an overload or short circuit of the isolated low voltage secondary winding. All of the items of equipment employing transformers met the transformer construction requirements in Title 30(8), having the primary and secondary windings physically separated. Under conditions of short circuiting the transformer secondary windings, the transformers of Items 1, 2, 3, 6, 8 and 11 burst into flame. These results do not comply with either UL 913(1) or "MESAP"(9).

8.6 SEPARATION OF CIRCUITS

8.6.1 Both UL 913(1) and "MESAP"(9), require that internal wiring of intrinsically safe circuits be positively separated from wiring of nonintrinsically safe circuits. Also, the construction of the equipment is required to be such that the field-installed conductors of an intrinsically safe circuit are separated from field- and factory-installed conductors connected to any other circuit and uninsulated live parts of any other circuit. Equipment intended for panel installation may have wiring terminals for intrinsically safe circuits separated by a distance of 50 mm from uninsulated live parts and wiring of any other circuit if clear installation instructions are provided. All items examined had constructions which did not comply with separation requirements.

8.6.2 The CFR Title 30(8) specifies that wiring for nonintrinsically safe circuits is not to be intermingled with wiring for intrinsically safe circuits. All items of equipment examined had constructions which did not comply with this requirement. Also, the requirement in Title 30(8) does not specify that wiring of intrinsically safe circuits is to be separated from uninsulated live parts of nonintrinsically safe circuits, other than wiring. As a result, careless wiring in the factory or during field installation may permit intrinsically safe conductors to be in contact with uninsulated line voltage parts.

8.7 MARKING

8.7.1 UL 913(1) and "MESAP"(9) require intrinsically safe equipment to be marked "Intrinsically Safe". Battery-powered equipment is required to be marked to indicate the manufacturer's name and catalog designation or equivalent of the battery intended to be used and the appropriate ratings.

8.7.2 Title 30(8) requires circuits and components of intrinsically safe equipment to be "adequately identified" by marking or labeling. The level of adequacy is not amplified in the requirements.

8.7.3 In addition, UL 913(1) and "MESAP"(9) require marking of such details as the name of the manufacturer or equivalent, responsible for the device, catalog designations, cautionary statements to service personnel, etc. as appropriate on the equipment. Each individual apparatus of the system is required to be identified as part of the system. These markings are not required in Title 30(8).

8.7.4 All items of equipment examined had marking which was not in compliance with the requirements in either Title 30(8), UL 913(1) or "MESAP"(9).

8.8 ELECTRICAL COMPONENTS

8.8.1 Component electrical parts of equipment are required by both UL 913(1) and "MESAP"(9) to meet applicable construction and performance requirements for the type of component. For example, components are required to have electrical insulation which will withstand the temperatures and voltages to which the component will be subjected. For investigations according to UL 913(1) each component part is usually covered by a different UL Standard, and for investigation according to "MESAP"(9) these component parts are covered by appropriate ANSI Standards. Only Item 8 complied with both UL 913(1) and "MESAP"(9) requirements for electrical components. CFR Title 30(8) does not specify that component electrical parts comply with any requirements.

8.9 TEST FOR ACCUMULATION OF STATIC ELECTRICITY

8.9.1 To determine whether or not a plastic enclosure will store an electrostatic charge, it is tested in accordance with detailed requirements in UL 913(1) and "MESAP"(9). The electrostatic charge used is limited to 15,000 v per requirements in "MESAP"(9). This is more severe than the test requirements in UL 913(1) in which the test voltage is limited to 5,000 v. The plastic battery enclosure used in Item 1, which is the only device having a plastic enclosure, complied with the requirements in both UL 913(1) and "MESAP"(9).

8.9.2 The requirements in Title 30(8) specify that nonmetallic rotating parts must be provided with means to prevent accumulation of static electricity. No method is specified for determining the adequacy of the preventive means employed. None of the items of equipment investigated had any rotating nonmetallic parts. Therefore this consideration was not necessary.

8.10 FASTENINGS/VIBRATION RESISTANCE AND CABLE CLAMPS AND GRIPS

8.10.1 The differences in the requirements of UL 913(1), Title 30(8) and "MESAP"(9) covering fastenings/vibration resistance and cable clamps and grips are due to the differences in the intended use and installation requirements for the types of equipment covered by each set of requirements.

8.10.2 The requirements in UL 913(1) cover intrinsically safe electrical equipment for installation and use in hazardous location in accordance with the National Electrical Code. Most of this equipment is permanently installed in a fixed location nonintrinsically safe wiring is usually routed in rigid metal conduit. This equipment is not intended to be subjected to the type of vibration conditions which exist on mining machines.

8.10.3 The requirements in CFR Title 30(8) and "MESAP"(9) cover intrinsically safe electrical equipment for installation and use in mines. It appears that most, if not all, of the items of equipment investigated are intended to be installed on cable-wired mining machines subject to vibration.

8.10.4 Items 2, 3, 4, 8, 10 and 11 were not in compliance with either Title 30(8) or "MESAP"(9) requirements for vibration resistance. UL 913(1) has no comparable requirements.

APPENDIX A

TEST REQUIREMENTS FOR INSTRUMENTS OR APPARATUS TO BE CONSIDERED FOR M.E.S.A. INTRINSICALLY SAFE CERTIFICATION (Tentative)

GENERAL

1. Scope

1.1 These requirements cover intrinsically safe electrical circuits and apparatus for installation and use in gassy locations in underground coal mines.

1.2 These requirements also apply to instruments intended to be installed in panels on machinery or vehicles except that the requirements for field-wiring connections may be modified if appropriate for the particular application.

1.3 These requirements also apply to associated parts located outside the gassy location, if the intrinsic safety of the electrical circuits or apparatus in the gassy location may be influenced by the design and construction of such parts.

1.4 The performance requirements apply only to intrinsically safe circuits and apparatus for use in gassy locations under normal atmospheric conditions. Normal atmospheric conditions are considered to be: (1) a maximum ambient temperature of 40°C (104°F), (2) a maximum concentration of oxygen of 21 percent, and (3) a maximum pressure of one atmosphere.

2. Units of Measurement

2.1 If a value for measurement as given in these requirements is followed by an equivalent value in other units, the first stated value is to be regarded as the requirement. A given equivalent value may only be approximate.

3. Glossary

3.1 For the purpose of this standard, the following definitions apply.

3.2 ASSOCIATED APPARATUS - Apparatus that is not intrinsically safe but that affects the intrinsic safety of other apparatus or circuits. Two categories of associated apparatus are recognized. Category A is apparatus located in fresh air, while category B is located in the gassy area and is required to be contained in a permissible (explosion-proof) enclosure. The permissible enclosure is subject to test requirements apart from those in this document.

3.3 COMMON BUS - The common side of multiple circuits.

3.4 FAULT - A defect or an electrical breakdown of any component, spacing, or insulation that alone or in combination with others may adversely affect the electrical or thermal characteristics of an intrinsically safe circuit. A fault includes a mechanical failure of electrical connections unless manufacturing methods negate the possibility of this type of fault.

3.5 FIELD WIRING - Wiring and associated interconnection boxes installed to interconnect individual pieces of intrinsically safe apparatus or intrinsically safe and associated apparatus. See paragraphs 3.8 and 3.13.

3.6 FIELD-WIRING CONNECTIONS - Terminals intended for the electrical connection of apparatus in the field.

3.7 FUSE-PROTECTED DIODE BARRIER - A network consisting of (1) a series fuse, (2) a shunt diode or diodes, (3) a series resistor, switch, or similar components, (4) a shunt diode or diodes, and (5) a series resistor, in the order given starting from the nonhazardous location side of the barrier.

3.8 INTERNAL WIRING - Wiring and electrical connections that are made inside of the apparatus by the manufacturer. Panel wiring is considered to be internal wiring. See paragraph 3.13.

3.9 INTRINSICALLY SAFE CIRCUITS AND APPARATUS - Circuits and apparatus incapable of releasing sufficient electrical or thermal energy under normal or specified abnormal conditions to cause ignition of any methane-air, coal dust-air, or methane-coal dust-air atmosphere. Abnormal conditions include accidental damage to any electrical components other than protective components as described in Section 5, application of overvoltage, adjustment and maintenance operation, and other similar conditions. Damage to field wiring is considered a condition of normal operation. See paragraph 13.6.

3.10 MAXIMUM SAFE LOCATION VOLTAGE - The maximum voltage applied to or generated within the associated apparatus (Categories A and B).

3.11 NORMAL OPERATION - Operation that conforms electrically and mechanically with the design specifications of the apparatus.

3.12 NORMAL USE AS APPLIED TO AN INTRINSICALLY SAFE CIRCUIT - The circuit operating in its intended manner with the field accessible adjustments at their most unfavorable position, without any faults in the circuit, with the exception that field wiring and field-wiring terminals may be open-circuited, or may be connected together or to ground, or both.

3.13 PANEL WIRING - Wiring and electrical connections that are made on or behind a panel, consisting of apparatus interconnected to perform a certain function or functions following detailed instructions from the manufacturer.

3.14 PROTECTIVE COMPONENT OR ASSEMBLY - A component or assembly that is not likely to become defective, in service or in storage, in such a manner as to lower the intrinsic safety of the circuit. Such a component or assembly is not considered to be subject to fault during fault analysis.

3.15 REINFORCED INSULATION - Insulation that has high temperature and dielectric strength ratings, such as a minimum of 0.17 millimeters (0.007 inch) thickness of mica or comparable insulation.

3.16 RESISTOR-PROTECTED DIODE BARRIER - A network that is identical to a fuse-protected diode barrier with the exception that the fuse is replaced by a resistor.

3.17 SAFETY FACTOR - Ratio of power or energy storage capability, used in approval testing, to the maximum power or energy storage expected under the normal or fault conditions being considered.

3.18 SHUNT DIODE BARRIER - A fuse or resistor-protected diode barrier.

CONSTRUCTION

4. General

4.1 The apparatus covered by this standard included:

A. Complete intrinsically safe equipment powered by:

1. A battery supply, or
2. Other supply of low energy.

B. Intrinsically safe circuits connected to associated apparatus that has energy-limiting features.

4.2 Apparatus shall also comply with the applicable requirements for similar devices for use in ordinary locations. (ANSI C19.3 -)

4.3 An apparatus shall employ materials that have been investigated and found to meet the requirements for such materials for the particular use, and shall be made and finished with the degree of uniformity and grade of workmanship practicable in a well-equipped factory.

4.4 Construction requirements for machine mounted circuits:

Apparatus intended for machine mounting shall use vibration-proof (resistant) component mounting techniques. Such techniques include soldering, riveting, elastomeric insert nuts, and wiring clamps among others.

4.5 A component of an apparatus shall comply with the requirements for that component, (ANSI C19.5 - ____) except that the requirements may be modified if appropriate for the particular application.

4.6 No conductor or conductor strand, not contained in a sealed package, (encapsulated) shall be smaller than #30 B & S (0.25 millimeter, 0.01 inch) unless special modifications are made to the testing apparatus prior to approval testing.

4.7 Electrical circuits and wiring of apparatus that are not intrinsically safe shall be provided with means of protection such as permissible enclosures (category B) or the nonintrinsically safe wiring and parts shall be mounted outside of the gassy location (category A).

4.8 A fault in a nonintrinsically safe circuit or part shall not result in passage of electric energy, capable of causing ignition, to the field wiring or to an intrinsically safe circuit intended for use in gassy locations.

4.9 Unless the manufacturer's installation instructions indicate otherwise, the investigation of an intrinsically safe system is based on a maximum distance of 1524 meters (5000 feet) between the equipment installed in the nongassy location and the equipment installed in the gassy location.

4.10 A plastic enclosure shall not store a hazardous electrostatic charge, as demonstrated by:

A. Compliance with the test requirements in Section 29, or

B. Experimental evidence.

5. Passive Protective Components

General

5.1 Intrinsically safe circuits may depend only on the use of passive protective components. If this approach is taken, the other components may be omitted from or left in the circuit depending upon which condition produces the most unfavorable effect. The possibility that unreliable components or short spacings may short out the protective components is to be considered.

Protective Transformers

5.2 A protective transformer shall comply with the requirements in paragraphs 5.3-5.12.

NOTE: Where the common bus is not grounded, insulated mounting hardware may be required. Such hardware will not be considered in the required tests.

5.3 Each ungrounded conductor of the input line-power circuit of a transformer shall be protected by a noninterchangeable fuse or circuit breaker that has been investigated and complies with the requirements for fuses or circuit breakers (ANSI _________). In addition, an embedded thermal fuse or protector may be used for protection against overheating.

Exception: Transformers that are of Type 2A or Type 3 construction.

5.4 The metal core of a transformer shall have a connection to a common bus.

Exception: Where such a connection is not practicable; for example, insulated toroidal core transformers used in direct-current to direct-current converters.

5.5 A transformer shall withstand the dielectric voltage-withstand test specified in paragraph 21.1 or paragraph 21.2, as appropriate.

5.6 A transformer shall be one of the types described in paragraphs 5.7-5.12. The winding intended for supplying an intrinsically safe circuit (output) shall be electrically separated from all other (input) windings.

5.7 TYPE 1 - The transformer shall have the input and output windings located either:

A. TYPE 1A - Side by side on one leg of the core separated with insulating material such as 0.79 millimeters (1/32 inch) thick phenolic, melamine resin, or equivalent construction; or

B. TYPE 1B - On different legs of the core.

5.8 A Type 1 transformer shall be subjected to the abnormal operation test described in paragraph 20.1.

5.9 TYPE 2 - The transformer shall have the input and output windings wound over each other and shall have either:

A. TYPE 2A - Reinforced insulation provided between the input and output windings, including splices and crossover leads if present, that complies with the abnormal operation test requirement in paragraphs 16.3 and 20.2.

B. TYPE 2B - A screen of copper foil or a wire winding placed between the input and output windings, including splices and crossover leads if present, in which case;

1. The thickness of the copper foil or the diameter of the winding wire, shall be such that the event of a short circuit between any winding and the screen, the screen will withstand, without breakdown, the current that flows until the fuse or circuit breaker required by paragraph 5.3 functions. See paragraph 5.10;

2. The screen shall be provided with two leads to the common bus, each of which can withstand without damage, the current that flows before the fuse or circuit breaker operates. See paragraph 5.11; and

3. A wire-wound screen shall consist of not less than two layers of windings.

5.10 The screen employed in a Type 2B transformer is considered to be adequate without testing if it is made of copper foil at least 0.13 millimeter (0.005 inch) thick.

5.11 The screen leads to the common bus are considered to be adequate without testing if each lead is at least equal in size to the primary leads of the transformer but not smaller than No. 24 AWG.

5.12 TYPE 3 - The transformer shall be either a Type 1 or Type 2 construction and shall be subjected to the abnormal operation test described in paragraphs 16.3 and 20.2. A transformer of a Type 2B construction may employ only one screen lead to the common bus.

Damping Winding

5.13 A damping winding shall not be considered subject to fault if it is of reliable mechanical construction such as seamless metal tubes, windings of bare wire continuously short-circuited by soldering, or equivalent construction.

Current-Limiting Resistor

5.14 A current-limiting resistor shall not be considered subject to short-circuit fault if it is of the metal film type or of the wire-wound type with protection to prevent unwinding of the wire in the event of breakage. The resistance element shall be on a ceramic core or substrate with a ceramic covering or equivalent construction. The resistor shall withstand continuously or fail safely in the open condition at any voltage up to and including 1.5 times the maximum fault voltage that can appear across the resistor as determined during fault analysis.

Blocking Capacitor

5.15 A blocking capacitor connected between an intrinsically safe circuit and a nonintrinsically safe circuit shall not be considered subject to fault by shorting if two such capacitors are connected in series and each capacitor can withstand an alternating test voltage of twice the fault voltage plus 1000 volts rms. A blocking capacitor shall be a high-reliability type such as a hermetically-sealed or ceramic capacitor; an electrolytic or tantalum capacitor is not acceptable for this purpose.

Shunt Safety Components

5.16 A shunt safety component shall not be considered subject to fault only if it is duplicated so that the assembly remains safe if one of the components becomes defective. Diodes shall be connected near the protected component in such a manner that they are not likely to become disconnected unless disconnection of either of the shunt components ensures that the protected component will be disconnected at the same time. Shortcircuiting of the protected component to ground shall be considered, unless the required spacings are provided -- see Section 8. Breaking of a conductor simultaneously with shortcircuiting to ground is not automatically assumed. Breaking of a conductor shall be judged on the basis of the physical construction and the likelihood of such an occurrence.

5.17 Diodes used as shunt safety components shall carry, without open-circuiting, the current that would flow if they short-circuited.

Shunt Diode Barriers

5.18 Shunt diode barriers shall not be considered subject to fault if they comply with the requirements of paragraphs 5.19-5.26.

5.19 A barrier component breakdown shall be safe under all transient and steady-state conditions likely to arise in service including the application to the network of maximum input voltage to the apparatus. The construction shall be such that:

A. A barrier resistor shall withstand continuously or fail safely in the open condition at any voltage up to and including 1.5 times the maximum voltage that can appear across the resistor, considering circuit faults.

B. A barrier diode shall withstand continuously or fail safely in the short-circuit mode when 1.5 times the maximum barrier current available through the fuse or resistor under fault conditions passes through the diode.

C. The fuse in a fuse-protected diode barrier shall open in not more than one-tenth of the minimum open-circuit time of any barrier diode that it protects with the entire fuse current passing through the diode.

5.20 It is to be assumed that the maximum voltage of the nonintrinsically safe circuit will not exceed 350 volts unless a higher value is specified by a manufacturer.

5.21 The design of a barrier that may be replaced in the field shall be obviously asymmetrical about the mounting studs, so that the barrier can readily be mounted correctly.

5.22 At least one suitable terminal or connection shall be provided on each barrier package, for connection of No. 12 AWG, minimum, wire conductor to the common bus as may be appropriate. The terminal shall be:

A. A No. 10 wire binding screw that engages at least two full threads in a metal terminal plate. The metal terminal plate shall not be less than 1.25 millimeters (0.05 inch) thick and shall be provided with upturned lugs or the equivalent to hold the conductor in place.

B. A pressure type wire connector complying with the requirements for pressure wire connectors. (ANSI C33.5 - ________)

C. Other equivalent construction -- a soldering lug, a push-in connector, or a quick-connect or similar friction-fit connector is not acceptable.

Exception: Bussing may be accomplished by bolting the barrier studs to the common bus wherever bussing of a barrier is acceptable.

5.23 Unless located in separate wiring compartments, ungrounded terminals for intrinsically safe circuit's hazardous location connections shall be separated from ungrounded terminals of nonintrinsically safe circuits by at least 50 millimeters and shall be protected to prevent unintentional contact with other leads. See the requirements for field wiring separation in Section 10.

5.24 Barrier components shall be mounted and arranged so as to prevent the occurrence of a fault that could impair the proper operation of the barrier; for example, a short circuit of any series resistor or fuse or an open circuit of any shunt diode.

5.25 A fuse-Protected diode barrier shall be encapsulated with an insulating material such as an epoxy, or equivalent setting-type material, and the encapsulated package shall be required to pass a dielectric withstand test, see 22.1.

5.26 Unless components of a resistor-protected diode barrier are encapsulated, the enclosure shall prevent access, without disassembly of the apparatus, to the components and shall provide adequate protection for all conditions of service for which the barrier is intended.

Other Constructions

5.27 Constructions other than those described in paragraphs 5.1-5.26 may be examined and tested to determine whether they meet the intent of the requirements for reliable components or networks. Other constructions include, but are not limited to, photoelectric barriers and electronic networks (active barriers).

6. Overcurrent Protection

6.1 A fuse may be used for circuit protection in associated equipment but is not considered to be a protective component for preventing transients or faults. To facilitate testing, fuses may be short-circuited during explosive mixture ignition tests.

6.2 A fuse shall not be used in apparatus intended for use in gassy locations unless it is provided with an appropriate means of protection such as a permissible enclosure.

> Exception: A fuse in an intrinsically safe circuit intended for use in a gassy location need not be within a permissible enclosure if tests show that the circuit and the fuse will not ignite the hazardous atmosphere.

7. Plugs and Receptacles

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

> Exception No. 1: If no hazard can arise from an interchange.

> Exception No. 2: The plugs and receptacles are so identified that interchange by competent personnel is unlikely.

8. Spacings

8.1 Any spacing including spacings to ground, that can affect adversely the intrinsic safety of the apparatus shall be considered subject to fault unless the spacings are not less than those specified in Table 8.1A for the intrinsically safe circuit of category A associated apparatus. Table 8.1B is suggested as a guide for category B associated apparatus. A spacing not less than one-third of the value in Table 8.1A or Table 8.1B, as appropriate, shall be considered to be a possible fault. A spacing less than one-third of the value in Table 8.1A or Table 8.1B may be considered as connected without being a fault. All spacings in category B associated apparatus may be tested at 1/15 atmosphere, absolute, with maximum required voltages between conductors.

TABLE 8.1A

Minimum Spacings Between Uninsulated
Conductive Parts Considered Not
Subject to Fault
Intrinsically Safe Circuits and Category A Associated Apparatus

Peak Volts[a]	Spacings in Millimeters (Inch)[b]	
	Through Air	Over Surface
0<V≤ 60	3 (0.118)	3 (0.118)
60<V≤ 90	4 (0.158)	4 (0.158)
90<V≤ 190	8 (0.315)	6 (0.236)
190<V≤ 375	10 (0.394)	6 (0.236)
375<V≤ 550	15 (0.591)	6 (0.236)
550<V≤ 750	18 (0.709)	8 (0.315)
750<V≤ 1000	25 (0.984)	10 (0.394)
1000<V≤ 1300	36 (1.417)	14 (0.552)

[a]The voltage is to be taken as a sum of the peak voltages in the intrinsically safe circuit and the nonintrinsically safe circuit unless the former does not exceed 20 percent of the latter in which case the peak voltage is to be taken as that of the nonintrinsically safe circuit.

[b]In the case of printed wiring boards where an adherent insulating coating such as epoxy, or the equivalent, is applied to the conductors, the distance between the two conductors may be reduced to one-third of the through-air values shown in Table 8.1A but not less than 1 millimeter (0.04 inch).

TABLE 8.1B

Minimum Spacings Between Uninsulated
Conductive Parts Considered not Subject to Fault
Category B Associated Apparatus

Peak Volts	Spacings in Millimeters (Inch)[a] Through Air	Over Surface
$0 < V \leq 60$	12 ( )	12 ( )
$60 < V \leq 250$	19 ( )	19 ( )
$250 < V \leq 500$	26 ( )	26 ( )
$500 < V \leq 750$	35 ( )	35 ( )

[a]Where adherent coatings are used for surface protection, spacings may be reduced but it is recommended that they not be less than the spacings of Table 8.1A.

8.2 The spacings between two circuits need not comply with the applicable Table if the circuits are effectively separated by a grounded metal barrier or a grounded conductor on a printed circuit board and shorting to ground does not adversely affect the intrinsic safety of the apparatus.

8.3 Where it is necessary to maintain intrinsic safety, conductors that are encapsulated together in a casting resin or similar insulating medium shall be separated by a distance not less than one-third of the through-air distance specified in Table 8.1A before encapsulation, but not less than 1 millimeter (0.04 inch). Dielectric withstand tests may be applied if deemed necessary in the opinion of the testing agency.

8.4 If an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces, or if a movable dead-metal part is in proximity to an uninsulated live part, the construction shall be such that the required spacing will be maintained.

8.5 A ceramic, vitreous-enamel, or similar coating is not acceptable as insulation in place of spacings unless, upon investigation, the coating is found to be uniform, of adequate minimum thickness, reliable, and otherwise acceptable for the purpose.

8.6 Enameled and similar film-covered wire is considered to be an uninsulated live part in determining whether a device complies with the spacing requirements.

9. Separation of Internal Wiring

9.1 Wiring of intrinsically safe and other circuits that may affect intrinsic safety shall be effectively separated from wiring of nonintrinsically safe circuits. Where positive separation cannot be ensured, a partition of metal or nonmetallic material that has been investigated and found to be acceptable may be provided to separate the two systems.

9.2 Among the factors that are to be considered in judging a partition material are (1) mechanical strength, (2) resistance to impact, (3) moisture absorptive properties, (4) combustibility, (5) resistance to liquids which may be present, and (6) resistance to distortion at temperatures to which the material may be subjected under conditions of normal and abnormal use. All of these factors are to be considered with respect to thermal aging and initial condition.

9.3 Separation of insulated conductors may be accomplished by clamping, routing, or equivalent means that ensures permanent separation from insulated or uninsulated live parts of a different circuit.

9.4 A partition used to provide separation between the wiring of different circuits shall be (1) of a material as described in paragraphs 9.1 and 9.2, (2) of adequate mechanical strength if exposed or otherwise likely to be subjected to mechanical damage, and (3) securely held in place.

9.5 Separation between intrinsically safe circuits and Class 2 and 3 power-limited circuits as defined in the National Electrical Code, CI-1975, may be accomplished by a sleeve of additional insulation rated at least 600 volts on the intrinsically safe or power-limited circuits. The insulating sleeve shall be of a type that has been investigated and complies with the requirements for insulating sleeving. (ANSI C33.15 - _____)

10. Field Wiring Connections

10.1 The construction shall be such that field-installed conductors of an intrinsically safe circuit will be separated from:

A. Field-installed and factory-installed conductors connected to any other circuits, for example, line-voltage, or low-voltage;

B. Uninsulated live parts of any other circuit of the device; and

C. Any uninsulated live part, the short circuiting of which would result in unsafe operation of the controlled device.

10.2 A partition of metal or nonmetallic material may be used to provide separation between the field wiring of the intrinsically safe or associated circuit and the wiring or uninsulated live parts of other circuits.

10.3 A metal partition used to provide separation shall be grounded and shall have strength and rigidity so that it is unlikely to be damaged during field installation of wiring. A partition of nonmetallic material shall be of such thickness and be so supported that its deformation cannot be readily accomplished so as to defeat its purpose, but in any case, the thickness shall not be less than 1.0 millimeter (0.04 inch).

10.4 If the field-wiring connections are separated by more than 200 millimeters (8 inches), separation of intrinsically safe or associated field-installed conductors from uninsulated live parts of the device connected to different circuits may be accomplished by arranging the location of the openings in the enclosure for the various conductors -- with respect to the terminals or other uninsulated live parts -- so that intermingling of the conductors or parts of different circuits is unlikely.

10.5 To determine if a device complies with the requirement in paragraph 10.1, it is to be wired as it would be in service; slack of 150 millimeters (6 inches) is to be left in each conductor within the enclosure, and not more than average care is to be exercised in stowing this slack into the wiring compartment.

10.6 Other equivalent constructions, such as a combination of partitions and spacings, that will separate the intrinsically safe from the nonintrinsically safe field wiring may be considered.

11. Panel Wiring

11.1 Apparatus that is intended for installation and wiring in a panel assembly (on machinery or vehicles) shall comply with the requirements for field-wiring connections, or may have wiring terminals for intrinsically safe and nonintrinsically safe circuits separated by a distance of not less than 50 mm (2.0 inches) if clear installation instructions regarding wire routing and field connections are provided.

11.2 Additional precautions such as wiring tiedowns or special wiring methods may be required to provide segregation of circuits in locations, such as at terminals that are arranged above one another, where spacings alone do not ensure separation. The layout of terminals and wiring method used shall prevent contact between circuits if a wire becomes disconnected.

12. Battery-Powered Apparatus

12.1 These requirements apply to portable and stationary battery-powered apparatus in which the entire assembly, including batteries, is intended to be used in a gassy location and is not provided with appropriate means of protection such as a permissible enclosure.

12.2 In addition to complying with the requirements under fault analysis in Sections 13-17, the power source -- batteries shall comply with 16.3 -- shall be incapable of causing ignition when voltage is increased by 10 percent and the current is then increased by a factor of 1.5 or the voltage by a factor of $\sqrt{1.5}$. For the purpose of this test, the battery supply output shall be measured and the maximum voltage and current values shall be simulated. If agreeable to all concerned, the intended batteries may be used for tests, with the power safety factor increased to 2.0.

12.3 An inherent current-limiting resistor complying with the requirements in paragraph 5.14 or other suitable current-limiting device may be provided in the batteries to limit the output current. Such an inherent device is not to be bypassed during tests.

12.4 If the current-limiting resistor is not an integral part of the battery, the apparatus may be tested with the resistor in the circuit if it is constructed as follows:

A. The battery housing is arranged and constructed so that the batteries can be installed and replaced without short-circuiting the battery output and without applying the battery output to the load side of the resistor.

B. For portable apparatus, the resistor is encapsulated with an insulating potting material that cannot be removed without destruction of the apparatus.

C. For portable apparatus, the construction of the battery compartment prevents the ejection of batteries when the apparatus is subjected to the drop test described in Section 27.

D. The apparatus is marked as specified in paragraph 30.8.

12.5 Apparatus that is provided with external contacts for recharging the batteries shall be provided with means to protect the batteries from short circuiting, as a result of unintentional contact between the charging contacts and metal objects. This may be accomplished by:

A. Recessing the charging contacts so that the circular disk probe 1.2 millimeters (3/64 inch) thick and 7.0 millimeters (9/32 inch) in diameter will not touch the contacts.

B. Providing blocking diodes in each contact circuit.

C. Other equivalent means.

FAULT ANALYSIS

13. General

13.1 Intrinsically safe apparatus, circuits, and associated apparatus shall be subjected to a fault analysis. From the analysis, the hazardous fault conditions are to be selected for further consideration. A power or energy safety factor of 1.5 is to be introduced. Sources of potential thermal ignition or failure are to be determined. Sources of spark ignition are to be checked against the appropriate ignition curves in Figures 15.1-15.4 and test circuits are to be selected as necessary.

13.2 In applying the fault analysis, one and two independent faults and the appropriate safety factors shall be considered. Only protective components complying with the requirements in Section 5 and with the spacings specified in Table 8.1 shall not be subjected to faults.

13.3 Subsequent electrical breakdown of other components that results from electrical or thermal consequences of an initial fault is considered to be part of the initial fault.

13.4 In the analysis, the field wiring of a circuit may be open-circuited or may be connected together or to ground or both. These conditions are not considered to be faults. If more than two leads are present, short-circuiting to an additional lead shall be considered as a fault.

13.5 A short spacing is to be judged under the most unfavorable condition that might result because of that short spacing. Short-circuiting of a spacing that is less than one-third that specified in Table 8.1 will not be counted as a fault. If multiple-capacitive and inductive circuits are involved, and if short-circuiting of spacings could result in those circuits becoming additive, with respect to energy storage, they shall be considered to be short-circuited.

13.6 For battery powered apparatus, the effects of corrosion and conductive paths due to battery leakage shall be considered.

14. Sources of Ignition

14.1 In the circuit fault analysis, the following sources of ignition shall be considered:

A. Sources of spark ignition:

1. Discharge of a capacitive circuit,

2. Interruption of an inductive circuit,

3. Intermittent making and breaking of a resistive circuit, and

4. Hot wire fusing.

B. Sources of thermal ignition:

1. Heating of small-gage wire strand,

2. Glowing of a filament, and

3. High surface temperature of components, including thermal runaway conditions in a transistor or similar component.

15. Spark Ignition Curves

15.1 A circuit can be accepted without tests if the current and voltage levels do not exceed 50 percent of the voltage or current determined from the appropriate propane ignition curves. Circuits that have voltage or current levels higher than 50 percent but less than 100 percent of those determined from the appropriate ignition curves shall be tested to determine that they are acceptable unless other data indicates that tests are not necessary. For higher values of voltage or current, tests are required.

15.2 Figures 15.1 and 15.2 apply to apparatus or circuits in which cadmium, zinc, or magnesium may be present. Figures 15.3-15.4 apply to apparatus or circuits where cadmium, zinc or magnesium is not present and field-installation of wiring is not anticipated.

15.3 Figures 15.1 and 15.3 apply only to resistive circuits in which the inductance is less than 100 microhenries. They identify the combinations of open circuit voltage and short circuit current that may cause the ignition of the most easily ignited propane-air mixture. These curves apply only to circuits that can be represented by a constant voltage and resistance but do not apply to circuits that have voltage or current regulators.

16. Thermal Ignition

16.1 To determine sources of thermal ignition, components located in the gassy location and not provided with appropriate enclosures, shall be tested under fault conditions. Temperatures of components shall not exceed 110 C.

> Exception: Temperatures higher than 110 C may be accepted for small components if it can be shown by tests or experimental evidence that such higher temperatures will not result in ignition.

16.2 Tests are based on an assumed ambient temperature of 40 C (104 F), unless the apparatus is intended for use in a higher ambient temperature. If the apparatus is intended to have an operating temperature exceeding 55 C (131 F), when blanketed with coal dust, the tests are to be based on the maximum operating temperature.

16.3 Where associated apparatus is contained within a permissible enclosure:

A. Failure of components within the enclosure at an ambient temperature of 100 C, or marked maximum operating temperature shall not cause a maximum box surface temperature of a dust covered box to exceed 110 C.

B. Failure of components within the enclosure at an ambient temperature of 100 C, or marked maximum operating temperatures shall not cause associated failures, electrical or thermal, of protective components or construction in such a manner as to reduce intrinsic safety.

17. Safety Factors

17.1 Intrinsically safe circuits shall be incapable of causing ignition (1) during normal operation, and (2) under fault conditions with a safety factor of 1.5 introduced.

17.2 Before the safety factor is introduced, the line or battery voltage shall be increased to 110 percent of either the test voltage specified in Table 18.1 or the rated voltage, as appropriate.

17.3 The power safety factor 1.5, shall be introduced into the circuit as follows:

A. The voltage shall be increased by a factor of $\sqrt{1.5}$ for purely capacitive circuits;

B. The volt-ampere product shall be increased by a factor of 1.5 for resistive circuits, having an inductance less than 100 microhenries by one of the following methods in the order given;

1. Decreasing the value of limiting resistance to obtain the necessary values of test current;

2. Increasing the line-power-supply voltage;

3. Increasing other supply voltages by 10 percent above the maximum possible in service; or

4. Increasing the setting of voltage limiting devices, for example shunt zener diodes, by 10 percent above the maximum possible in the circuit being evaluated.

C. The volt-ampere product shall be increased by a factor of 1.5 for circuits having an inductance of 100 microhenries or more; the current being increased by reducing the value of series resistance, if practicable, but otherwise by increasing the voltage.

D. As an alternative to items A, B, or C, a safety factor may be introduced by using a more sensitive test mixture.

18. Line Powered Apparatus

18.1 The apparatus, circuit, or component parts shall be subjected to the following tests, as appropriate.

18.2 For a line-connected device, the test potential shall be increased 10 percent in accordance with Table 18.1 before the introduction of a safety factor.

18.3 Equipment having a multiple rating may be tested at any of the ratings to ensure that tests are conducted under the most adverse conditions.

TABLE 18.1

TEST VOLTAGE

Voltage Rating of Device	Test Voltage In Volts	110 Percent of Test Voltage in Volts[a]
110-120 ac	120 ac	132 ac
110-125 dc	125 dc	138 dc
208 ac	208 ac	229 ac
220-240 ac	240 ac	264 ac
220-250 dc	250 dc	275 dc
265-277 ac	277 ac	305 ac
440-480 ac	480 ac	528 ac
550-600 ac	600 ac	660 ac

[a]For a device having a voltage rating not specified in Table 18.1, the rated voltage shall be increased to 110 percent before the introduction of a safety factor.

19. Spark Ignition

General

19.1 An intrinsically safe circuit shall be subjected to the tests described in paragraphs 19.3-19.12. There shall be no ignition of the 5.25±0.25 percent propane test mixture.

19.2 Spark ignition tests on an intrinsically safe circuit for use in methane-air, coal dust-air, or methane-coal dust-air, are considered to have been accomplished through the use of the propane test mixture.

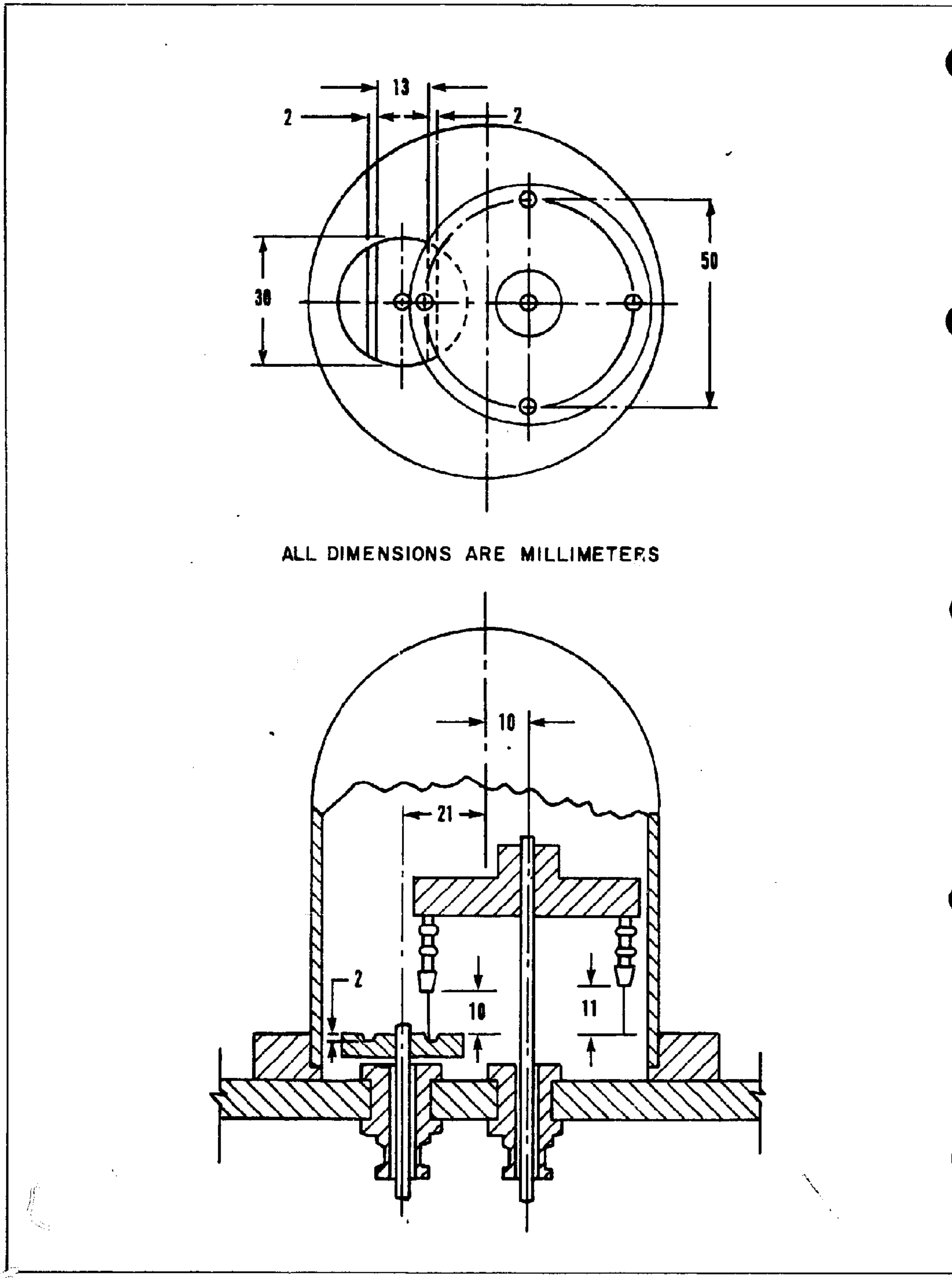


FIG. 19.1 – SPARK TEST APPARATUS

Spark Test Apparatus

19.3 The apparatus illustrated in Figure 19.1 is the basic apparatus to be used for conducting the spark ignition tests. It may be modified in special circumstances indicated below.

19.4 This apparatus is to consist of a set of four tungsten wires having a free length of 11 millimeters (0.43 inch) equally spaced on a diameter of 50 millimeters (2.0 inch) rotating in one direction at a speed of 80 revolutions per minute. The farthest ends of the wires are to be spaced 10 millimeters (0.39 inch) from a cadmium disk 30 millimeters (1.18 inch) in diameter having two slots shaped as shown and revolving in the opposite direction. The ratio of the speed of the shaft driving the tungsten wires to that of the shaft driving the cadmium disk is to be 50 to 12. The diameter of the tungsten wires is to be 0.20 millimeters (0.008 inch). The sparking mechanism is to be enclosed in an explosion chamber having an interior volume of at least 250 cubic centimeters (15 cubic inches), that can be filled with the 5.25±0.25 percent propane test mixture.

19.5 Test apparatus wiring and brushes shall deliver at least 95 percent of the source voltage between the two rotating plates at the maximum test current to be used in the particular apparatus.

19.6 Because the test apparatus uses small tungsten wires it is suitable for testing at currents up to 3 amperes. For circuits having currents exceeding this value, the tungsten wires will be replaced by wire of the material used in the circuit, and having a cross sectional area not exceeding 50 percent of that of the smallest circuit wiring conductor at the point of investigation.

19.7 For tests of capacitive circuits, modified apparatus or speed may be needed to allow adequate charging time.

19.8 In no instance shall the diameter of the wire used in the testing machine exceed 80 percent of the diameter of the smallest conductor or strand used in wiring the circuit at the point of consideration. If the smallest conductor or strand used in wiring the apparatus is less than No. 30 B&S, the testing machine shall use a wire electrode having a diameter of 80 percent or less of the diameter of the smallest conductor or strand in the circuit at the point of consideration. The wire electrode material shall be the same as used for wiring the apparatus at the point of test.

19.9 For circuits in which cadmium, zinc, and magnesium will not be present, a brass or tin disk may be substituted for the cadmium disk. See paragraph 15.2

Calibration of Spark Test Apparatus

19.10 Immediately preceding and following each spark ignition test, the apparatus shall be calibrated using a special circuit having an adequate supply of 24 volts, direct current, an air core inductance of 100±10 percent millihenries of which the actual value is to be known within 2 percent and sufficient resistance to give an inductive current according to the equation $I = 1.10 \left[\sqrt{\frac{9.6 \times 10^{-4}}{L}} \right]$. For resistive circuits (less than 100 microhenries), the inductance shall be omitted and a current of 1.00 ampere shall be used.

19.11 During the calibration test, the tungsten electrodes shall be connected in the positive side of the circuit.

19.12 If the apparatus does not produce at least one ignition in 400 continuous revolutions of the tungsten wire drive spindle before and after the test at the current prescribed, the test is not considered valid.

Test Method

19.13 When the apparatus has been properly calibrated, the circuit to be tested, with the fault conditions and applicable safety factors introduced, shall be connected to the two electrodes of the test apparatus and attempts made to ignite the explosive mixture.

19.14 For a direct-current circuit, the test shall be continued for not less than 400 revolutions, reversing the polarity after not less than 200 revolutions.

19.15 For an alternating-current circuit, the test shall be continued for not less than 2000 revolutions.

19.16 The testing agency may require additional tests at the peak voltages experienced in alternating current circuits with a current such that the maximum power under fault conditions is represented. The speed of the test apparatus spindles may be varied to obtain worst case conditions.

20. Protective Transformer Abnormal Operation

20.1 The temperature rise of a Type 1 transformer shall not exceed the acceptable value for the class of insulation employed when the transformer is loaded to 1.5 times the rating of the primary fuse or circuit breaker and is operated continuously until temperatures are constant. For the test, the protective device shall be by-passed. The secondary shall be loaded until 1.5 times the rating of the overcurrent protection device is reached. If the secondary cannot be loaded enough to reach 1.5 times the current, the primary voltage shall be adjusted to result in 1.5 times the current. The test voltage shall be at rated frequency and initially as specified in Table 18.1. Three samples shall be tested and immediately after the test shall be subjected to dielectric voltage-withstand test in Section 21.

20.2 There shall be no emission of flame or molten metal when a Type 2A transformer is operated with any or all secondary windings short-circuited. The samples shall be operated continuously at the voltage specified in Table 18.1 and at rated frequency until temperatures are constant or until burnout occurs. Three samples shall be tested and immediately after the test shall be subjected to the dielectric voltage-withstand test in Section 21.

20.3 The temperature rise of a Type 3 transformer shall not exceed the acceptable value for the class of insulation employed when the transformer is operated as described in paragraph 20.2. Thermal fuses or overcurrent protective devices, if provided shall be short-circuited during the test. Three samples shall be tested and immediately after the test shall be subjected to the dielectric voltage-withstand tests in Section 21.

21. Protective Transformer Dielectric Voltage-Withstand

21.1 A protective transformer that is intended for direct connection to an external supply system shall withstand the application of the following 60 hertz essentially sinusoidal potentials applied for 1 minute between:

A. Input and output windings; four times the highest rated voltage of any winding or 2500 volts, whichever is higher.

B. All windings and the core and screen; twice the highest rated voltage of any winding or 1000 volts, whichever is higher.

C. Each winding supplying an intrinsically safe circuit and every other winding; twice the highest rated voltage of any winding plus 1000 volts or 1500 volts, whichever is higher.

21.2 A protective transformer that is not intended for direct connection to an external supply system shall be subjected to the test described in paragraph 21.1.

Exception: The potential between the input and output windings may be reduced to twice the highest rated voltage plus 1000 volts, or 1500 volts, whichever is higher.

21.3 The dielectric voltage-withstand tests described in paragraphs 21.1 and 21.2 shall be conducted on the samples subjected to the abnormal operation test specified in Section 20. Three samples shall be tested.

22. Dielectric Voltage-Withstand on Circuits

22.1 Circuits shall withstand for 1 minute without breakdown a 60 Hertz essentially sinusoidal potential of 1500 volts or twice the highest rated voltage plus 1000 volts whichever is higher, applied between intrinsically safe circuits and nonintrinsically safe circuit terminals unless separation of the circuits is accomplished by a conductive type barrier; for example, a zener barrier.

23. Battery Rupture

23.1 A rechargeable battery shall not rupture when subjected to a temperature of 90 C (194 F) for 7 hours.

24. Therml Ignition-Component Overload

24.1 The component shall be connected to a supply circuit that is determined during the fault analysis. The component shall be operated continuously until maximum temperature is attained. Also see Section 16.

25. Thermal Ignition-Transistor

Thermal Runaway

25.1 Three samples of the transistor shall be subjected to this test at the maximum rated operating temperature of the apparatus. The transistor collector and emitter shall be connected in series with the power source. The polarity shall be such that the emitter junction is forward biased. A variable resistor shall be connected between the transistor base and collector. The resistance shall be slowly decreased until a thermal-runaway condition occurs, or until the resistance is reduced to zero. The test is to be continued under these conditions until maximum temperatures are attained. Also see Section 16.

25.2 The test described in paragraph 25.1 is to be conducted with the transistor heat sink in place if the transistor and heat sink are assembled together in such a manner that the assembly will remain intact, giving consideration to the method of assembly. However, if agreeable to all concerned, the test may be conducted without the heat sink.

26. Thermal Ignition-Heating of Small Gage Wire Strand

26.1 Small gage wires of the type used in the circuit under test may be subjected to their maximum current under fault conditions while in the presence of a 7.75±0.25 percent methane-air mixture and while embedded in a coal dust layer. No ignitions of the tests mixture shall result.

26.2 The length of wire employed shall not exceed the minimum length required to bridge the battery-supply terminals by more than 13 millimeters (1/2 inch). If coiled wire is employed in the device, it shall be used in lengths as specified above. Also see Section 16.

27. Drop Test on Portable Battery-Operated Apparatus

27.1 Battery-operated apparatus shall be subjected to a drop test unless current-limiting devices are an integral part of the battery. When the device is dropped on a concrete floor ten times from a height of 900 millimeters (36 inches), there shall be no ejection of the battery or batteries nor other manifestation of a hazard.

27.2 For the first five drops, the device is to be allowed to fall freely in a manner that would normally be the case if the device were to fall from a horizontal surface to the floor. In the remainder of the test, the device is to be held at various angles 900 millimeters (36 inches) above the concrete surface and dropped to the floor.

28. Lamp Breakage

28.1 The heated filament of a tungsten-filament lamp or the arc of a gaseous-discharge lamp shall not ignite the surrounding explosive mixture during the lamp breakage or lamp filament tests. The explosive mixture shall be 7.75 percent ±0.25 methane in air. A series of at least 30 tests shall be conducted.

28.2 For the lamp breakage tests, the device having rated voltage or test potential as specified in Table 18.1 is to be installed in a test chamber provided with inlet and outlet connections to the pipelines carrying the explosive mixture. The explosive mixture is to be caused to flow readily around the lamp bulb. The explosive mixtures are to be prepared by auxiliary equipment capable of maintaining predetermined concentrations of the mixtures.

28.3 The explosive mixture is to be allowed to flow into the test chamber until the original air has been displaced. Samples are then to be taken for analysis from (1) the test chamber, and (2) the line carrying the explosive mixture. The lamp is then to be lighted by the normal power supply provided for the device and the glass envelope of the lamp subsequently broken, leaving a mechanically undamaged filament.

28.4 If the lamp or lampholder assembly contains a special ejection device or a filament-breaking device, the glass envelope shall be broken within the test chamber without attempting to defeat the circuit breaking device.

29. Test for Accumulation of Static Electricity

29.1 To determine whether a plastic enclosure complies with the requirement in paragraph 4.10, no sparks shall be observed when a grounded metal sphere is brought into close proximity with the plastic enclosure after it has been electrostatically charged.

29.2 The sample is to be conditioned for at least 48 hours in a chamber having a relative humidity of not more than 35 percent.

29.3 Immediately after conditioning, the sample is to be suspended by means of insulated supports in a dark room having a relative humidity of not more than 35 percent. Conductive parts of the enclosure are to be grounded as intended in service. An electrostatic charge is to be sprayed on nonconductive parts of the enclosure using a source limited to 15,000 volts.

29.4 A 3/8 inch diameter grounded metal sphere is to be brought into close proximity with nonconductive parts of the sample.

Exception: These tests may be waived if evidence is present that the plastic material does not charge electrostatically under the conditions for use.

MARKING

30. Details

30.1 It is desirable that as much information as possible shall be provided on the apparatus label but it is recognized that it may be impracticable to make some small pieces of apparatus with all the required information.

30.2 For this reason, all the information necessary to external connections affecting safety shall be provided with the equipment (e.g., maximum voltage, minimum resistance, maximum inductance or, in special cases, a specific type of apparatus to be connected).

30.3 The minimum marking shall be:

(a) The manufacturer's name, the MESA logo, the approval or certification number, and the model, type or part number.

(b) For shunt diode safety barrier assemblies only, the maximum voltage that can safely be applied to the nonintrinsically safe terminals.

30.4 In addition to the minimum marking specified above, the apparatus shall, where practicable, have the marking specified in 30.5 or 30.6 as appropriate.

30.5 Intrinsically safe apparatus.

(a) A warning label stating "Any substitution of components may impair intrinsic safety."

(b) If necessary, a warning drawing attention to the special conditions mentioned in the certification documents.

30.6 Associated apparatus:

(a) A warning label stating "Any substitution of components may impair intrinsic safety."

(b) If necessary, a warning drawing attention to the special conditions mentioned in the certification documents.

(c) All other necessary information (e.g. specific installation requirements).

30.7 Terminal Marking. Terminals, terminal boxes and plugs and receptacles of intrinsically safe circuits shall be clearly marked such as with a label "Intrinsically Safe" and shall be clearly distinguishable. Where a color is used for this purpose, it shall be bright blue.

30.8 Battery-powered equipment shall be marked to indicate the type, voltage, and size of batteries to be used in the equipment.

30.9 If necessary for proper operation of the apparatus, the polarity of the output leads or terminals of a direct-current circuit shall be permanently marked.

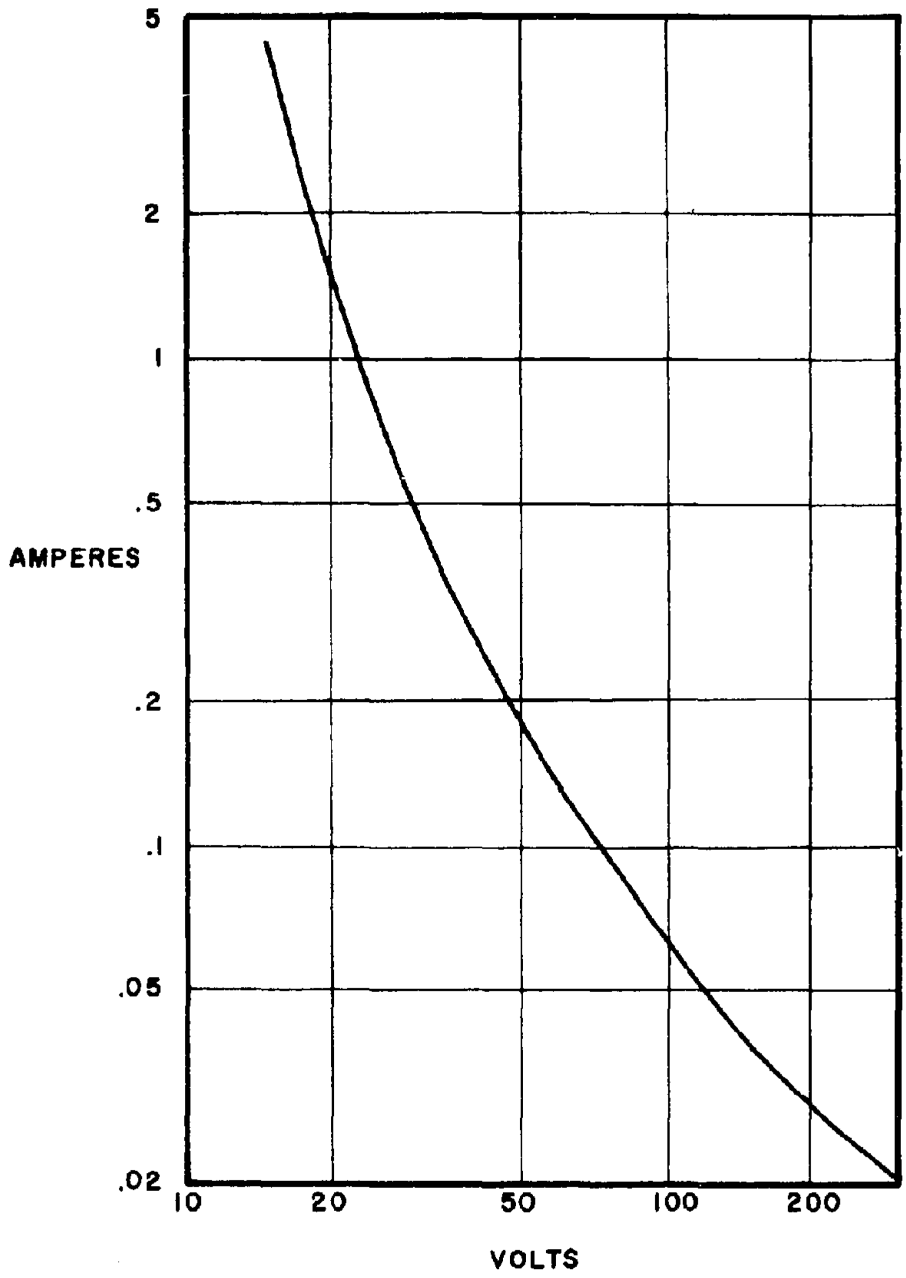
30.10 Apparatus intended for use in an ambient temperature exceeding 40 C shall be marked to show the maximum ambient temperature in which it is to be used.

30.11 All permanent marking shall be legible and prominent and, shall be so located that they will be visible after installation of the equipment.

Exception No. 1: Permanent marking that is required to be on apparatus need not be located on the outside of the enclosure of apparatus that is intended for use in fresh air or a permissible enclosure provided it is readily visible by opening a door or removing a cover after installation.

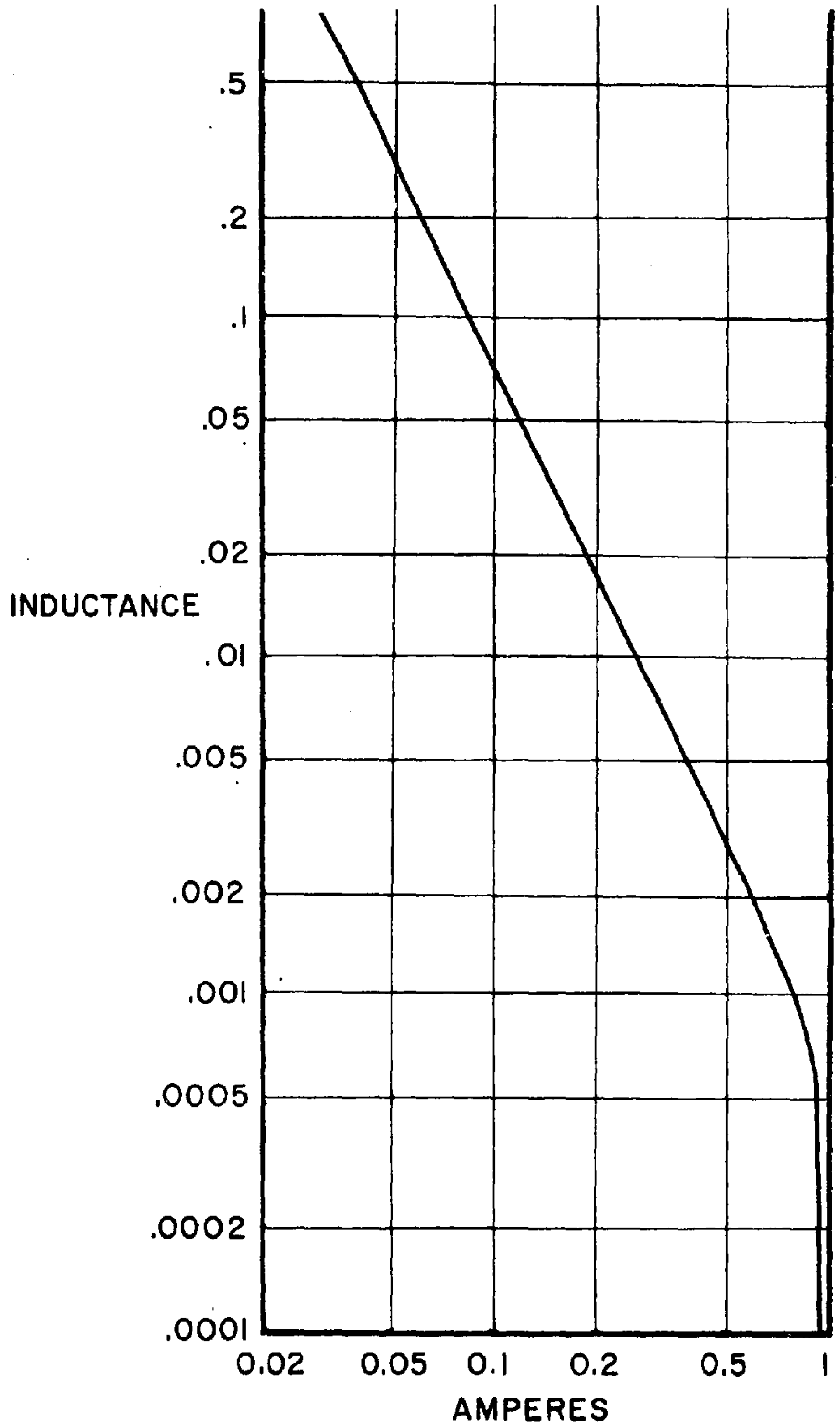
Exception No. 2: Permanent marking that is required to be on apparatus need not be located on the outside of the enclosure of small portable battery-operated apparatus if the marking is loated so that it is readily visible when replacing batteries.

30.12 Marking that is required to be permanent shall be molded, die-stamped, paint-stenciled, stamped or etched metal that is permanently secured, or indelibly-stamped lettering on pressure-sensitive labels secured by adhesive, that, upon investigation, is found to be adequate and suitable for the application. Ordinary usage, handling, or the like of the apparatus and the atmosphere in which used, is considered in the determination of the permenancy of the marking.



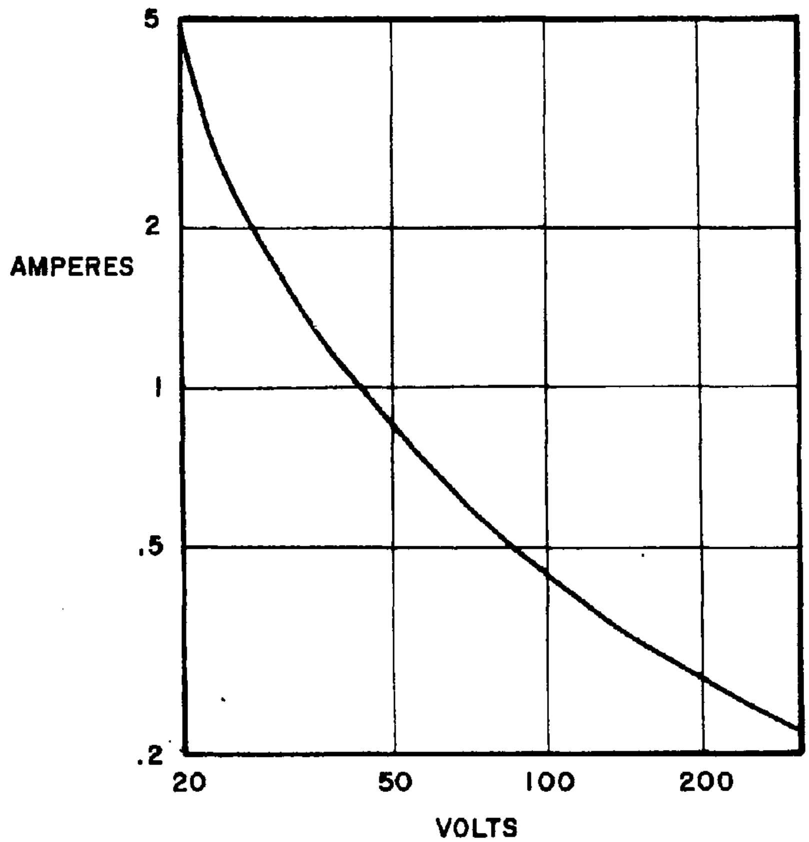
Minimum igniting currents for resistive circuits (L≤100 microhenries) (5.0 – 5.5% propane by volume in air). This curve is applicable to circuits in which cadmium, zinc or magnesium may be present.

FIG. 15.1 – RESISTIVE CIRCUITS



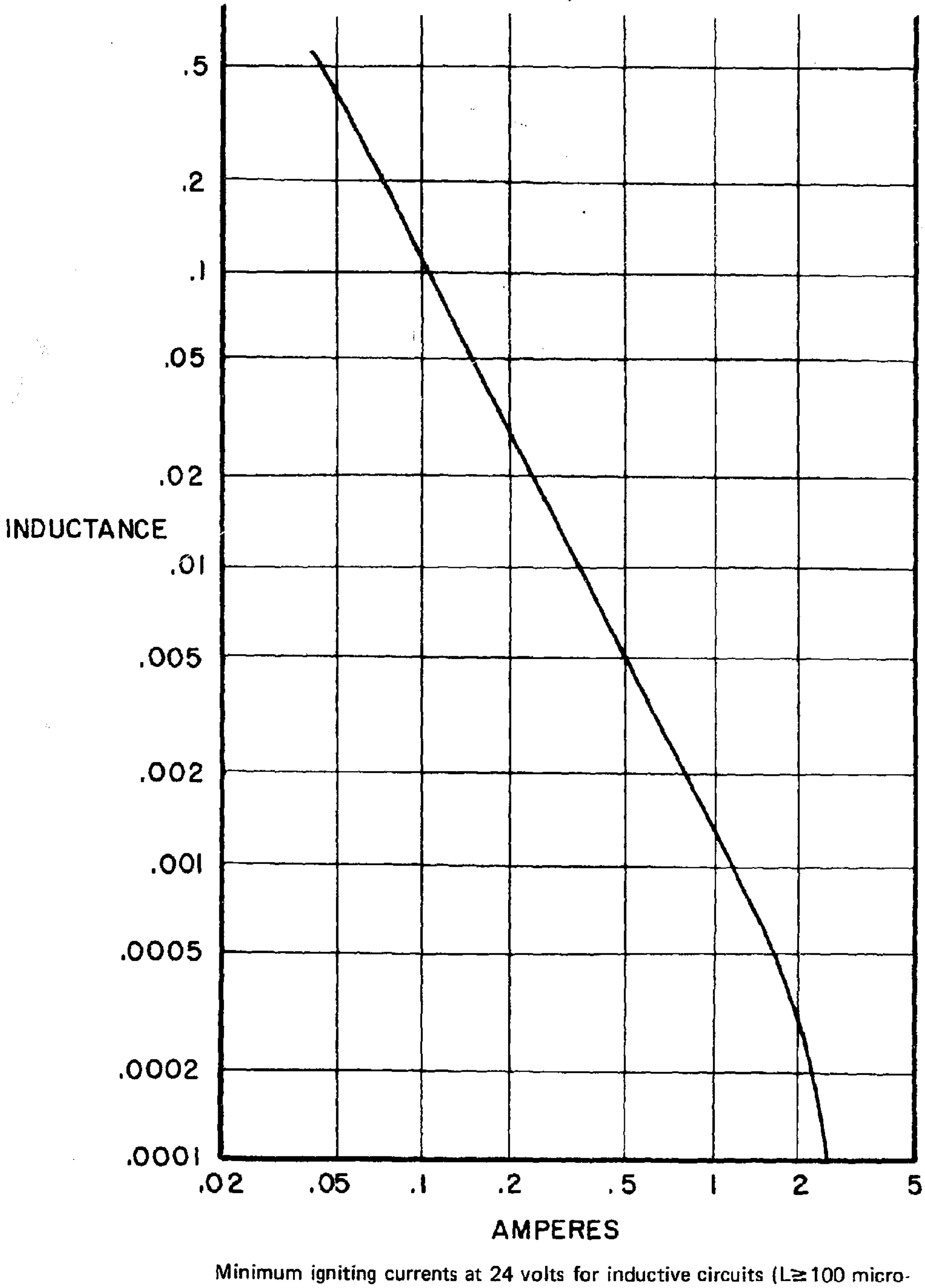
Minimum igniting currents at 24 volts for inductive circuits (L≥ 100 microhenries) (5.0 – 5.5% propane in air by volume). This curve is applicable to circuits in which cadmium, zinc or magnesium may be present.

FIG. 15.2 – INDUCTIVE CIRCUITS



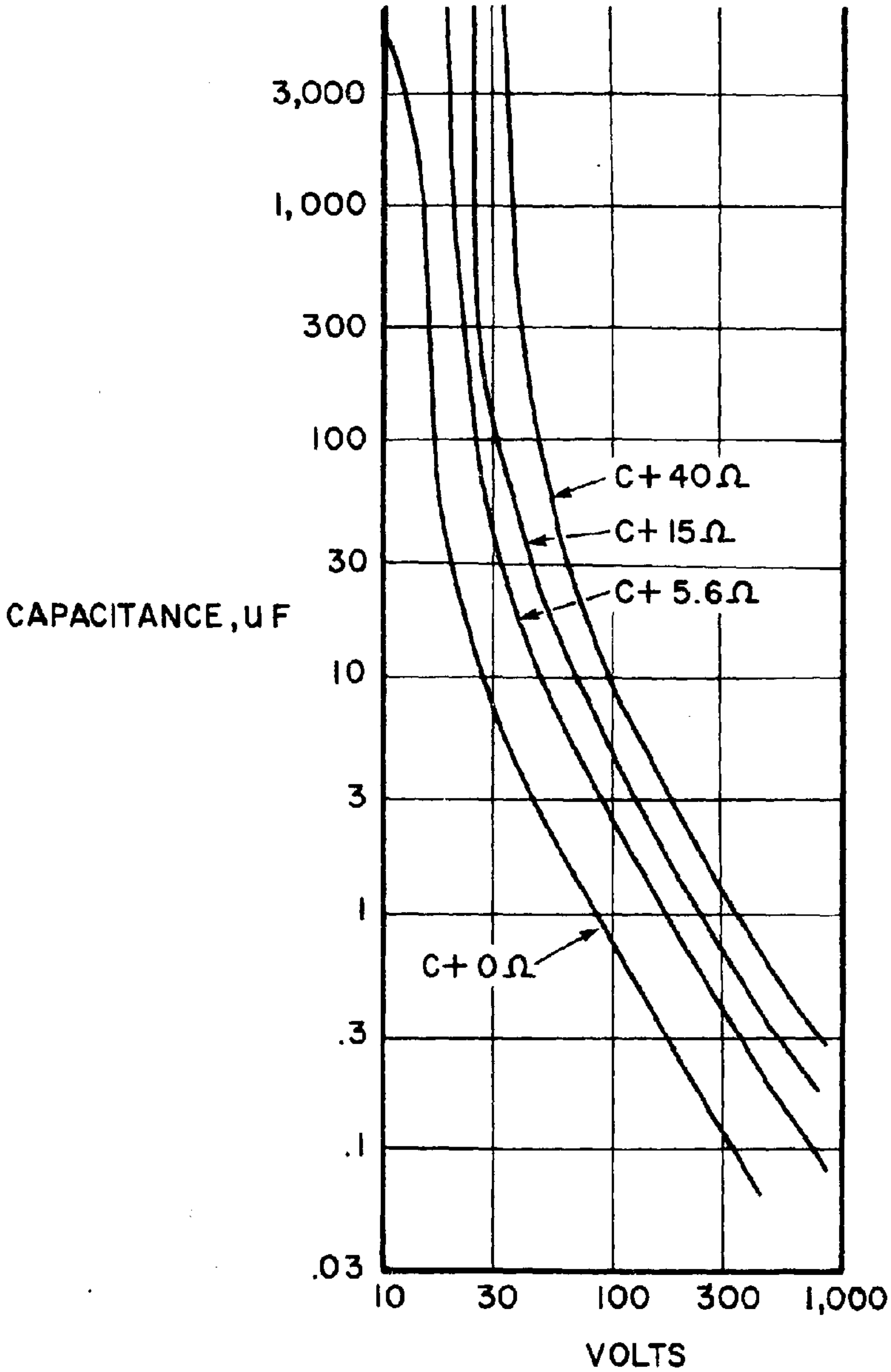
Minimum igniting currents for resistive circuits (L≤100 microhenries) (5.0 — 5.5% propane in air by volume). This curve is applicable to circuits in which cadmium, zinc or magnesium will not be present.

FIG. 15.3 — RESISTIVE CIRCUITS



Minimum igniting currents at 24 volts for inductive circuits (L≳100 micro-henries) (5.0 – 5.5% propane by volume in air). This curve is applicable to circuits in which cadmium, zinc or magnesium will not be present.

FIG. 15.4 – INDUCTIVE CIRCUITS



Minimum ignition voltages for capacitive circuits (8.3% methane by volume in air). These curves correspond to the values of current limiting resistance indicated, and are shown for illustrative purposes only.

FIG. 15.5 – CAPACITIVE CIRCUITS

A P P E N D I X B

The following paragraphs taken from Part 1 of the UL Standard for Intrinsically Safe Electrical Circuits and Equipment for Use in Hazardous Locations, UL 913(7), First Edition, represent the requirements used in determining compliance with Sections 18.24 and 18.60(e) of CFR Title 30, paragraphs 4.2 and 4.4 of UL 913(1), Second Edition and paragraph 4.2 of "MESAP".

GENERAL

26. The apparatus shall employ materials that are suitable for the particular use and shall be made and finished with the degree of uniformity and grade of workmanship practicable in a well-equipped factory.

27. A component of the apparatus shall comply with the requirements for that component, except that the requirements may be modified if appropriate for the particular application.

CONSTRUCTION

28. The apparatus shall be so formed and assembled that it will have the strength and rigidity necessary to resist the abuses to which it is liable to be subjected, without increasing its fire hazard due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other series defects.

29. The apparatus shall be provided with an enclosure of material suitable for the particular application, which shall house all electrical parts that may present a fire, shock, or accident hazard under any condition of use. See paragraph 31.

30. Enclosures of individual electrical components, outer cabinets, and combinations of the two are taken into consideration in applying the requirement in paragraph 29.

31. A portion of an overall enclosure may be omitted if the apparatus is designed to be so installed in conjunction with other equipment that the latter will complete the enclosure, and suitable installation instructions are provided.

32. Among the factors taken into consideration when acceptability of an enclosure is being judged are (1) physical strength, (2) resistance to impact, (3) moisture absorptive properties, (4) combustibility, (5) resistance to corrosion, (6) resistance to distortion at temperatures to which the enclosure may be subjected under conditions of normal or abnormal use, (7) resistance to solvents as covered by the hazardous area group classification, and (8) resistance to the generation of dangerous static charges. For a nonmetallic enclosure, all of these factors are considered with respect to thermal aging.

Mounting

76. Provision shall be made for securely mounting a permanently connected device of other than the freestanding type to a supporting surface. Bolts, screws, or other parts used for mounting a device shall be independent of those used for securing component parts of the device to the frame, base, or panel.

Overcurrent and Overload-Protective Devices

89. The construction of intrinsically safe equipment incorporating a fuseholder and the location of fuses in other than a low-voltage circuit, the normal function of which requires renewal, shall be such that fuses will be readily accessible, when the switch contacts are open, so that they may be replaced without a person touching any live part. The electrical arrangement of a single-throw switch shall be such that, if properly connected, fuse terminals will be dead when the switch contacts are open.

90. A control-circuit fuse is not considered to require renewal as a normal function under any of the following conditions:

A. The fuse and control-circuit load (other than a fixed control-circuit load, such as a pilot lamp) are within the same enclosure.

B. The fuse protects a component (such as pilot light, a relay-operating coil, a valve, or the like) whose load characteristics are shown by an appropriate endurance test are not likely to increase.

C. The fuse can be ruptured only by incorrect wiring; i.e., excess voltage, incorrect frequency, or the like.

91. A protective device shall be wholly inaccessible from outside the apparatus without opening a door or cover, except that the operating handle of a circuit breaker, the operating button of a manually-operable motor protector, and similar parts may project outside the enclosure.

92. Except as noted in paragraph 93, the door or cover of an enclosure shall be hinged and shall be provided with a catch or spring latch if it gives access to any overload-protective device, the normal functioning of which requires renewal, or if it is necessary to open the cover in connection with the normal operation of the protective device.

93. A hinged cover is not required for a device in which the only fuses enclosed are control-circuit fuses, the fuses and control-circuit loads (other than a fixed control-circuit load, such as pilot lamp) are within the same enclosure.

94. Means shall be provided for holding the door or cover over a fuseholder in a closed position; and the door or cover shall be tight-fitting. The holding means shall not depend solely upon screws or other similar means requiring the use of a tool or manipulation of a handle to retain the cover in a closed position.

Mechanical Assembly

95. A switch, a lampholder, an attachment-plug receptacle, a motor attachment plug, or similar component shall be mounted securely and, except as noted in paragraphs 96 and 97, shall be prevented from turning. See paragraph 98.

96. The requirement that a switch be prevented from turning may be waived if all four of the following conditions are met:

A. The switch is to be of a plunger or other type that does not tend to rotate when operated. (A toggle switch is considered to be subject to forces that tend to turn the switch during the normal operation of the switch.)

B. Means for mounting the switch make it unlikely that operation of the switch will loosen it.

C. The spacings are not to be reduced below the minimum acceptable values if the switch rotates.

D. Normal operation of the switch is to be by mechanical means rather than by direct contact by persons.

97. A lampholder of a type in which the lamp cannot be replaced (such as a neon pilot or indicator light in which the lamp is sealed in a nonremovable jewel) need not be prevented from turning if rotation cannot reduce spacings below the minimums required.

98. The means for preventing the turning mentioned in paragraph 95 is to consist of more than friction between surfaces, e.g., a suitable lock washer, properly applied is acceptable as means for preventing a small stem-mounted switch or other device having a single-hole mounting means from turning.

Protection Against Corrosion

99. Except as noted in paragraph 100, all surfaces of iron or steel parts shall be suitable protected against corrosion by enameling, galvanizing, plating, or other suitable means.

100. The requirement in paragraph 99 does not apply to:

A. Bearings, balance weights, laminations, or minor parts of iron or steel (such as washers, screws, or the like);

B. Other parts of iron or steel, if failure of such parts would not be liable to result in hazardous conditions; and

C. The interior surface of a vessel that contains or conducts liquid solvent.

Field Wiring Connection

General

102. For the purpose of these requirements, a field-wiring terminal is considered to be a terminal to which a power supply or control connection will be made in the field when the apparatus is installed.

103. Field-wiring terminals or leads that are supplied from circuits which are judged to be low-voltage circuits, i.e., National Electrical Code (NEC), Class 2, are not required to be further enclosed. These circuits may be intrinsically safe.

Wiring Terminals and Leads

111. The wiring terminals or leads shall be suitable for the connection of field-installed conductors having an ampacity, as required for the device, in accordance with NEC.

112. If the apparatus is intended to be adapted upon installation for either of two different supply voltages (e.g., 120 volts, two wire or 120/240 volts, three wire), it shall be provided with means by which the appropriate connections may be made during field installation, without the necessity of changing or disrupting internal wiring or connections other than at the point of field connection. This requirement does not apply to apparatus which is factory-wired internally for a specific voltage and so marked on the nameplate.

113. A wiring terminal shall have a suitable pressure wire connector, firmly bolted or held by a screw; except that a wire-binding screw may be employed at a wiring terminal intended to accommodate a No. 8 AWG or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position.

114. A wiring terminal shall be prevented from turning.

115. A wire-binding screw shall thread into metal.

116. Except as noted in paragraphs 117 and 118, a wire-binding screw at a wiring terminal shall be no smaller than No. 8.

117. A No. 6 screw may be used for a terminal to which a No. 14 AWG wire or smaller would normally be connected.

118. A wire-binding screw at a wiring terminal supplied from circuits which are judged to be low-voltage, shall be no smaller than a No. 5 machine screw. These low-voltage circuits may be intrinsically safe.

119. A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch thick except that a plate not less than 0.030 inch thick is acceptable if the tapped threads have adequate strength. There shall be two or more full threads in the metal, which may be extruded, if necessary, to provide the threads.

120. Upturned lugs, a cupped washer, or equivalent shall retain a conductor of the size indicated in paragraph 111 under the head of the screw or the washer.

121. A terminal for connection of a grounded power supply conductor shall be of, or plated with, a metal substantially white in color and shall be readily distinguishable from the other terminals; or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as on a wiring diagram adjacent to the terminals.

122. A wire-binding screw intended for the connection of an equipment-grounding conductor shall have a green-colored head that is hexagonal-shaped, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly identified, such as by being marked, G, GR, GROUND, GROUNDING, or the like, or by a suitable marking on a wiring diagram provided on the equipment. The wire-binding screw or pressure wire connector shall be located so that it is unlikely to be removed during normal servicing of the unit.

123. A terminal for connection of an equipment-grounding conductor shall be capable of securing a conductor of the size suitable for the particular application.

124. A soldering lug, a push-in (screwless) connector, or a quick-connect or similar friction-fit connector, shall not be used for the grounding terminal.

125. The surface of a lead intended for connection of a grounded-power-supply conductor shall be white or natural grey, and shall be readily distinguishable from the other leads.

126. The surface of an insulated lead intended for connection of an equipment-grounding conductor shall be green or green with one or more yellow stripes, and no other lead shall be so identified.

127. The requirements in paragraphs 125 and 126 relating to color coding for identification do not apply to internal wiring that is not visible in a wiring compartment in which field connections are to be made.

128. The free length of a lead inside an outlet box or wiring compartment shall be 6 inches or more if the lead is intended for field connection to an external circuit.

129. A lead intended for field connection and exiting from the apparatus through a conduit hub shall be at least 18 inches in length measured from the point of exit of the apparatus to the connection end of the lead.

130. A lead intended to be connected to field-installed wiring shall be no smaller than No. 18 AWG.

Internal Wiring

146. The internal wiring and connections between parts of the apparatus shall be enclosed except that a suitable length of flexible cord may be employed for external connections if flexibility is essential.

147. For the purpose of these requirements, the internal wiring of an apparatus is considered to be all the wiring within the apparatus or forming an integral part thereof.

148. Unless it is to be judged as an uninsulated live or grounded part, insulated internal wiring (including an equipment-grounding conductor) shall consist of wire of a type or types suitable for the particular application, when considered with respect to:

A. The temperature and voltage to which the wiring is liable to be subjected;

B. Exposure to oil, grease, cleaning fluid, or other substances liable to have a deleterious effect on the insulation;

C. Exposure to moisture; and

D. Other conditions of service to which it is liable to be subjected.

149. Except as indicated in paragraphs 150, 151, and 152, insulated wire employed for internal wiring shall (1) be standard building, or fixture wire or appliance-wiring material recognized as being suitable for the purpose, and (2) have an insulation thickness of 1/32 inch or more.

150. Appliance wiring material having 1/64 inch thick insulation and provided with a suitable outer braid or jacket is acceptable.

151. Recognized appliance wiring material having thermoplastic insulation, or equivalent, no less than 1/64 inch thick and without an outer braid or jacket is acceptable in the secondary circuit of an isolated power supply rated 100 volt-amperes or less and 600 volts or less.

152. Appliance wiring material having a heat-resistant rubber insulation, of other than a silicone type, 3/64 inch or more thick and without an outer braid is acceptable.

153. Unless the apparatus includes a heating element and unless the wire is subjected to a temperature of more than 80 C (176 F), asbestos-insulated wire shall not be employed if the wire is liable to be exposed to moisture, including any condensation resulting from operation of the apparatus.

154. If the wiring inside an apparatus may be subjected to physical injury, it shall be in armored cable, conduit, or electrical metallic tubing or shall be otherwise suitably protected.

155. Wiring shall be protected from sharp edges (including male screw threads), burrs, fins, moving parts, or the like, that might cause abrasion of the insulation on conductors.

156. A hole for insulated wires to pass through a sheet metal wall within the overall enclosure shall be provided with a smoothly rounded bushing or the surfaces upon which the wires may bear shall be smooth and free of burrs, fins, sharp edges, or the like, which might abrade the insulation.

157. Insulated wires may be bunched and passed through a single opening in a metal wall within the enclosure of the apparatus.

158. No wires, other than those leading to a part mounted on the door or cover, shall be brought out through the door or cover of an enclosure.

159. All splices and connections shall be mechanically secured and shall provide adequate and reliable electrical contact.

160. Except as indicated in paragraph 161, a soldered connection shall be mechanically secured before being soldered.

161. The requirement in paragraph 160 is not applicable to components mounted to a printed wiring board where dip or wave soldering is used.

162. A splice shall be provided with insulation equivalent to that of the wires involved if permanence of spacing between the splice and other metal parts is not ensured.

163. Insulation consisting of two layers of friction tape, of two layers of recognized thermoplastic tape, or of one layer of friction tape on top of one layer of rubber tape is acceptable on a splice if the voltage involved is less than 250 volts. In determining whether or not splice insulation consisting of coated fabric, thermoplastic, or other type of tubing is acceptable, consideration is given to such factors as its dielectric properties, heat resistant and moisture-resistant characteristics, or the like. Thermoplastic tape wrapped over a sharp edge is not acceptable.

164. The connection of stranded internal wiring to a wire-binding screw shall be such that the loose strands of each wire are prevented from contacting other live parts not always of the same polarity as the wire and from contacting dead-metal parts. This may be accomplished by the use of a pressure terminal connector, a soldering lug, a crimped eyelet, soldering all strands of the wire together, or other suitable reliable means.

165. An open-end spade lug shall not be used unless suitable means are provided to hold the lug in place if the wire-binding screw or nut becomes slightly loosened. Upturned ends on the tang of the lug or a retaining barrier are considered acceptable to hold the lug in place.

Printed Wiring

166. A printed wiring board, a printed wiring assembly, and a printed cable shall be recognized as being suitable for the use.

Live Parts

167. A current-carrying part in a circuit, other than one classified as low-voltage, shall be of silver, copper, or copper alloy, or other material suitable for the purpose.

168. Suitably plated iron or steel may be used for a current-carrying part (1) whose temperature during normal operation is more than 100 C (212 F), (2) within a motor or associated governor, or (3) if permitted in accordance with paragraph 27. Plain (unplated) iron or steel is not acceptable. These restrictions do not apply to stainless steel and other corrosion-resistant alloys.

169. An uninsulated live part shall be secured to the base or mounting surface so that it will be prevented from turning or shifting in position if such motion may result in a reduction of spacings below the minimum acceptable values.

170. Friction between surfaces is not acceptable as the sole means to prevent the turning of a live part; but a suitable lock washer properly applied is acceptable for this purpose.

Electrical Insulation

171. Insulating washers, bushings, or the like, and bases or supports for the mounting of live parts shall be of a material that (1) is moisture resistant (such as porcelain or phenolic composition, or other material recognized as being suitable for the particular application), (2) is not affected injuriously by the temperatures to which the part will be subjected under conditions of actual use, and (3) has the strength and rigidity necessary to withstand the stresses of actual service.

172. Insulating material employed in an apparatus is judged with respect to its suitability for the particular application. Materials such as mica, some molded compounds, and certain refractory materials are usually acceptable for use as the sole support of live parts. Other materials are not suitable for general use, such as asbestos and magnesium oxide, may be accepted if used in conjunction with other more suitable insulating materials and located and protected so that physical injury and the absorption of moisture are prevented. If an investigation is necessary in order to determine whether or not a material is acceptable, consideration is given to its physical strength, dielectric strength, insulation resistance, heat resistant qualities, the degree to which it is enclosed or protected, and any other features that have a bearing on the fire and accident hazards involved, in conjunction with the conditions of actual service. All of these properties mentioned here are to be considered with respect to the effects of thermal aging.

173. Ordinary vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not as the sole support for uninsulated current-carrying parts except as indicated in paragraph 174.

174. In low-voltage circuits, vulcanized fiber may be used for sole support of current-carrying parts if failure of the insulation does not result in an increase in the energy output to an intrinsically safe circuit.

Transformer

175. A transformer shall be housed within its own enclosure, or within the main enclosure of the apparatus, or within a combination thereof.

176. The transformer shall be suitable for the particular application and shall operate under normal conditions without introducing hazardous conditions as described in paragraph 226.

177. The transformer winding shall resist the absorption of moisture and shall be formed and assembled in a workmanlike manner.

Overcurrent Protection

178. A fuseholder or circuit breaker shall be recognized as suitable for the particular application.

179. A plug fuseholder intended for the fuse mentioned in paragraph 178 shall be Type S or shall be Edison-base with a factory-installed, nonremovable adapter of Type S construction.

180. An overload or overcurrent-protective device shall not open the circuit during normal operation of the apparatus.

Lampholders

181. If the apparatus is intended to be connected to the identified (grounded) conductor of the power supply circuit, the screw shell of any Edison-base lampholder in the appliance shall be connected to that conductor.

182. If more than one Edison-base lampholder is provided, the screw shells of all such lampholders shall be connected to the same conductor unless there is no shock hazard present when replacing the lamps.

183. A lampholder shall be designed or installed so that uninsulated live parts or other than a screw shell will not be exposed to contact by persons removing or replacing lamps in normal service.

Switches

185. A switch shall be located or protected so that it will not be exposed to physical injury during normal use.

186. A switch shall be suitable for the particular application, and shall have a current and voltage rating no less than that of the circuit (load) which it controls when the apparatus is operated normally.

187. A switch or other device that controls a motor shall have voltage and horsepower ratings no less than the corresponding ratings of the motor it controls.

188. A switch or other device that controls a contactor, a relay coil, or other electromagnetic device shall have voltage and volt-ampere ratings no less than the corresponding ratings of the load it controls.

189. The current-carrying capacity of a switch that controls an inductive load, such as a transformer or an electric-discharge-lamp ballast, shall be no less than twice the rated full load current of the transformer or ballast unless the switch has been recognized as being suitable for the particular application.

190. A switch that controls a medium-base lampholder of other than a pilot or indicating light shall be suitable for use with tungsten-filament lamps.

191. In an apparatus intended for connection to a grounded power supply conductor, a switch with marked "off" position shall disconnect all ungrounded conductors of the supply circuit.

Capacitors

192. The voltage rating of a capacitor shall be no less than the maximum steady state potential to which the capacitor is subjected during operation of the apparatus.

Spacings

195. Except as noted in paragraphs 198 to 200, the spacings in the apparatus shall be no less than those indicated in Tables 6 and 7.

TABLE 6

MINIMUM SPACINGS IN INCHES

Potential Involved in Volts		Maximum Rating 600 Volts						
		Unlimited Volt-Amperes				2000 Volt-Amperes, Maximum		
		0-50	51-150	151-300	301-600	0-50	51-300	301-600
Between any uninsulated live part and an uninsulated live of opposite polarity, uninsulated grounded part other than the enclosure, or exposed-metal part	Through Air	1/16[a]	1/8[a]	1/4	3/8	1/16[a,6]	1/16[a]	3/16[a]
	Over Surface	1/16[a]	1/4	3/8	1/2	1/16[a,b]	1/8[a]	3/8
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable[c]	Shortest Distance	1/16[a]	1/2	1/2	1/2	1/16	1/4	1/2

[a]The spacing between field wiring terminals of opposite polarity and the spacing between a wiring terminal and a grounded dead-metal part shall be no less than 1/4 inch if short circuiting or grounding of such terminals may result from projecting strands of wire.

[b]These spacings may be 3/64 inch between opposite polarity conductors on printed wiring boards of suitable construction.

[c]For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is liable to reduce spacings between the metal piece and uninsulated live parts. If an integral protection or a metal piece attached to the enclosure is fixed in relation to the live parts so that deformation of the enclosure does not affect spacings, the integral projection or metal piece is not considered part of the enclosure.

TABLE 7

MINIMUM SPACINGS IN ISOLATED SECONDARY OF A TRANSFORMER IN INCHES

Potential Involved in Volts		Maximum Rating 600 Volts, 100 Volt-Amperes or Less 0-50	51-600
Between any uninsulated live part and an uninsulated live part of opposite polarity, an uninsulated grounded dead-metal part other than the enclosure, or exposed-metal part	Through Air or Oil	1/16[a,b]	1/16[a,b]
	Over Surface	1/16[a,b]	1/16[a,c]
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable	Shortest Distance	1/16[a]	1/8

[a]These spacings do not apply to components or parts where the short circuiting or grounding of the parts will not result in manifestation of a shock or fire hazard in the equipment nor increase the energy output of the intrinsically safe circuit.

[b]These spacings may be 3/64 inch between opposite polarity conductors on printed wiring boards of recognized construction.

[c]These spacings may be 3/64 inch between opposite polarity conductors on printed wiring boards of recognized construction used in circuits of 150 volts or less.

196. If an uninsulated live part is not rigidly fixed in position (by means other than friction between surfaces), or if a movable dead-metal part is in proximity to an uninsulated live part, the construction shall be such that the required minimum spacing will be maintained.

197. All uninsulated live parts connected to different circuits shall be spaced from one another as though they were parts of opposite polarity, and shall be judged on the basis of the highest voltage involved.

198. The spacing between uninsulated live parts of opposite polarity and between such parts and dead-metal which may be grounded in service is not specified for parts of a circuit which is classified as low-voltage.

199. As indicated in footnote [a] of Table 7, the spacing between uninsulated live parts of opposite polarity and between such parts and dead-metal which may be grounded in service is not specified for parts of circuits which are classified as isolated limited secondary circuits under paragraph 21. The spacing is based on acceptable performance of applicable dielectric withstand and abnormal operation tests.

200. The spacings in a component device (such as a snapswitch, lampholder, or the like) supplied as part of the equipment shall be no less than the minimum spacings required for the component device or the spacings indicated in Tables 6 and 7, whichever are smaller.

201. A ceramic, vitreous-enamel, or similar coating is not acceptable as insulation in place of spacings unless, upon investigation, the coating is found to be uniform, of adequate minimum thickness, reliable and otherwise suitable for the purpose.

202. Enamel-insulated and similar film-insulated wire is considered to be the same as an uninsulated live part in determining compliance of a device with the spacing requirements in this Standard.

203. If an isolated dead-metal part is interposed between or is in close proximity (1) to live parts of opposite polarity, (2) to a live part and an exposed dead-metal part, or (3) to a live part and a dead-metal part that may be grounded, the spacing may be not less than 3/64 inch between the isolated dead-metal part and any of the other parts previously mentioned, provided the sum of the spacings between the isolated dead-metal part and the two other parts is not less than the value indicated in Table 6.

204. The spacing at a field wiring terminal is to be measured with a wire of the appropriate size (for the rating) connected to the terminal as in actual service.

Insulating Barrier or Liners

205. Except as noted in paragraphs 206, 207, and 208, an insulating barrier or liner that is used to provide spacings shall be of material suitable for the particular application and shall be a nominal 1/32 inch (minimum 0.028 inch) thick.

206. A barrier or liner that is used in conjunction with not less than one-half the required spacing may be less than 1/32 inch but shall be a nominal 1/64 inch (minimum 0.13 inch) thick, provided the barrier or liner is (1) of a good quality of suitable insulating material, (2) resistant to moisture, (3) of adequate mechanical strength if exposed or otherwise liable to be subjected to mechanical injury, (4) reliably held in place, and (5) located so that it will not be affected adversely by operation of the equipment in service - particularly arcing.

207. An insulating barrier or liner used as the sole separation between live parts and grounded parts or between live parts of opposite polarity, shall be of material of a type that is suitable for the mounting of uninsulated live parts and is a nominal 1/32 inch (minimum 0.028 inch) thick. Otherwise, a barrier shall be used in conjunction with at least a 1/32 inch air spacing.

208. Insulating material having a thickness less than that specified in the preceding paragraphs may be used if, upon investigation, it is found to be suitable for the particular application, and is equivalent to materials of the thicknesses contemplated.

Separation of Circuits

209. Unless provided with insulation suitable for the highest voltage involved, insulated conductors of different circuits (internal wiring) shall be separated by barriers or segregated; and shall, in any case, be separated or segregated from uninsulated live parts connected to different circuits.

210. Segregation of insulated conductors may be accomplished by clamping, routing, or equivalent means which ensures permanent separation from insulated or uninsulated live parts of a different circuit.

211. If a barrier is used to provide separation between the wiring of different circuits, it shall be (1) of grounded metal or of suitable insulating material, (2) of adequate mechanical strength if exposed or otherwise liable to be subjected to mechanical injury, and (3) reliably held in place. Unclosed openings in a barrier for the passage of conductors shall not be larger than 1/4 inch in diameter and shall not exceed in number, on the basis of one opening per conductor, the number of wires which will need to pass through the barrier. The closure for any other opening shall present a smooth surface wherever an insulated wire may be in contact with it; and the area of any such opening, with the closure removed shall not be larger than required for the passage of all necessary wires. Also see paragraph 156.

212. Field-installed conductors of any circuit shall be segregated or separated by barriers from:

A. Field-installed and factory-installed conductors connected to any other circuit, unless the conductors of both circuits are or will be insulated for the maximum voltage of either circuit. Also see paragraph 215.

B. Uninsulated live parts of any other circuit of the device, and from any uninsulated live parts whose short-circuiting would result in unsafe operation of the controlled device, except that (1) a construction in which field-installed conductors may make contact with wiring terminals is acceptable, provided that Type RH, T, RF-2, or equivalent conductors are or will be installed, and (2) a construction in which field-installed conductors which do or may have insulation less than those types of wire mentioned in item (1) may make contact with low-voltage wiring terminals is acceptable, provided that the short-circuiting of such terminals would not result in unsafe operation of the controlled device.

213. A barrier used to provide separation between the field wiring of one circuit and the wiring or uninsulated live parts of another shall be spaced not more than 1/16 inch from the enclosure walls and from interior mechanism and component mounting panels, or the like, which serve to provide segregated compartments.

214. A metal barrier used to provide segregation shall be (1) grounded, (2) of adequate strength and rigidity, and (3) at least the thickness specified under the "With Supporting Frame" column of Table 2 for the dimensions of the barrier. A barrier of insulating material shall be of such thickness and be so supported that its deformation cannot be readily accomplished so as to defeat its purpose, but in any case, the nominal thickness shall be 1/32 inch (minimum 0.028 inch). A barrier between uninsulated live parts connected to different circuits, and a barrier between uninsulated live parts of one circuit and the wiring of another circuit shall also comply with the requirement of paragraphs 206 and 207.

215. With respect to item A of paragraph 212, if the intended uses of the device are such that in some applications a barrier is not required, a removable barrier or one having openings for the passage of conductors may be employed, provided adequate instructions for the use of the barrier are a permanent part of the device. Complete instructions in conjunction with a wiring diagram may be acceptable in lieu of a barrier if, upon investigation, the combination is found to be adequate.

216. Segregation of field-installed conductors from other field-installed conductors and from uninsulated live-metal parts of the device connected to different circuits may be accomplished by arranging the location of the openings in the enclosure for the various conductors (with respect to the terminals or other uninsulated live-metal parts) so that the intermingling of the conductors or parts of different circuits is unlikely.

217. If the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the device, and if each opening is located opposite a set of terminals, it is to be assumed, for the purpose of determining compliance with paragraph 212, that the conductors entering each opening will be connected to the terminals opposite the opening. If more than the minimum number of openings are provided, the possibility of conductors entering at points other than opposite the terminals to which they are intended to be connected and contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated.

218. To determine if a device complies with the requirement of paragraph 212, it is to be wired as it would be in service; and in doing so, a reasonable amount of slack is to be left in each conductor, within the enclosure, and no more than average care is to be exercised in stowing this slack into the wiring compartment.

PERFORMANCE

General

219. Unless otherwise indicated, a representative sample of the product shall be subjected to the tests described. The order of tests, as far as applicable, shall be as presented here.

220. Unless otherwise indicated, the tests shall be conducted at rated frequency and at the voltage indicated in Table 8.

TABLE 8

VOLTAGE FOR TEST

Voltage Rating of Device[a]	Test Potential in Volts
110-120 ac	120 ac
110-125 dc	125 dc
208 ac	208 ac
220-240 ac	240 ac
220-250 dc	250 dc
265-277 ac	277 ac
440-480 ac	480 ac
550-600 ac	600 ac

[a]If the rating of the equipment does not fall within any of the indicated voltages ranges, it is to be tested at its rated voltage.

221. Apparatus having a dual rating may be tested at either or both ratings to ensure that tests are conducted under the most adverse conditions.

Product Tests

Power Input

222. Except as indicated in paragraph 223, the power input shall not exceed the marked rating of the device by more than 10 percent when it is operated under the conditions of normal use and with the device connected to a supply circuit as indicated in Table 8.

223. A device rated 20 watts or less may have an input of not more than 25 percent above its marked rating.

Power Output

224. The open-circuit voltage and short circuit current shall be measured at the output terminals, if provided. These values will be used as the basis for establishing the connection and marking requirements as indicated elsewhere in this Standard. In the power circuits, the output may be measured with assumed failures of electronic components. However, only one failure is to be introduced at a time.

Normal Temperature

226. When tested under the conditions described in paragraphs 227-235, the apparatus shall not attain a temperature at any point sufficiently high to constitute a fire hazard or to affect injuriously any materials employed in the device, nor show temperature rises at specified points greater than those indicated in Table 9.

TABLE 9

MAXIMUM TEMPERATURE RISES

Materials and Components	Degrees Celsius	Degrees Fahrenheit
1. Knife-switch blades and contact jaws	30	54
2. Laminated contacts	50	90
3. At any point within a terminal box or wiring compartment of permanently-connected apparatus in which power-supply conductors are to be connected, including such conductors themselves, unless the apparatus is marked in accordance with paragraph 372	35	63
4. Class 90 (Class 0) insulation[a]		
A. Thermocouples method	50	90
B. Resistance method	60	108
5. Class 2 transformer enclosure	60	108
6. Varnished cloth insulation	60	108
7. Solid contacts, busses and connecting bars	65	117
8. Fuses	65	117
9. Fiber employed as electrical insulation	65	117
10. Wood and other combustibles	65	117
11. Power transformer enclosure	65	117
12. Class 105 (Class A) insulation on coil windings[a]		
A. In open motors:		
Thermocouple method	65	117
Resistance method	75	135
B. In totally enclosed motors:		
Thermocouple method	80	126
Resistance method	80	144
C. Other coils:		
Thermocouple method	65	117
Resistance method	85	153
13. Class 130 (Class B) insulation[a]		
A. Thermocouple method	85	153
B. Resistance method	95	171

TABLE 9 (Cont'd)

MAXIMUM TEMPERATURE RISES

Materials and Components	Degrees Celsius	Degrees Fahrenheit
14. Phenolic composition employed as electrical insulation or as a part where failure would result in a hazardous condition[b]	125	225
15. All rubber or thermoplastic-insulated wire and cords except those mentioned in item 16[b]	35	63
16. Types RFH, FFH, and RH wire	50	50
17. Other types of insulated wire	c	c
18. Sealing compounds	40 less than melting point	72 less than melting point
19. Capacitors	d	d

[a]See paragraph 227.

[b]The limitation on phenolic composition and on rubber and thermoplastic insulation does not apply to compounds which have been investigated and recognized as having special heat resistant properties.

[c]For standard insulated conductors other than those mentioned in items 15 and 16, reference should be made to the American National Standard National Electrical Code, C1-1971 and the maximum allowable temperature rise in any case is 25 C (45 F) less than the recognized temperature limit of the wire in question, except as noted in paragraph 228.

[d]For a capacitor, the maximum allowable temperature rise is 25 C (45 F) less than the marked temperature limit of the capacitor, except as noted in paragraph 228.

227. With reference to items 12 and 13 in Table 9, the temperature rise observed by means of a thermocouple on the surface of a coil, where Class A or B insulation is involved and where the temperature at that point is affected by an external source of heat, may be 15 C (27 F) higher than that indicated in the table, provided that the temperature rise by the resistance method for the item in question is not more than that specified in that table.

228. All values for temperature rises in the table are based on an assumed ambient (room) temperature of 25 C (77 F); however tests may be conducted at any ambient temperature higher than 25 C (77 F), the test is to be conducted at the higher ambient temperature and the allowable temperature rises specified in Table 9 are to be reduced by the difference between the higher ambient and 25 C (77 F).

229. A low potential source of supply may be utilized for conducting temperature tests on parts other than coils or transformer windings. Unless otherwise noted, the tests on all parts are to be made simultaneously, as the heating of one part may affect the heating of another part.

230. Ordinarily, coil or winding temperatures are to be measured by thermocouples mounted on the outside of the coil wrap. If the coil is inaccessible for mounting thermocouples (e.g., a coil immersed in sealing compound) or if the coil wrap includes thermal insulation, such as asbestos or more than 1/32 inch of cotton, paper, rayon, or the like, the change-of-resistance method is to be used. For a thermocouple measured temperature of a coil of a motor (items 12 and 13 of Table 9), the thermocouple is to be mounted on the integrally applied insulation of the conductor.

231. The resistance method consists of the determination of the temperature of a copper winding by comparing the resistance of the winding at the temperature to be determined with the resistance of the winding at a known temperature, according to the formula:

$$T = \frac{R}{r}(234.5 + t) - 234.5$$

which: t = is the known temperature in degrees C,
r = is the resistance in ohms at the known temperature,
R = is the resistance in ohms at the temperature to be determined, and
T = is the temperature in degrees C to be determined.

232. Temperatures are to be measured by thermocouples consisting of wires no larger than No. 24 Awg and no smaller than No. 30 Awg, except that a coil temperature is to be determined by the change-of-resistance method if the coil is inaccessible for mounting thermocouples - see paragraph 230. When thermocouples are used in determining temperatures in electrical equipment, it is standard practice to employ thermocouples consisting of instrument; and such equipment will be used whenever referee temperature measurements by thermocouples are necessary. 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 the American National Standard, C96.1-1964 "Temperature Measurement Thermocouples". A temperature is considered to be 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.

233. A thermocouple junction and the adjacent thermocouple lead wire are to be securely held in good thermal contact with the surface of the material whose temperature is being measured. In most cases, adequate 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.

234. The temperature rise attained by the motor of a timing device, when stalled and while connected to a supply circuits as indicated in Table 8, shall not exceed the limits given in Table 9, if stalling the motor is part of the normal operation.

235. To determine if the equipment complies with the requirements of paragraphs 226-234, the device is to be operated under normal conditions, unless otherwise indicated. The potential of the supply circuit is to be in accordance with Table 8.

Operation

240. An electromagnet (e.g., relay, solenoid) provided on apparatus intended for use on direct-current shall be able to withstand 10 percent above the test voltage for the apparatus (in accordance with Table 8) continuously without injury to the operating coil and to operate successfully at 20 percent less than the rated voltage. This does not apply to a force coil intended to produce a modulated force as a function of current.

241. An electromagnet provided on apparatus intended for use on alternating-current shall be able to withstand 10 percent above the test voltage for the apparatus (in accordance with Table 8) continuously without injury to the operating coil and to operate successfully at 15 percent less than the test voltage. This does not apply to a force coil intended to produce a modulated force as a function of current.

242. For the operation at minimum voltage, the apparatus is to be subjected to the normal test voltage per Table 8 until constant temperature is reached, and the electromagnet is then tested immediately for closing at the minimum voltage.

Dielectric Withstand

243. A device shall be capable of withstanding for 1 minute without breakdown the application of a 60 hertz potential of 1000 volts plus twice maximum test voltage in accordance with Table 8:

A. Between line-voltage live parts and grounded or exposed-metal parts or the enclosure with the contacts open and closed;

B. Between line-voltage live parts of opposite polarity with the contacts closed;

C. Between live-metal parts of line and low-voltage circuits; and

D. Between live-metal parts of different line-voltage circuits.

244. Low-voltage circuits shall be capable of withstanding the application of a 60 hertz potential of 500 volts for 1 minute without breakdown. The potential shall be applied between live parts and the enclosure, grounded dead-metal parts, or exposed, isolated (insulated) parts.

245. Isolated limited energy circuits shall be capable of withstanding the application of 60 hertz root-mean-square potential equal to three times the maximum peak voltage of the circuit, but not less than 500 volt root-mean-square for 1 minute without breakdown. The potential shall be applied between live parts of different circuits and between live parts and grounded dead-metal parts, or exposed, isolated (insulated) parts.

246. If the isolated limited energy circuit has no alternating-current potential, the test may be performed using a direct-current potential of three times the maximum direct current voltage of the circuit but not less than 500 volts.

247. If the low-voltage or isolated limited energy secondary circuit is grounded at one or more points, the grounding points shall be removed for the tests covered in paragraphs 244-246.

<u>Intrinsically Safe Circuit Spacings</u>

294. The spacings in the apparatus shall be no less than those indicated in Table 13 and paragraph 298.

295. If an uninsulated live part is not rigidly fixed in position (by means other than friction between surfaces), or if a movable dead-metal part is in proximity to an uninsulated live part, the construction shall be such that the required minimum spacing will be maintained.

296. A ceramic, vitreous-enamel, or similar coating is not acceptable as insulation in place of spacings unless, upon investigation, the coating is found to be uniform, of adequate minimum thickness, reliable, and otherwise suitable for the purpose.

297. Enamel-insulated and similar film-insulated wire is considered to be an uninsulated live part in determining compliance of a device with the spacing requirements in this Standard.

298. Except as noted in paragraph 299, the spacing between and the arrangement of field wiring terminals of different intrinsically safe circuits shall be such that short circuiting of the circuits at the terminals is unlikely.

299. No spacings are required between field wiring terminals of different intrinsically safe circuits, if a short circuit between the terminals will not increase the energy output of either intrinsically safe circuit.

TABLE 13

MINIMUM SPACINGS BETWEEN INTRINSICALLY SAFE CIRCUITS AND LINE CONNECTED CIRCUITS IN INCHES[a]

Potential Involved in Volts		0-50	51-150	151-300	301-600
Between any uninsulated live part of an intrinsically safe circuit and an uninsulated live part of a line-connected circuit	Through Air	1/4	1/4	1/4	3/8
	Over-surface	1/4	1/4	3/8	1/2

[a]For the purpose of these requirements, the intrinsically safe circuit includes the entire protective component. In circuits where more than one protective component is employed, these requirements apply to the minimum number of protective components necessary to maintain the integrity of the intrinsically safe circuits.

Intrinsically Safe Operation In Class I Atmospheres

348. Intrinsically safe equipment and wiring shall be subjected to tests consisting of making and breaking the intrinsically safe circuit in specific explosive mixtures representative of the hazardous atmospheres in which the intrinsically safe equipment and wiring is intended to be used. The tests shall be conducted under normal and abnormal (electrical fault) conditions using any of the following mechanisms and/or their equivalent for making and breaking the circuits in exposive atmospheres. The tests shall be conducted using the power supplies specified in paragraphs 316 through 320.

Test Mechanism 3 - The device consists of an explosion chamber of about 15-1/4 cubic inches volume, in which circuit making and breaking sparks are produced in the presence of explosive-gas - or vapor-air mixtures. Components of the contact arrangement are a brass disc with two slots and four tungsten wires of 0.008 in. diameter which slide over the disc. The free length of the tungsten wires is 0.433 inches. The driving spindle, to which the tungsten wires are attached, makes 80 revolutions per minute. The spindle on which the brass disc is mounted revolves in the opposite direction. The ratio of the speeds of the driving spindle to the other spindle is 50 to 12. The spindles are insulated from one another and from the housing. The explosion chamber is designed to withstand pressures up to 213 psig. Because the test apparatus uses fine tungsten wires, it is considered suitable for testing currents up to 3 amperes. The apparatus is suitable for testing circuits up to 300 volts. For circuits exceeding these parameters, a different type of apparatus may be needed. For tests of capacitive circuits, modified apparatus may be needed to allow adequate charging time.

349. The above methods of test cover, in general, equipment and wiring consisting of copper wire and a steel case or parts. If the current-carrying parts should consists of other materials, further tests may be conducted using the other materials for making and breaking the circuits.

A P P E N D I X   C

Figures

Figure 1 - Ensign I.S. Relay, Part No. 6651-005.

Figure 2 - Ensign I.S. Relay, Part No. 6651-004.

Figure 3 - MSA Power Supply, Part No. 45875.

Figure 4 - MSA Monitor Model VI, Part No. 45696C.

Figure 5 - Service Machine Company, I.S. Power Supply, Part No. B-742-001.

Figure 6 - General Monitors Model 420 Power Supply, Part No. 8080-4008.

Figure 7 - General Monitors Model 420 Control Indicator Unit, Part No. 18-00-810-1.

Figure 8 - Bendix Power Converter, for Part No. 2417032-1000.

Figure 9 - Bendix Control Circuit, for Part No. 2417032-1000.

Figure 10 - Bacharach Minnie Monitor Power Supply, Part No. 23-7282.

Figure 11 - Bacharach Minnie Monitor Readout Enclosure Assembly, Part No. 23-7298.

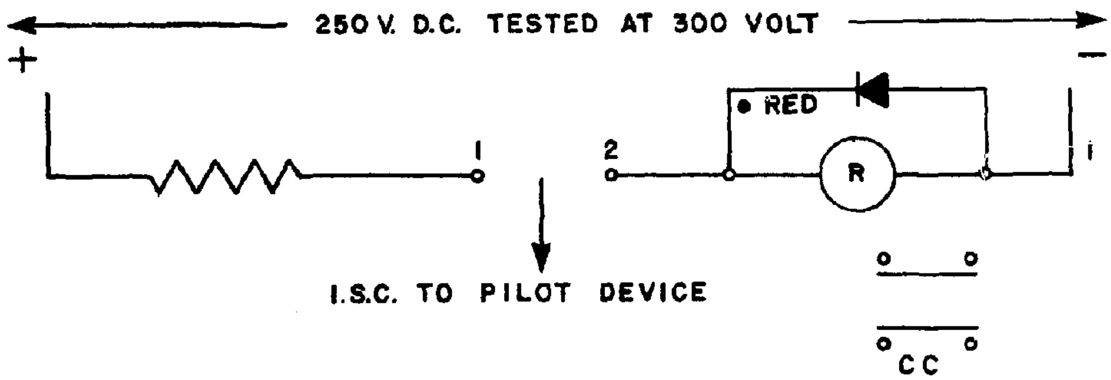
Figure 12 - Bacharach Low Profile Monitor Power Supply, Part No. 23-7259.

Figure 13 - Bacharach Low Profile Control Chassis Board Al, Part No. 23-1245.

Figure 14 - Bertea Power Supply, Part No. 261861.

Figure 15 - Bertea Pilot Valve - Hand Controller Hookup.

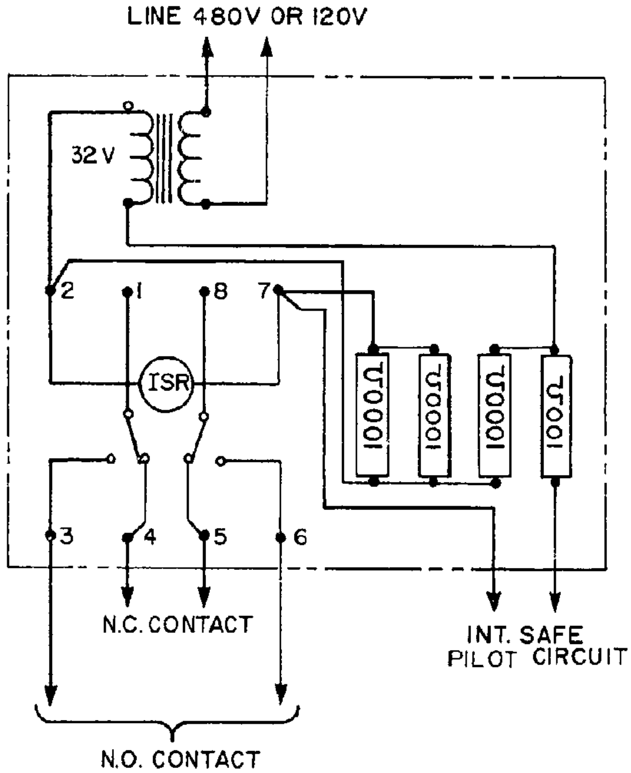
Figure 16 - Appalachian Model 102A Power Supply, Part No. 7163.



CONTROL CIRCUIT OF STARTER MUST BE ARRANGED SO I. S. R. DOES NOT RECEIVE INDUCTIVE KICK WHEN MAIN COILS ARE OPENED.

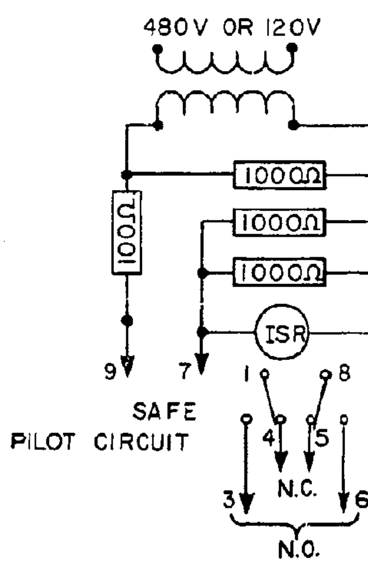
WARNING: Any changes in the intrinsically safe circuitry or components may result in an unsafe condition.

FIG. 1 – ENSIGN I.S. RELAY, PART NO. 6651-005



Wiring Diagram

WARNING: Any changes in the intrinsically safe circuitry or components may result in an unsafe condition.



Schematic Diagram

FIG. 2 — ENSIGN I.S. RELAY, PART NO. 6651-004

FUSE DATA	
AMPS	TYPE
3/8	HVA-3/8 HIGH VOLT.
3/4	HVA-3/4 HIGH VOLT.
2	ABC-2 LOW VOLT.

INPUT VOLTS 50/60 1PH	TB-1				
	CONNECT	RX	FROM	TO	FUSE
110	6	10Ω, 3W	AC	D	3/4A
220	6	10Ω, 3W	AC	C	3/4A
440	100	200Ω, 3W	AC	B	3/8A
550	100	200Ω, 3W	AC	A	3/8A

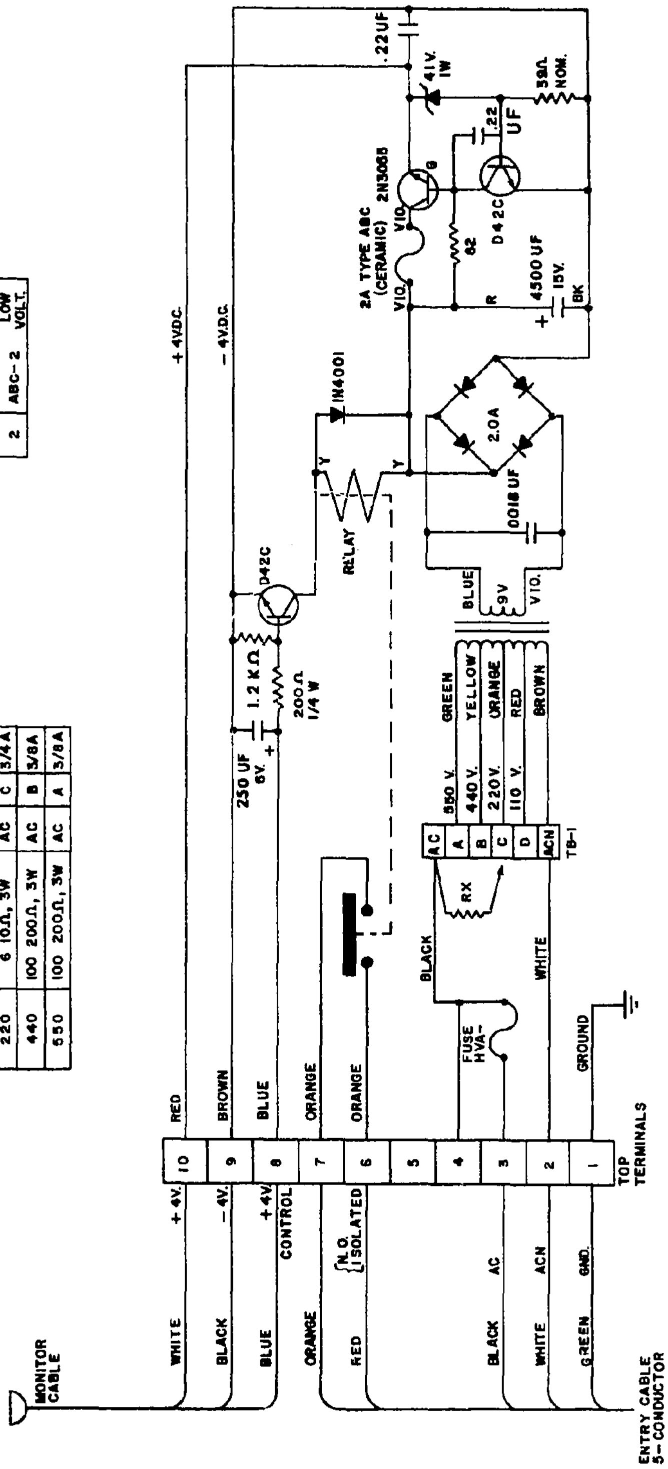


FIG. 3 — MSA POWER SUPPLY, PART NO. 458175

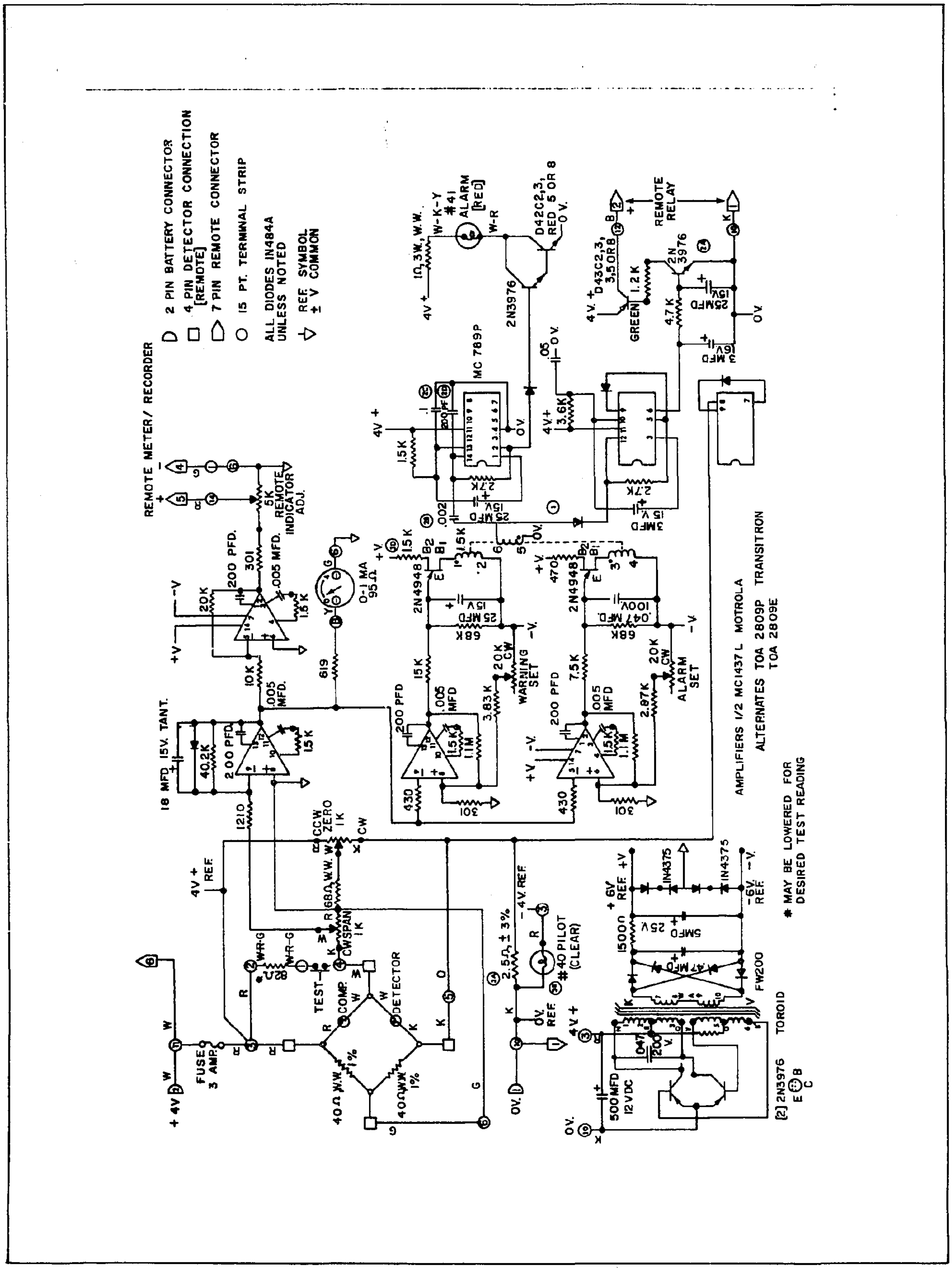
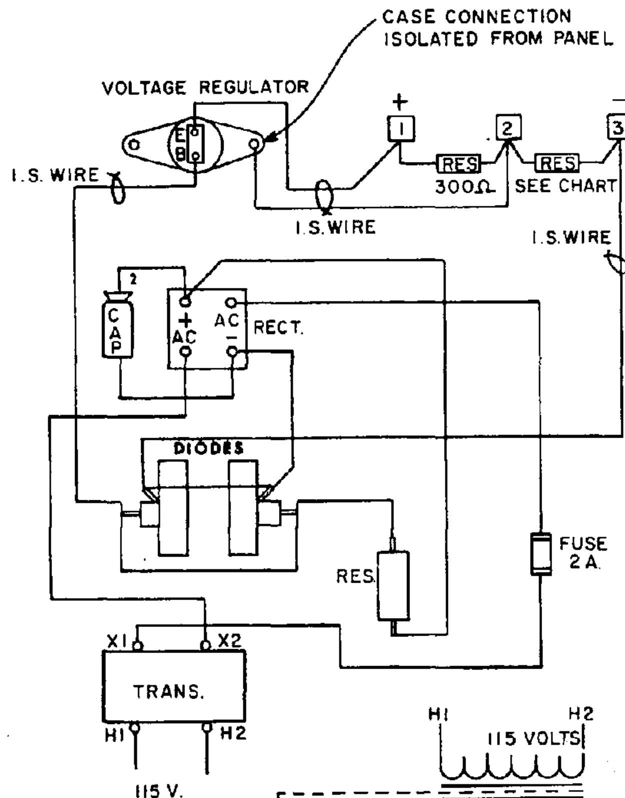


FIG. 4 – MSA MONITOR MODEL VI, PART NO. 456960

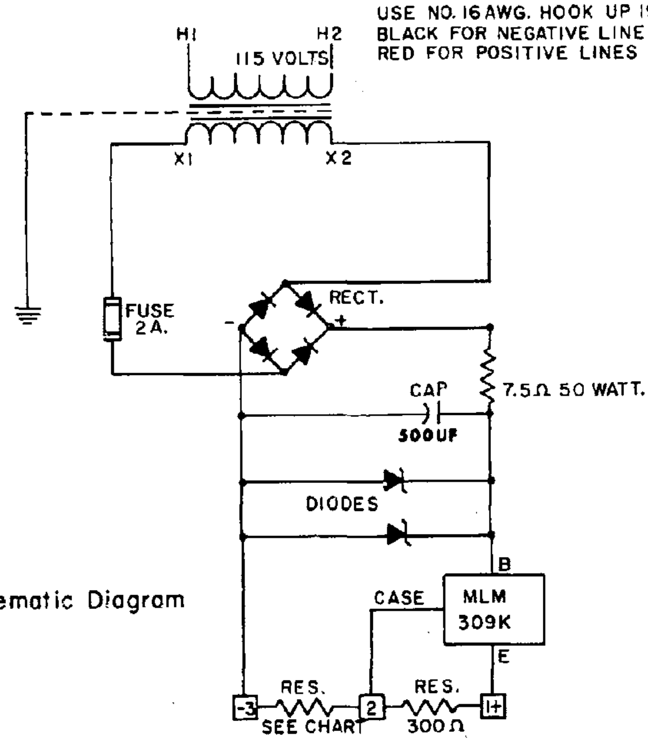


Wiring Diagram

RESISTOR PART NO.	RATED OUTPUT
JUMPER	5 VOLTS
4082	6 VOLTS
4092	7 VOLTS
4096	8 VOLTS
4099	9 VOLTS
4102	10 VOLTS
4104	11 VOLTS
4105A	12 VOLTS

ALL ABOVE RESISTOR'S ARE 5% WIRE WOUND 1.5 W.

ISOLATE I.S. WIRES FROM POWER WIRES
USE NO. 16 AWG. HOOK UP 19 STRAND
BLACK FOR NEGATIVE LINES
RED FOR POSITIVE LINES



Schematic Diagram

FIG. 5 – SERVICE MACHINE CO. I.S. POWER SUPPLY, PART NO. B-742-001

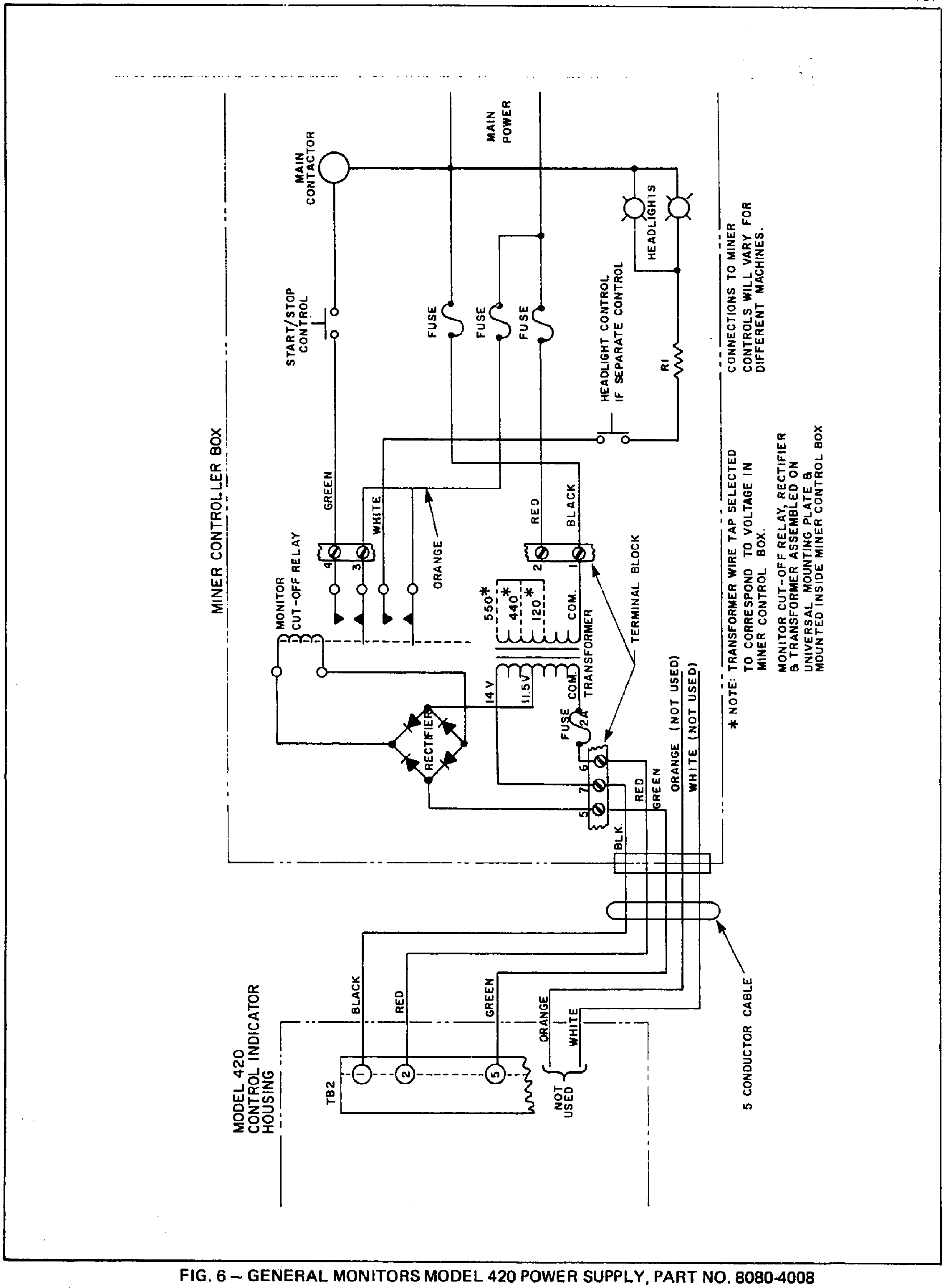


FIG. 6 – GENERAL MONITORS MODEL 420 POWER SUPPLY, PART NO. 8080-4008

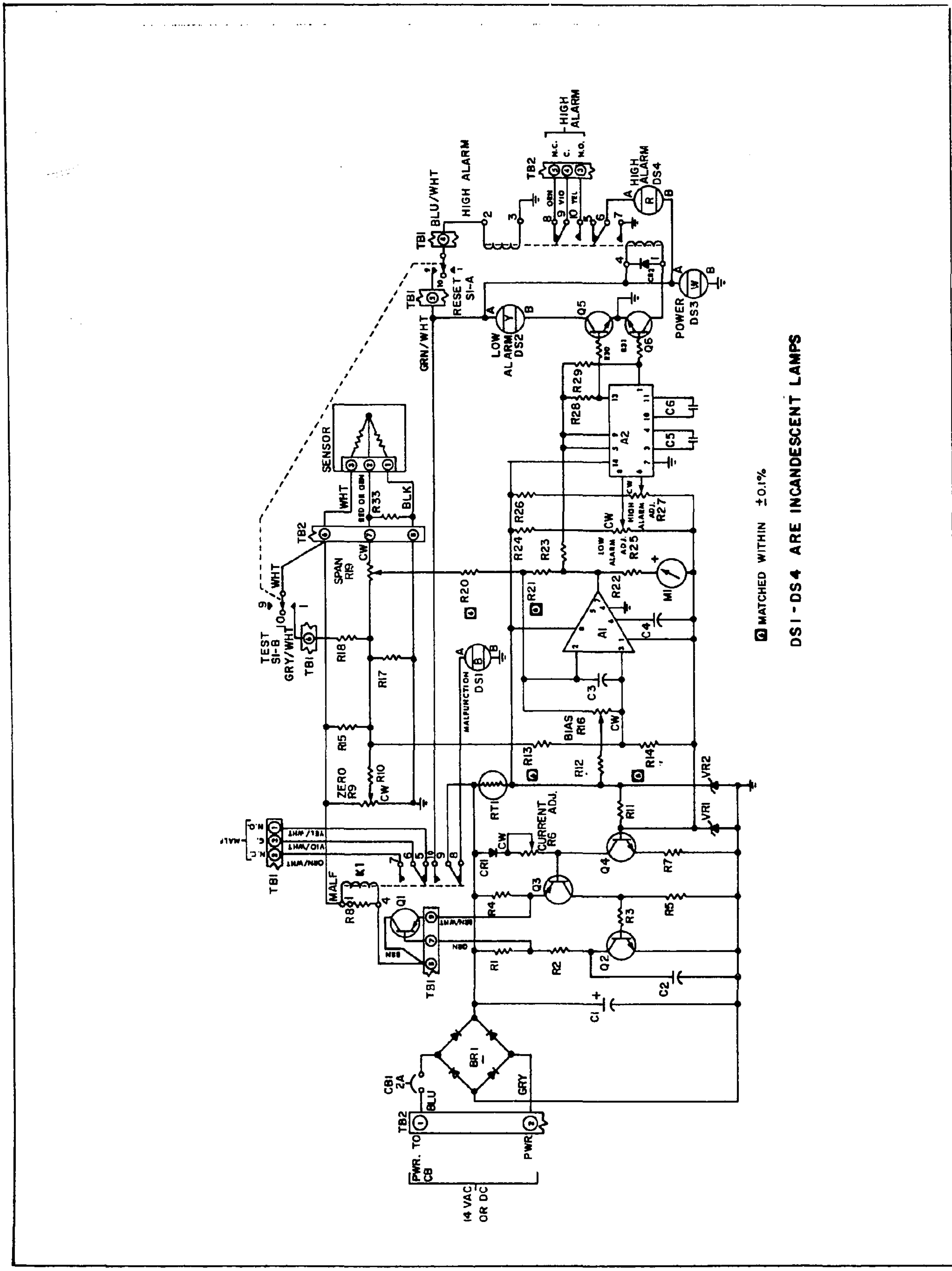


FIG. 7 – GENERAL MONITORS MODEL 420 CONTROL INDICATOR UNIT, PART NO. 18-00-810-1

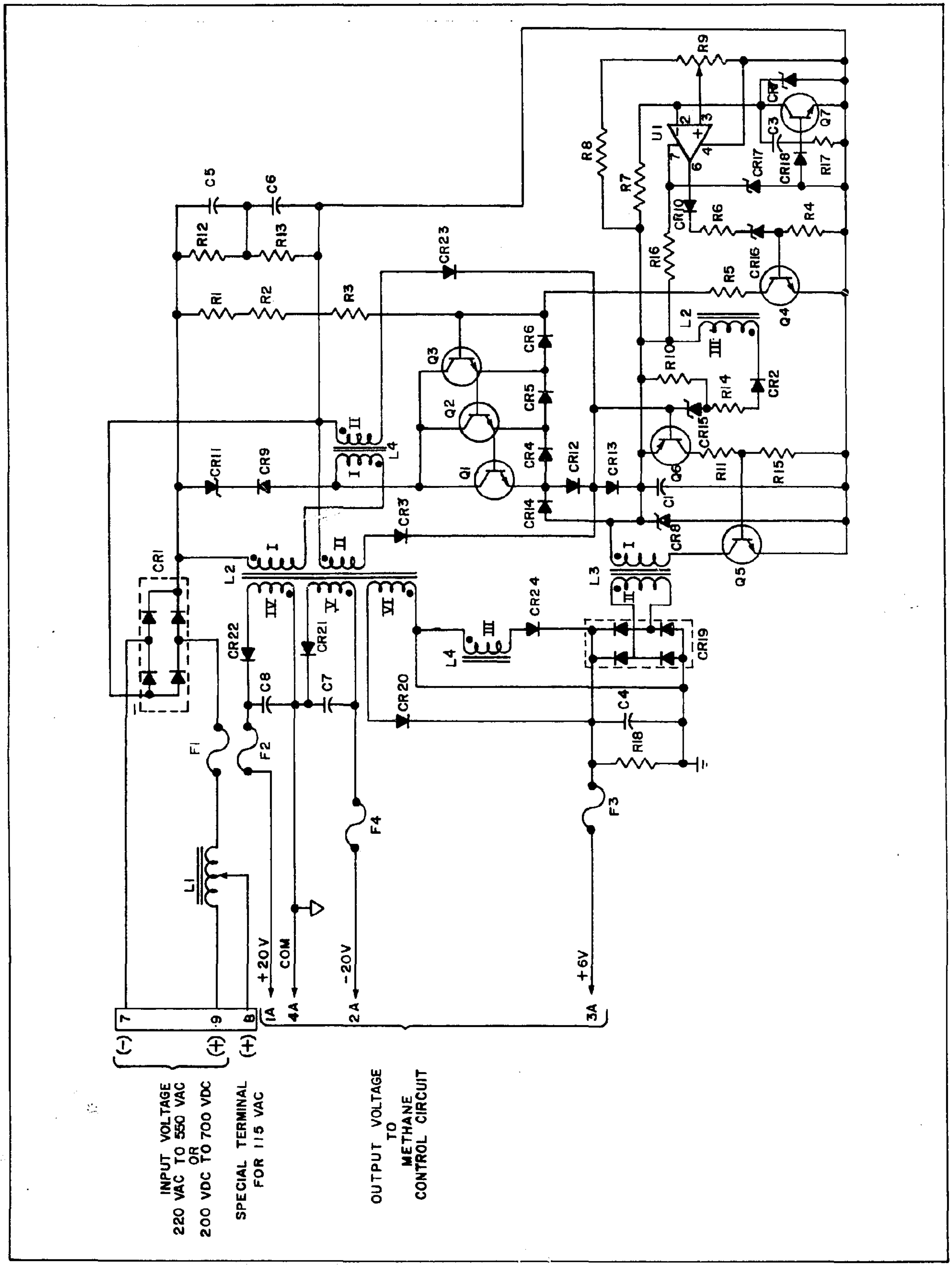


FIG. 8 – BENDIX POWER CONVERTER, FOR PART NO. 2417032-1000

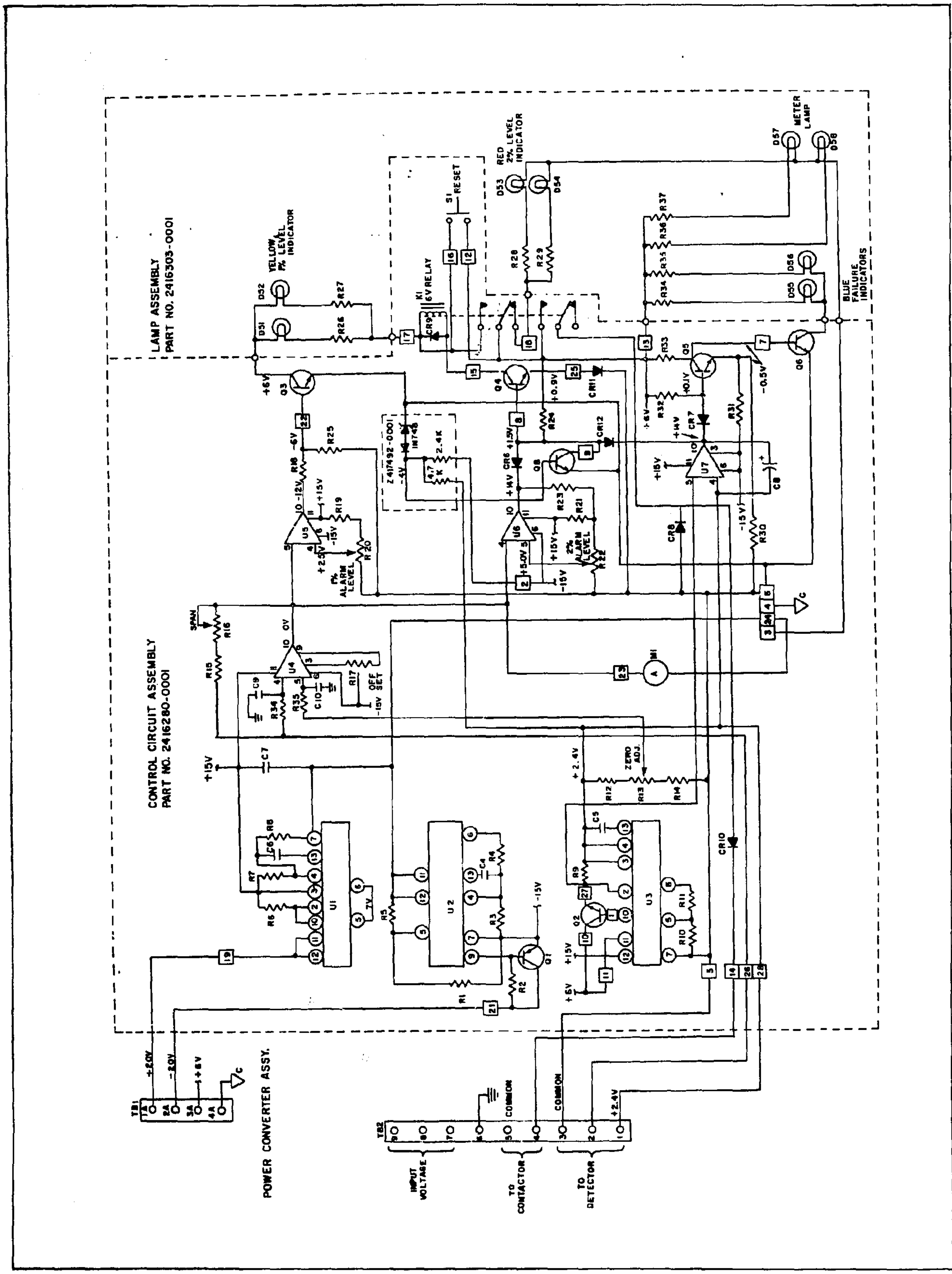


FIG. 9 — BENDIX CONTROL CIRCUIT, FOR PART NO. 2417032-1000

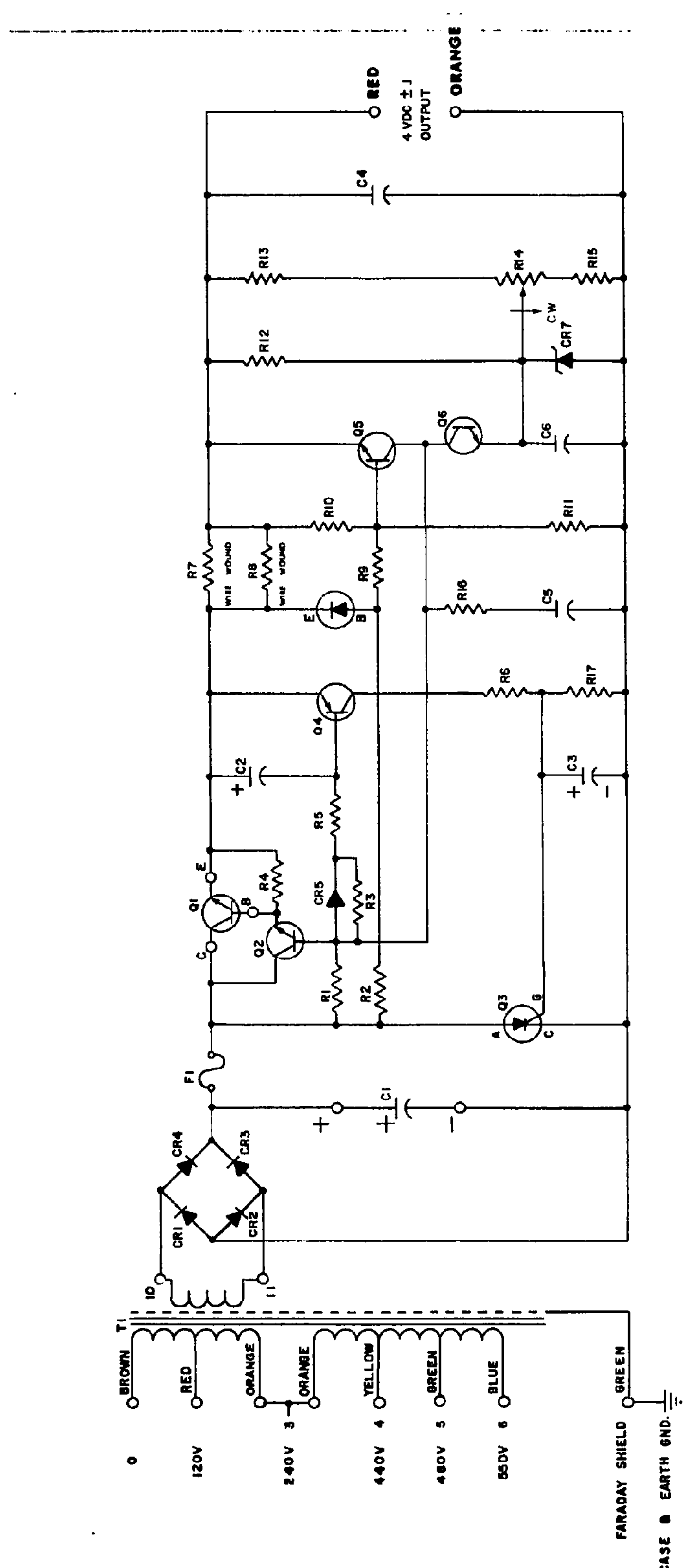


FIG. 10 – BACHARACH MINNIE MONITOR POWER SUPPLY, PART NO. 23-7282

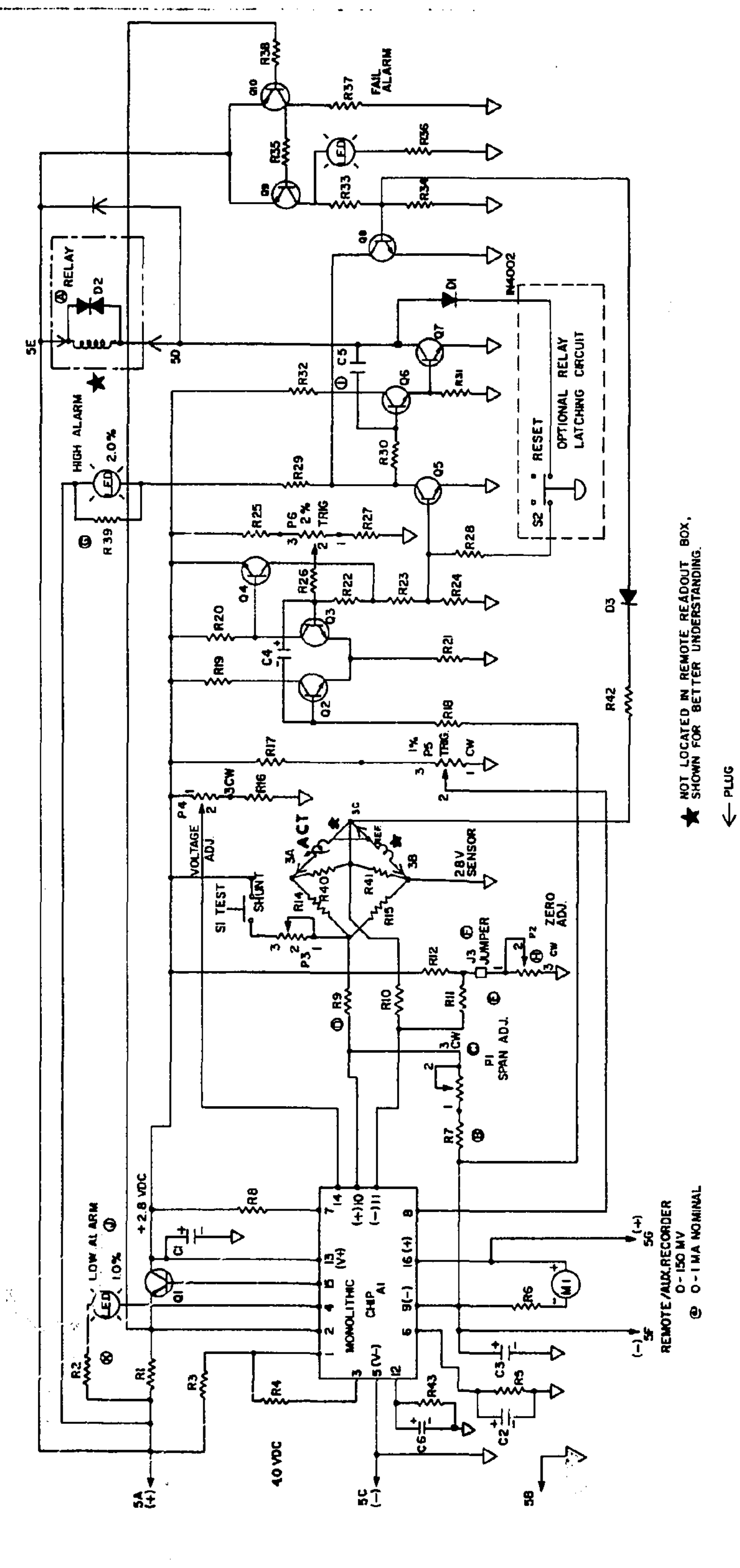


FIG. 11 — BACHARACH MINNIE MONITOR READOUT ENCLOSURE ASSY, PART NO. 23-7298

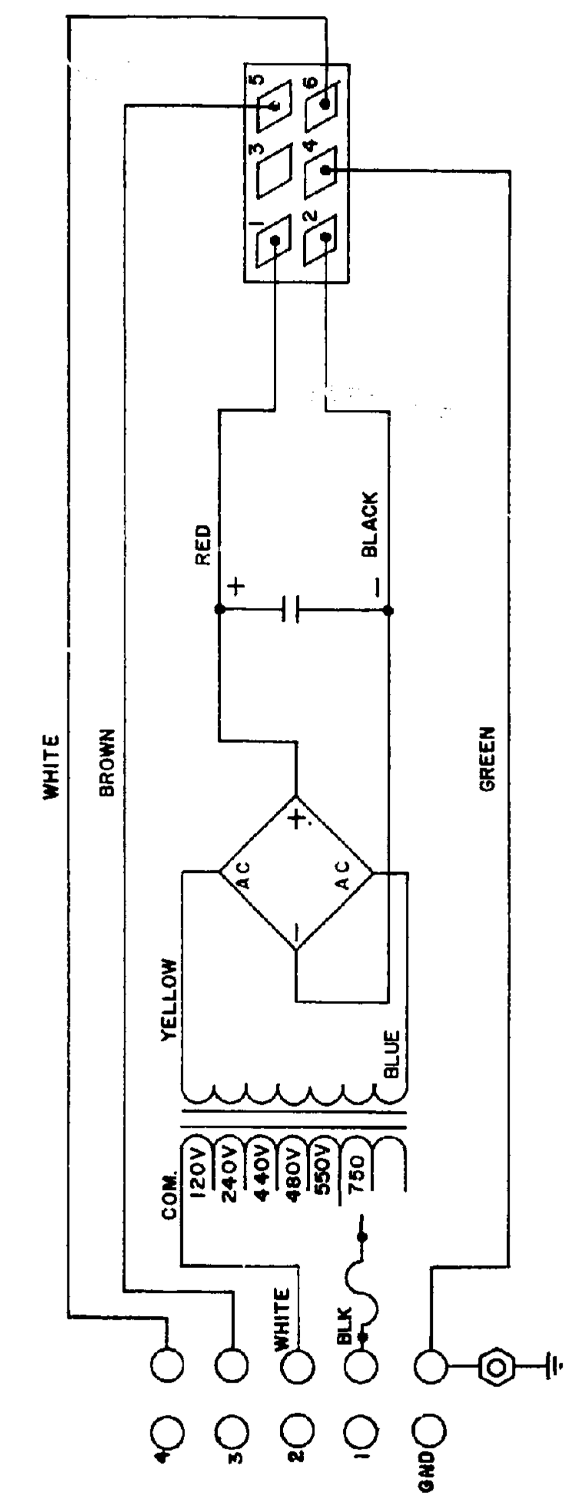


FIG. 12 – BACHARACH LOW PROFILE MONITOR POWER SUPPLY, PART NO. 23-7259

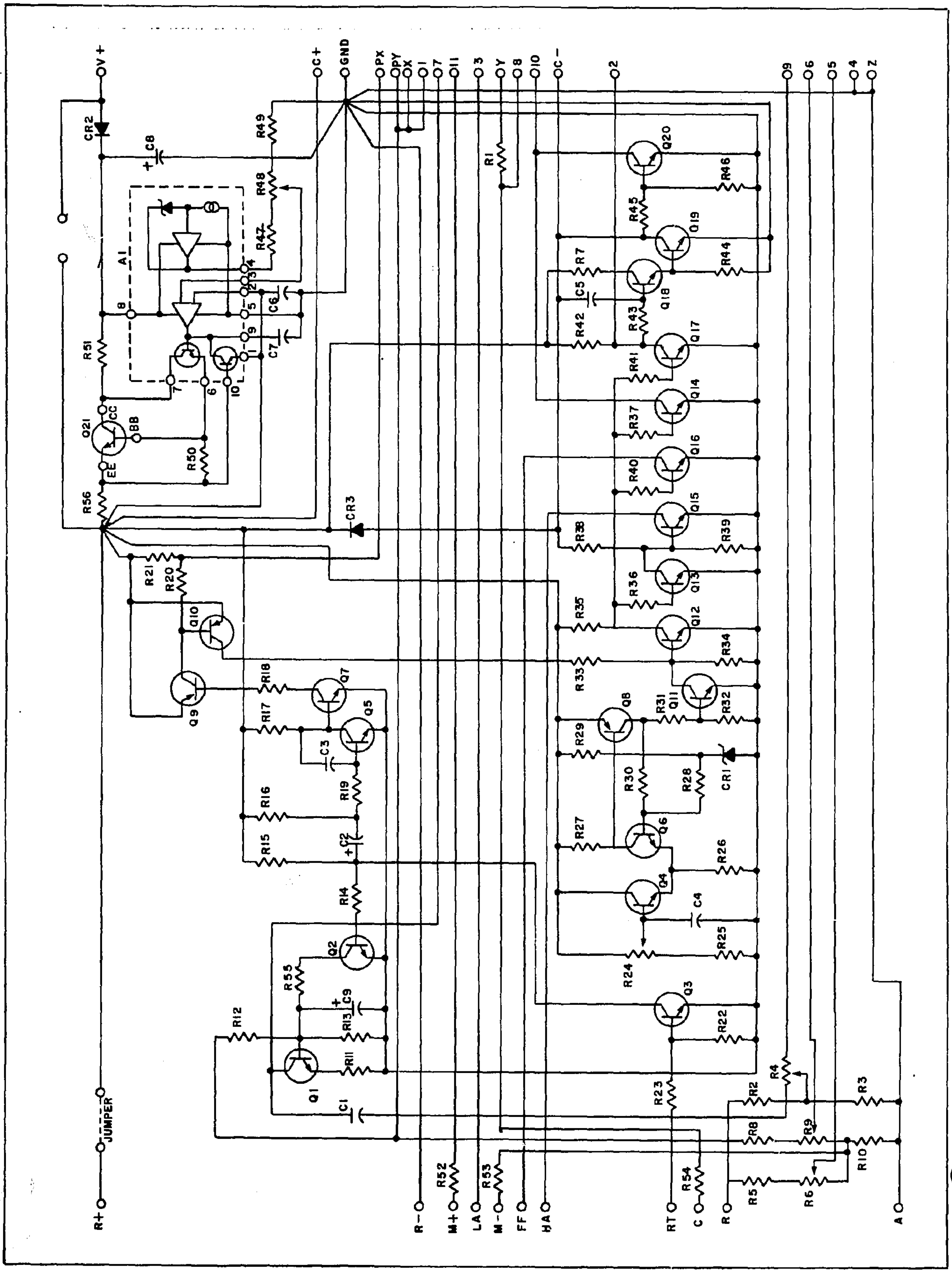


FIG. 13 — BACHARACH LOW PROFILE CONTROL CHASSIS BOARD A1, PART NO. 23-1245

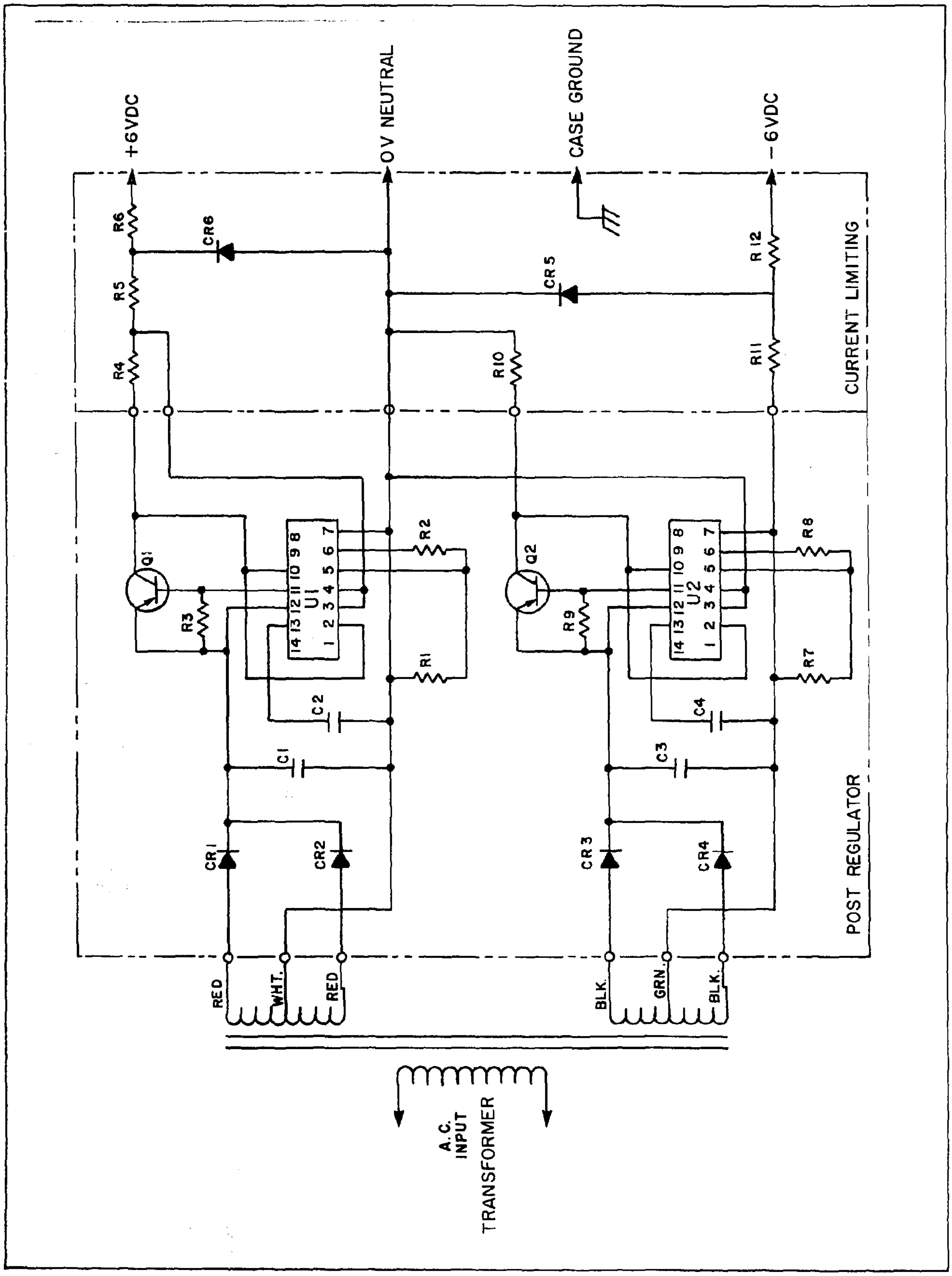


FIG. 14 – BERTEA POWER SUPPLY, PART NO. 261861

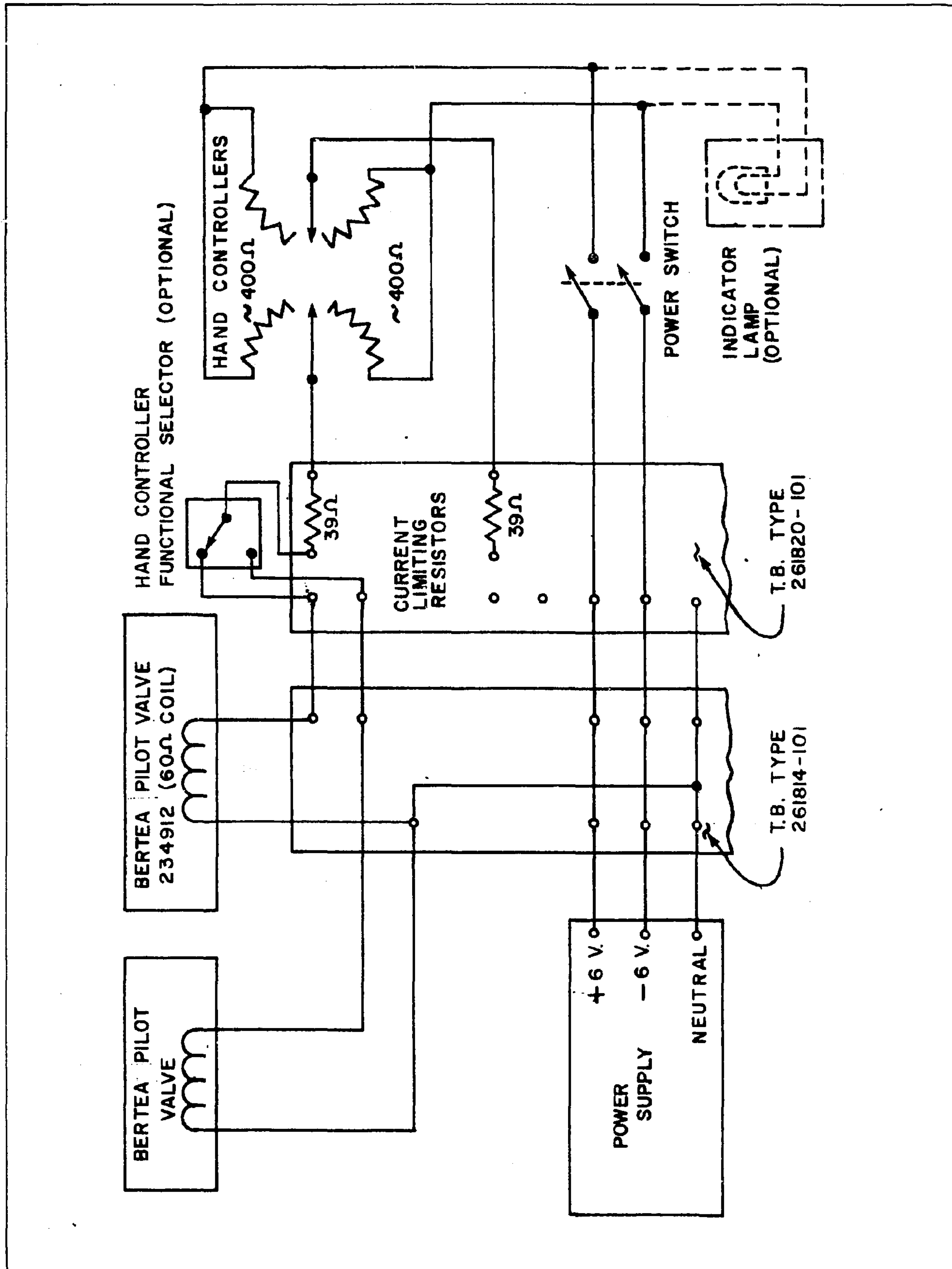


FIG. 15 — BERTEA PILOT VALVE — HAND CONTROLLER HOOKUP

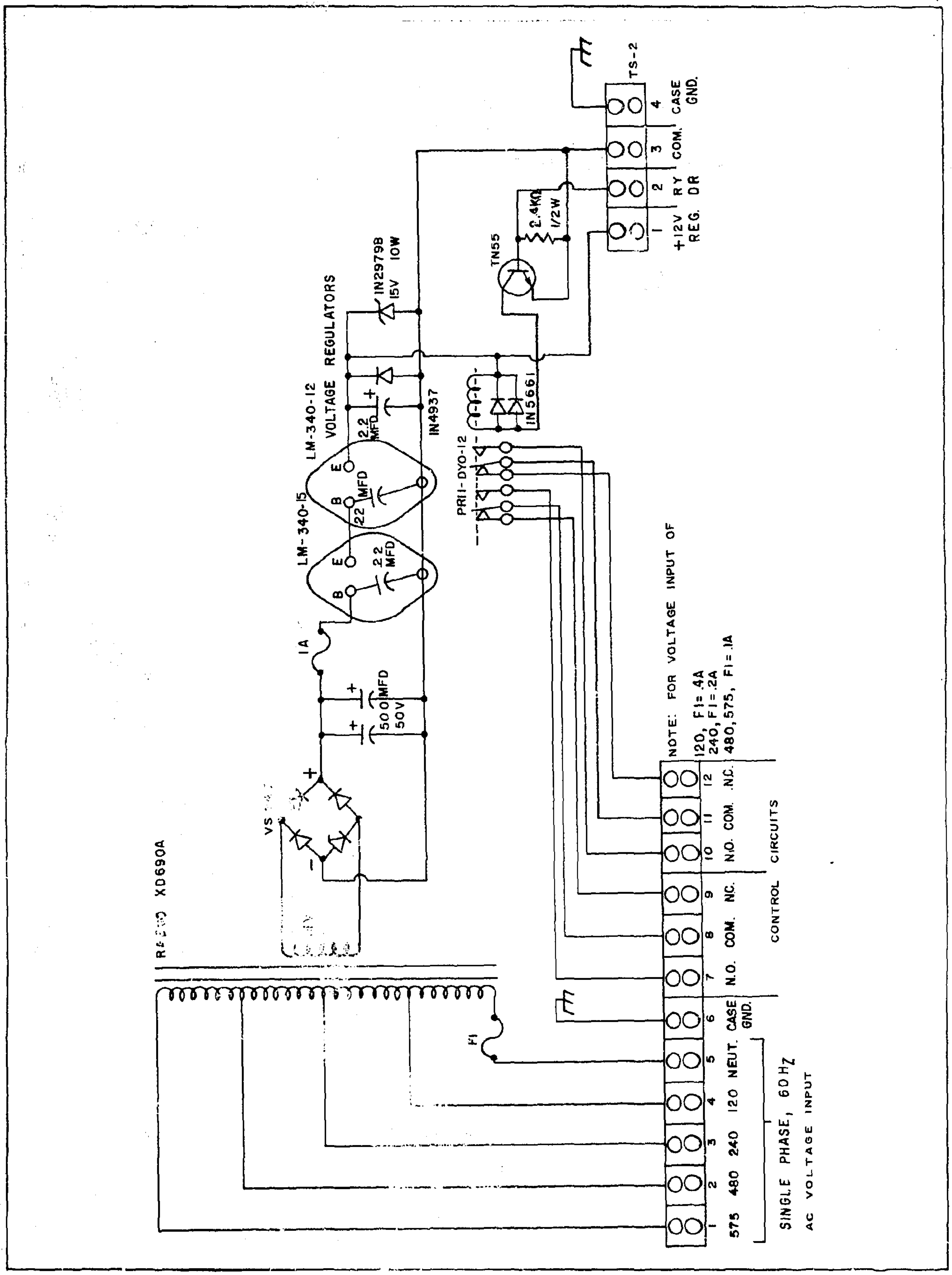


FIG. 16 – APPALACHIAN MODEL 102A POWER SUPPLY, PART NO. 7163

A P P E N D I X D

Subject Inventions

Contract J0188046

Underwriters Laboratories certifies that there were no Subject Inventions made in the performance of this contract, as defined in Clause A.(3) of the Patents and Inventions Article (Aug. 1975), Appendix B of the Contract.

By:

H. E. Bond

H. E. BOND
Secretary