CQS FILE 031197

Test Report No. 16376

Rev. 1 - 1/6/84

Rev. 2 - 1/17/84

Rev. 3 - 7/16/84

Rev. 4 - 8/16/84

No. of Pages 102

APPENDICES A - H

Report of Test

FOR

ENVIRONMENTAL QUALIFICATION
OF SC-1300 AND ET-1200 FAMILIES
OF SIGNAL TRANSMITTERS AND ELECTRONIC TRIPS
AND EI-4400 ANALOG ISOLATOR SYSTEM

ROCHESTER INSTRUMENT SYSTEMS
255 NORTH UNION STREET
ROCHESTER, NY 14605

Purchase Order No. 69651

Prepared by: William J. Lanier Date 11/15/83
William J. Lanier, Project Engineer
Acton Environmental Testing Corporation
533 Main Street, Acton, MA 01720

Reviewed & Approved by: N. J. Fredkin Jr. Date 11-15-83
N. J. Fredkin, Jr., Project Engineer
Acton Environmental Testing Corporation

REVISION RECORD

DATE	REVISION NUMBER	PAGE NUMBER	PARAGRAPH NUMBER	CHANGES OR ADDITIONS	APPROVED BY
11/15/83	0	-----------------FIRST ISSUE-----------------------			
1/6/84	1	Cover		Added Rev. 1 - 1/6/84	WL
		5-1	5.0	Reference to 1.0×10^4 rads TID added	
		6-5	Table I	Acceptance criteria also given in terms of measured voltage	
		6-8	Table II	Acceptance criteria also given in terms of measured voltage	
		6-8	Table II	Reference added to Table III	
		6-11,6-13	Table III	Acceptance criteria also given in terms of measured voltage	
		6-18	Table IV	(+) sign deleted for ET-1214	
		6-20	6.4.1	Acceptance criterion added. Reference to acceptable voltage readings added.	
		7-16, 7-17	Table VIII	Qualified lives and part numbers corrected	
		7-17	Table VIII	Reference added to proposed replacement of the PVC wires	
		7-19	7.1.4	Acceptance criterion revised	

REVISION RECORD

DATE	REVISION NUMBER	PAGE NUMBER	PARAGRAPH NUMBER	CHANGES OR ADDITIONS	APPROVED BY
11/15/83	0	-----------------FIRST ISSUE------------------------			
1/6/84	1 (cont'd)	7-19/7-20	7.1.4	Calculation corrected	WL
		7-21/7-22	Table IX	Manufacturer, specifications, and qualified lives changed as necessary	
		7-29	Table XI	Item number corrected	
		8-3	Figure 8	Callouts corrected	
		8-13	8.5	Added reference to Figure 16A	
		8-13A	Figure 16A	Page added	
		9-2	Figure 17	Callout corrected	
		10-2	10.0, Item 1	Additional test results added	
		10-4	10.0, Item 5	Last sentence revised, note added	
		10-6	10.0, Item 7	Qualified life revised, reference to recalibration after seismic testing deleted due to lack of supporting data	
		10-9	10.0, Item 10	Qualified life statements changed	
		10-10	10.0, Item 10	Reference to recalibration after aging deleted	

Test Report No. 16376

REVISION RECORD

DATE	REVISION NUMBER	PAGE NUMBER	PARAGRAPH NUMBER	CHANGES OR ADDITIONS	APPROVED BY
11/15/83	0	-----------------FIRST ISSUE-------------------------			
1/6/84	1 (cont'd)	10-11	10.0, Item 12	Qualified life statements changed	
		10-12	10.0, Item 12	Relay aging analysis added	
		10-14	10.0, Item 15	Item number corrected	
		10-15	10.0, Item 15	Reference to transformer substitutions added	
		10-17	10.0, Item 17	Reference to 0.1 uf capacitor added	
		10-18	10.0, Item 18	Reference to transformer substitutions added	
			Appendix A	Editorial changes made to the following pages as needed: A-3, A-7, A-28, A-29, A-30, A-31, A-32	
			Appendix D	Data added for capacitors in EI-4479 Power Supply	
			Appendix F Data Sheets	1. The following pages* were deleted: 8, 26, 43, 58, 131, 148, 153, 156, 159, 164, 169, 181, 184, 210, 267, 309 * The referenced page numbers are the revised page numbers.	

REVISION RECORD

DATE	REVISION NUMBER	PAGE NUMBER	PARAGRAPH NUMBER	CHANGES OR ADDITIONS	APPROVED BY
11/15/83	0	-----------------FIRST ISSUE-------------------------			
1/6/84	1 (cont'd)		Appendix F Data Sheets	2. The following pages* were revised and/or renumbered as necessary: 11, 16, 18, 19, 23, 36, 46, 59, 60, 64, 75, 82, 84, 133, 140, 149, 162, 168, 173, 174, 175, 196, 203, 215, 216, 225, 238, 239, 241, 246, 270, 272, 276, 279, 280, 281, 284, 286, 290, 304, 305, 306, 307, 308, 317, 321, 327, 328, 329, 330, 331, 335, 336, 337, 338, 339, 342, 343, 344, 345, 348, 349, 350, 351, 352, 353 * The referenced page numbers are the revised page numbers.	WL
			Appendix G	1. Calibration dates added to pages G-2 through G-7 2. Page numbers corrected for pages G-5, G-6, and G-7 3. Page G-8 added	

Test Report No. 16376

REVISION RECORD

DATE	REVISION NUMBER	PAGE NUMBER	PARAGRAPH NUMBER	CHANGES OR ADDITIONS	APPROVED BY
11/15/83	0	-----------------FIRST ISSUE-- ----------------------			
1/17/84	2	Cover		Added Rev. 2 - 1/17/84	WL
		A-26	Appendix A	Manufacturer's part numbers added	
		40, 315	Appendix F	References to "tweeking" replaced with "After recalibration"	
7/16/84	3	Cover		Added Rev. 3 - 7/16/84, changed Appendices A - G to read A - H	WL
		ii	List of Appendices	Added Appendix H - Mounting Configurations	
		8-1	8.1	Added reference to Appendix H	
			Appendix H	Appendix added	
8/16/84	4	Cover		Added Rev. 4 - 8/16/84	WL
		G-2 to G-9		Added CH331, CH336, CH356, and CH366 to test equipment list	

Test Report No. 16376

ADDENDUM TO AETC REPORT 16376

The information contained in this addendum should be used with reference to the various sections addressed. Contained in the addendum is information regarding qualified life, as well as other data which is intended to clarify certain sections of the report.

1. PVC Wire

   Reference Table VIII page 7-16, 7-17

   Due to the low activation energy of PVC wire a simulated 20 year thermal aging period was not attainable because of the time constraints of the program. 11.79 years was reached thus an 11.79 year qualification for several instruments resulted. In order to extend the qualified life to the planned 20 years, AETC suggested that the PVC wire jumpers and interconnections in all production units contain irradiated cross link polyethylene wire. This recommendation will be implemented, thus the following instruments will be qualified for 20 years (with the exception of the maintenance items listed in Table VIII):

   SC-1302, SC-1326, SC-1326W, SC-1330, SC-1372, SC-1373, ET-1214 and ET-1215.

2. EI-4477 Power Supply

   Reference Table VIII page 7-17, Table IX page 7-22

   The 3000 uf/35V electrolytic capacitor, C1, has a limited qualified life of 1.71 years. This is based on a continuous 2 amp load on the 24 volt output. A decrease in the load will increase the qualified life of this capacitor. As an example, a continuous 500 ma load will result in a 7.55 year qualified life for C1. Table I and the load curve attached to this addendum provide a comparison of qualified life to load. C1's maintenance interval will be based on the applied load.

3. EI-4479 Power Supply

   Reference Table VIII page 7-17, Table IX page 7-22

   a. The capacitor analysis of C2, a 10 uf/25V electrolytic, resulted in a 1.13 year qualified life. Due to the short qualified life, this capacitor will not be used in the production units. A 10uf/35V tantalum capacitor, identical to the type used in the qualified EI-4420 modules, will be substituted in place of the electrolytic. The qualification of the tantalum capacitor in the EI-4420 will justify its use in the EI-4479 power supply thus eliminating C2 as a maintenance item.

3. EI-4479 Power Supply (cont'd)

b. The capacitor analysis of C5, a 330uf/35V electrolytic capacitor, resulted in a qualified life of 2.26 years. Due to the short qualified life, this capacitor will not be used in the production units. This capacitor will be replaced with an Illinois type RMR capacitor of the same series used in several of the other instruments. Analysis of the Illinois RMR capacitors indicate that the qualified life is 9.06 years. Capacitor C5 will become a maintenance item based on this qualified life.

4. SC-1326W-323-H1, Item 33

Reference Section 10.6, pages 10-5 and 10-6

The report addresses the need for special handling of the 1044-249 transformers. The correct installation and operation of these transformers will be verified by visual inspection and testing of all production units.

5. SC-1372-323-I.1, Item 19

Reference Section 10.8, page 10-8

The report recommends that all units containing the subject transformers be tested prior to leaving the factory.

Since testing and inspection are mandatory for each production unit any failures or marginal material will be detected prior to shipment.

6. Recalibration of Equipment

Reference Section 10.0, Test Results

As a result of the extreme environment encountered during the various phases of the environmental tests, it was necessary to periodically re-calibrate several of the instruments. As a matter of routine maintenance it is recommended that the calibration of the production units be checked at one year intervals throughout their qualified life.

Prepared by J. Burgdorf, Sr. Q.A. Engineer 1/18/8[illegible]

Approved by A.W. Engelbrecht, Mgr. of QA 1/18/84

TABLE 1

QUALIFIED LIFE - VS LOAD

FOR EI-4477*

DC CURRENT LOAD (AMPS)	I_{RMS} RIPPLE (AMPS)	T_{RISE} 0°C	QUALIFIED LIFE (@51.9°C) HOURS	YEARS
0.5	0.86	1.916	60,790	6.94
0.75	1.25	4.048	52,439	5.99
1.0	1.60	6.633	43,836	5.00
1.25	1.94	9.751	35,316	4.03
1.5	2.33	14.066	26,187	2.99
1.75	2.61	17.650	20,426	2.33
2.0	2.92	22.090	14,980	1.71

ESR MAX = 0.15 ohm

Manufacturer's Life Test = 7000 hours @ 85°C

Qualified Life (Hrs) = $7000 \times 2^{((85-T2)/10)}$

where $T2 = \overbrace{\left[I^2 (ESR)/KA\right]}^{T_{RISE}} + 51.9°C$

$$T2 = \left[I^2_{RMS} (0.15)/(.006 \times 9.649)\right] + 51.9°C$$

*Using Acton capacitor life analysis method (Ref Section 7.1.4)

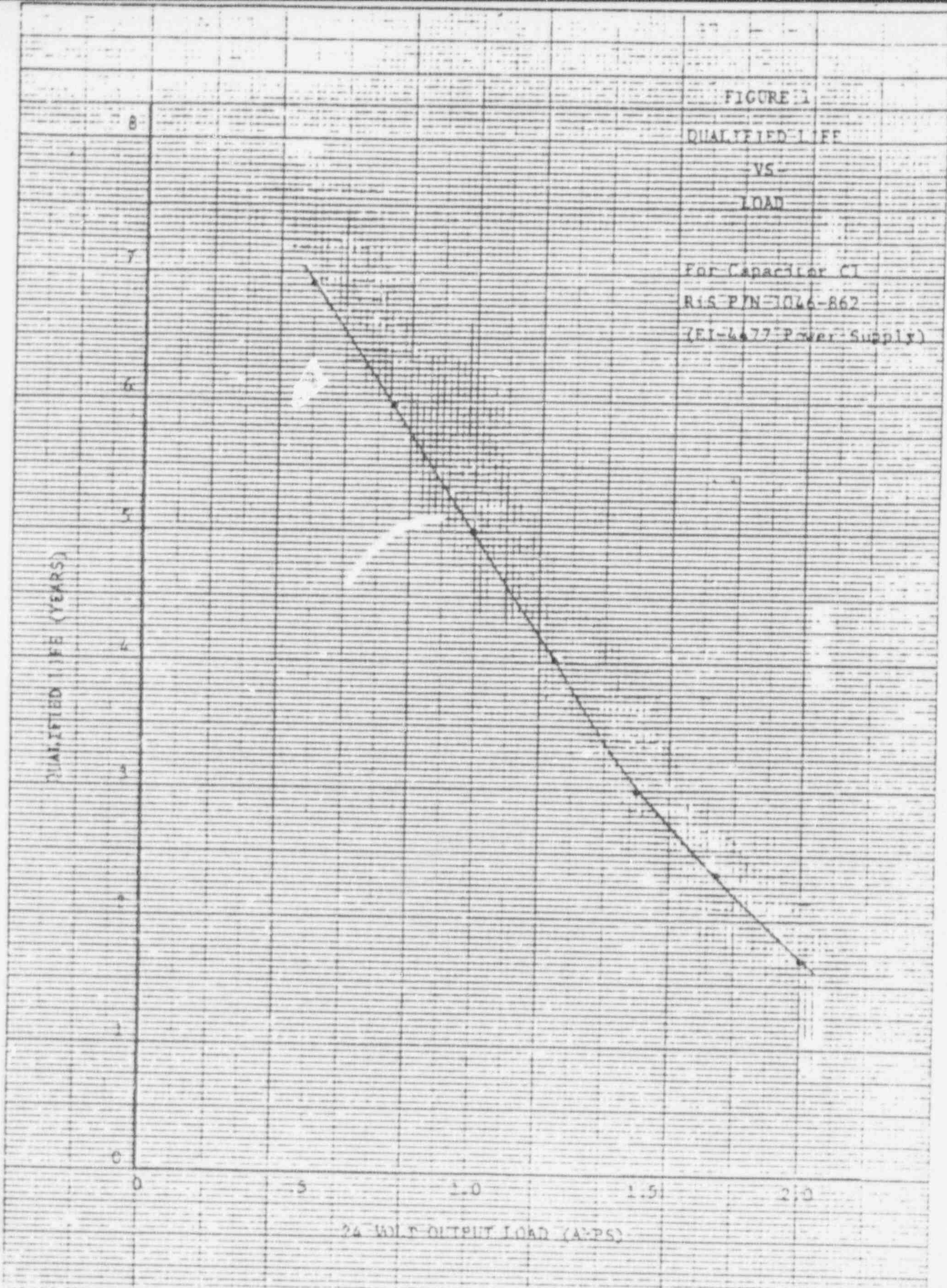


FIGURE 1
QUALIFIED LIFE
VS
LOAD
For Capacitor C1
RIS P/N 1046-862
(EI-4477 Power Supply)
QUALIFIED LIFE (YEARS)
8
7
6
5
4
3
2
1
0
0
.5
1.0
1.5
2.0
24 VOLT OUTPUT LOAD (AMPS)

TABLE OF CONTENTS

Report No. 16376

ACTON ENVIRONMENTAL TESTING

TABLE OF CONTENTS
(continued)

LIST OF APPENDICES

Report No. 16376

1.0 GENERAL

1.1 Scope

This document is prepared by Acton Environmental Testing Corporation (AETC) for Rochester Instrument Systems, Inc., to detail the Qualification Program and results for the SC-1300 and ET-1200 Families of Signal Transmitters and Electronic Trips and the EI-4400 Analog Isolator System to the requirements set forth in IEEE 323-1974 and IEEE 344-1975.

1.2 Objectives

This qualification report will present the approach, testing methods, and technical justifications for the qualification of SC-1300 and ET-1200 Families of Signal Transmitters and Electronic Trips, and the EI-4400 Analog Isolator System.

1.3 Definitions

The definitions which follow establish the meanings of words used in this qualification report.

1.3 Definitions (continued)

AGING

The actual process of simulation procedure which results in the cumulative effects of various environmental conditions including the frequency and duration of transients due to planned or unplanned events, up to, but not including, design basis and post-design events, which impact equipment during its installed life.

AUDITABLE DATA

Technical information which is documented and organized in a readily understandable and traceable manner that permits independent auditing of the inference or conclusions based on that information.

BASELINE FUNCTIONAL TEST

Reference measurements made of critical parameters needed to determine operating status.

CLASS 1E

The safety classification of the equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling and containment and reactor heat removal, or are otherwise essential in preventing significant release of radioactive materials to the environment.

1.3 Definitions (continued)

COMMON MODE FAILURES

Multiple failures attributable to a common cause.

COMPONENTS

Items from which equipment is assembled.

CONTAINMENT

That portion of the engineered safety features designed to act as the principal barrier, after the reactor system pressure boundary, to prevent the release, even under conditions of a reactor accident, of unacceptable quantities of radioactive materials beyond a controlled zone.

INSTALLED LIFE

The interval from installation to removal during which equipment or components thereof may be subjected to design service conditions and systems demands.

MAINTENANCE INTERVAL

The period, defined in terms of real time, operating time, number of operating cycles or a combination of these, during which specified performance is expected without maintenance or adjustment.

1.3 Definitions (continued)

MARGIN

The difference between the most severe specified service conditions of the plant and the conditions used in type testing to account for normal variations in commercial production of equipment and reasonable errors in defining satisfactory performance.

OPERATING EXPERIENCE

Accumulation of verifiable service data for conditions equivalent to those for which particular equipment is to be qualified.

QUALIFIED LIFE

The period of time for which it has been demonstrated that the equipment will meet all design requirements when operated within the service conditions for which it was qualified over a set of service conditions and during which a common mode failure will not occur.

SERVICE CONDITIONS

Environmental, loadings, power and signal conditions expected as a result of normal operating requirements, expected extremes in abnormal operating requirements, postulated conditions appropriate for design basis events of the situation.

ACTON ENVIRONMENTAL TESTING

2.0 APPLICABLE DOCUMENTS

2.1 Institute of Electrical & Electronics Engineers, Inc. Std. No. 1, 4/19/68, IEEE General Principles for Temperature Limits in the Rating of Electric Equipment.

2.2 Institute of Electrical & Electronics Engineers, Inc. Std. 98, 1972, IEEE Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of Temperature Indexes of Solid Electrical Insulating Materials.

2.3 Institute of Electrical & Electronics Engineers, Inc. Std. 101-1972, IEEE Guide for the Statistical Analysis of Thermal Life Test Data.

2.4 Institute of Electrical & Electronics Engineers, Inc. Std. 323-1974, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

2.5 Institute of Electrical & Electronics Engineers, Inc. Std. 344-1975, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

2.6 Institute of Electrical & Electronics Engineers, Inc. Std. IEEE 650-1979, IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations.

2.7 U.S. Nuclear Regulatory Commission, NUREG-0588, Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment.

2.8 Selecting Electolytes for Longer System Life, C. Forge, Electronic Design, February 17, 1983.

Report No. 16376

ACTON ENVIRONMENTAL TESTING

3.0 TEST ITEM DESCRIPTION

Two equipment groups were submitted for qualification. One consisted of the SC-1300 family and ET-1200 family of signal transmitters and electronic trips. The other group consisted of the EI-4400 analog isolator group as well as the interfacing power supplies and chassis. These groups are described further in the following paragraphs.

3.1 Signal Transmitters and Electronic Trips

This group was divided into three (3) distinct categories (See Figure 1). The first group consisted of the SC-13XX signal transmitters specifically including:

1) SC-1302 Isolator Transmitter w/H1, & HO options
2) SC-1326 Isolated Millivolt Transmitter w/I, & C options
3) SC-1326 Isolated Millivolt Transmitter w/H1 option
4) SC-1326W Isolated Thermocouple Transmitter w/I1 option
5) SC-1326W Isolated Thermocouple Transmitter w/H1 option

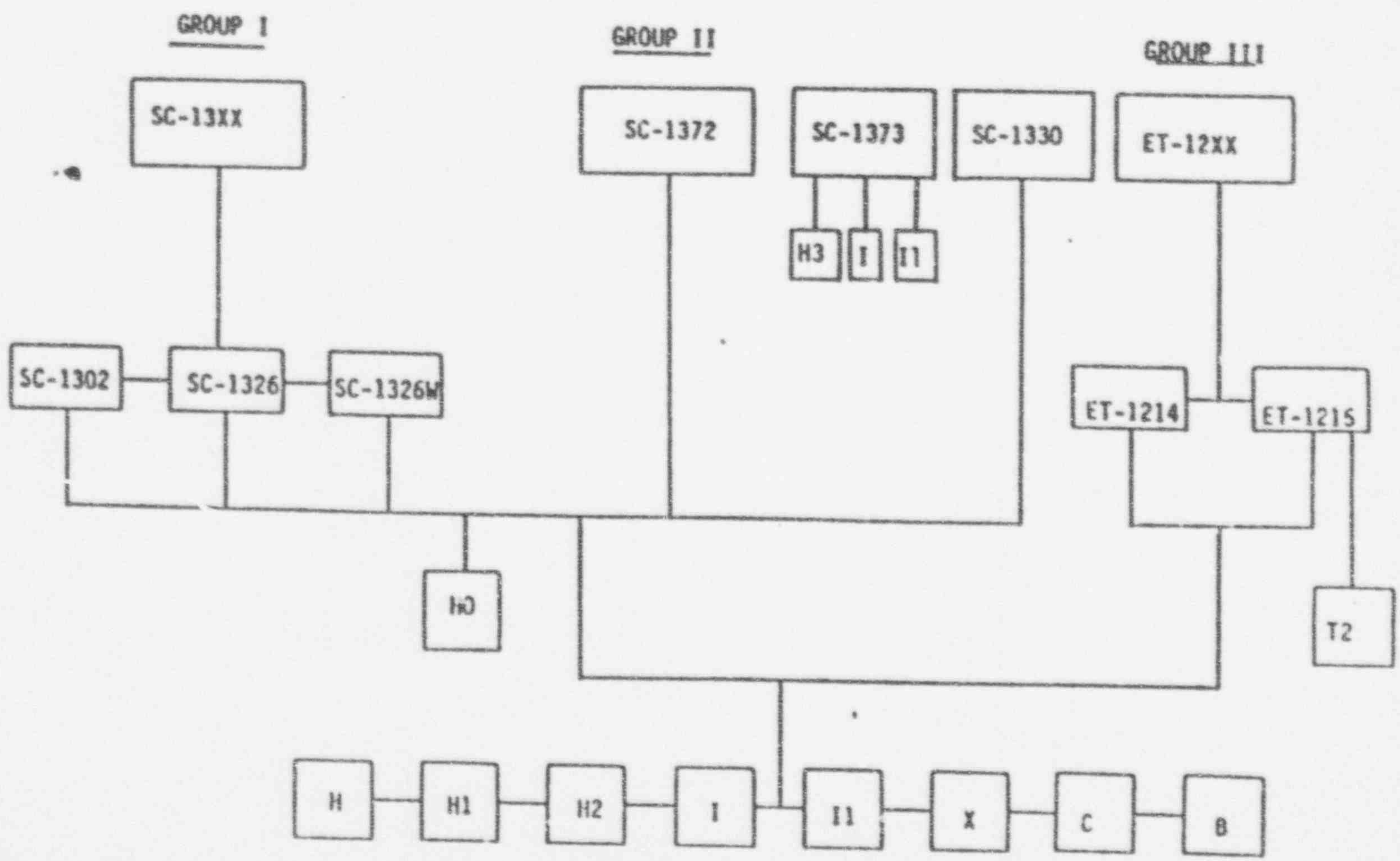

GROUP I
GROUP II
GROUP III
SC-13XX
SC-1372
SC-1373
SC-1330
ET-12XX
H3
I
I1
SC-1302
SC-1326
SC-1326W
ET-1214
ET-1215
H0
T2
H
H1
H2
I
I1
X
C
B

FIGURE 1

3.1 Signal Transmitters and Electronic Trips (continued)

The SC-1302 is an interface instrument designed for use with standard process signals. It provides compatibility for a wide range of electrical signals. The circuitry is designed such that it can accept signals that operate at a potential above or below ground. Complete isolation is provided between inputs and outputs. High allowable load variation rejection is provided in the SC-1302 due to a high effective impedance of the current output and very low impedance of the voltage output. Amplifier stability is maintained at zero ohms for current output and an open circuit for voltage outputs.

The SC-1326 is a solid-state isolated millivolt temperature transmitter. The SC-1326W is identical to the SC-1326 except that the input is generated by thermocouples. Cold junction compensation is built in for all standard thermocouple types, to allow transmitter ambient temperatures from 0°F to 140°F with very low drift. This unit also has the capability to compensate for instrument internal temperature rise. A regulated, temperature-stable power supply provides power to the built-in cold junction

3.1 Signal Transmitters and Electronic Trips (continued)

compensation circuitry. As was the case for the SC-1302, a high impedance at the current output and low impedance of the voltage output provides for a high allowable load variation rejection.

The second group consisted of the following:

1. SC-1372 Isolated RTD Transmitter (with H1 and I1 Option)
2. SC-1373 Dual Isolated RTD Transmitter (with H3 and I1 Option)
3. SC-1330 Square Root Extractor (with H1 Option)

The SC-1372 is designed to accept inputs from resistance type temperature detectors, and generate outputs in any of the standard process control signal ranges. Each instrument is equipped with a bridge excitation circuit for powering the resistance element. An excitation supply provides for detector lead wire resistance compensation. A synchronous chopper isolation stage provides full isolation at the input, and permits application of this instrument where high common mode voltages may exist (e.g., monitoring the winding temperature in large motors).

3.1 Signal Transmitters and Electronic Trips (continued)

The SC-1330 Square Root Transmitter is a field-mountable process instrument designed to provide a linear output from a square function input. This is accomplished through an electronic multiplier circuit using pulse width-height technique.

The SC-1330 contains 20 turn cermet trimmers used for input and output zero control, balance, span, and dropout controls. These pots are accessible from the front of the enclosure.

The SC-1373-323 is a dual-range, panel-mountable RTD-to-current transmitter. The input stage is fully isolated from the power supply and output signal. An RTD bias is standard for a wide range of inputs. Current output spans of 20 mA to 50 mA are available as standard options.

The third group consisted of the ET-12XX voltage/ current alarms specifically including:

1) ET-1214 Single current/voltage alarms w/H option
2) ET-1214 Single current/voltage alarms w/H1 option
3) ET-1215 Dual/Duplex current/voltage alarms w/H1 & T2 options
4) ET-1215 Dual/Duplex current/voltage alarms w/H1 option

3.1 Signal Transmitters and Electronic Trips (continued)

The ET-1214 and ET-1215 are solid-state single and dual/duplex instrument, respectively, designed to accept standard voltage and current inputs and provide relay output(s). The ET-1214 is equipped with one (1) DPDT 5-amp relay output; the ET-1215 provides two (2) SPDT 5-amp relay outputs. These units are fixed deadband instruments with field-selectable values between 0.2% and 10% of span.

The majority of the options listed below are common to all of the above groups.

H Option - 24 VDC power input, deletion of transformer, T1, and some additional wiring added.

H1 Option - 117 VAC power input

H2 Option - 230 VAC power input, internal wiring change

H3 Option - 117 VAC power input

I Option - 24 VAC isolated power input (add printed circuit board)

I1 Option - 48 VDC isolated power input (add printed circuit board)

X Option - Input impedance change (add a resistor)

C Option - Addition of conduit mounting plate and terminal cover

B Option - Addition of conduit mounting plate

3.1 Signal Transmitters and Electronic Trips (continued)

The following option is common only to the SC-1330 and the first two (2) groups (i.e., SC-13XX and SC-1372), but not to the SC-1373.

HO Option - High loop drive (add printed circuit board)

The following option is common only to the ET-1215 series:

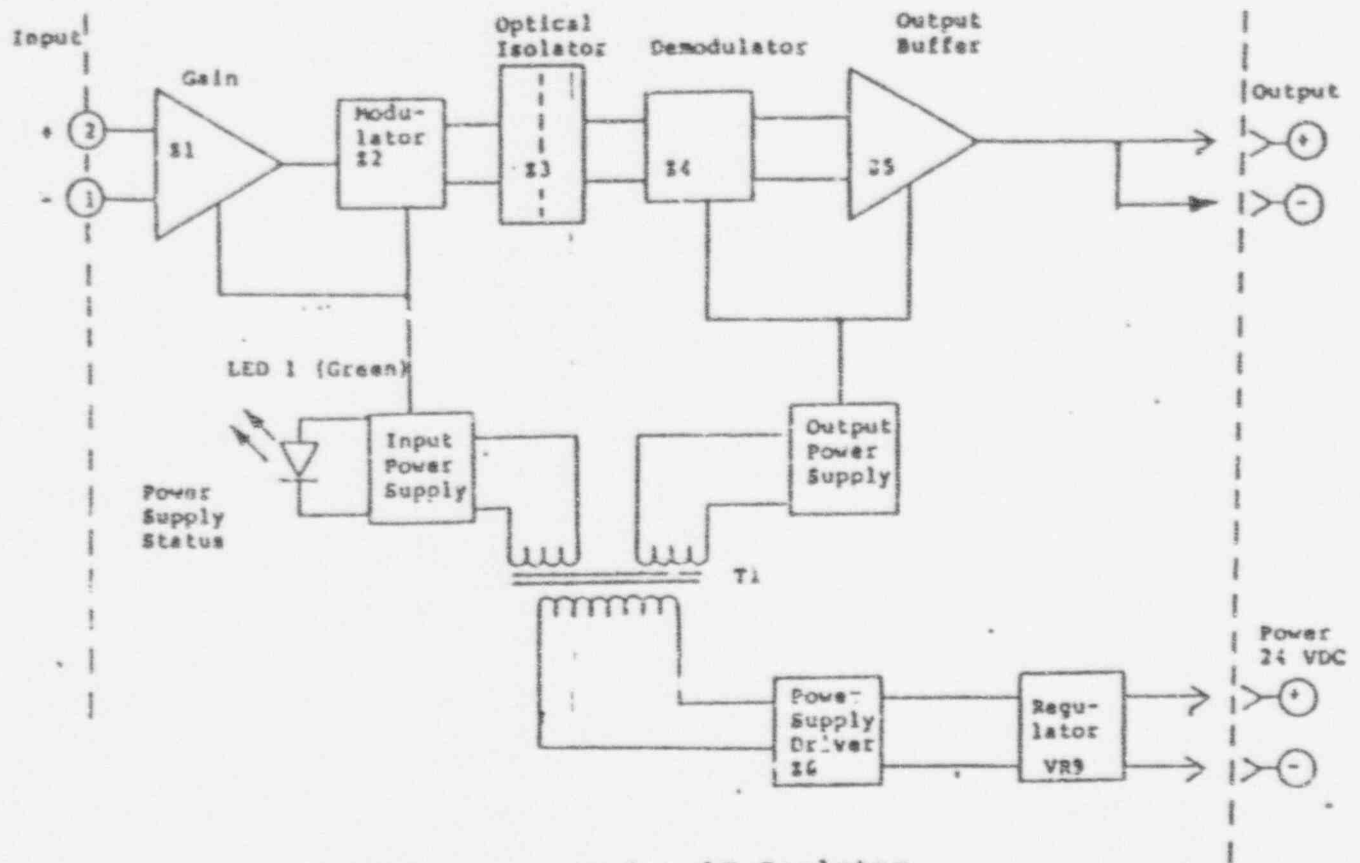
T2 Option - Additional terminal block and wiring for extra contact outputs.

3.2 Analog Isolator System

The Rochester Instrument Systems series of EI-4400 Analog Isolator Module System consists of single channel plug-in cards, providing electrical and physical isolation.

This system is designed so that any circuit or component failure on either side of the separation will not produce a failure on the other side of separation. This is achieved using an optical coupler and/or galvanometer technique to provide circuit isolation.

The isolator modules are mounted onto a module chassis capable of accommodating up to 20 modules. A block diagram is shown in Figure 2.



Block Diagram Analog 1E Isolator

FIGURE 2

3.2 Analog Isolator System (continued)

Also included in the qualification program is a 120 VAC, 24 VDC power supply No. EI-4477 which supplies power to the isolator module, and the EI-4479 power supply which can be used for several applications with up to a 4-amp load.

The EI-4420 isolator modules can be mounted in either an EI-4481 or EI4482 chassis. The EI-4481 chassis contains terminal blocks for interfacing connections, while the EI-4482 chassis contains connectors used for the same purpose. The EI-4481/EI-4482 chassis submitted for test contains both terminal blocks and connectors.

ACTON ENVIRONMENTAL TESTING

4.0 TEST SEQUENCE

The qualification testing for the RIS SC-1300 and ET-1200 families of signal transmitters and electronic trips as well as the EI-4420 analog isolator was performed in the following sequence:

1. Incoming Inspection and Identification
2. Baseline Functional Testing
3. Thermal Aging
4. Verification Functional Testing
5. Mechanical Aging
6. Radiation Aging
7. Verification Functional Tests
8. Seismic Testing
9. Verification Functional Testing
10. Abnormal Environment Test
11. Verification Functional Tests

Report No. 16376

5.0 DEFINITIONS OF SERVICE CONDITIONS

The following service conditions represent the normal service conditions as determined by RIS/AETC for a majority of the nuclear power plants in the country. The values tabulated below do not include margin.

Temperature	1.1 to 51.5°C
Relative Humidity	20 to 95%, 70% normally
Pressure	ATM

5.1 Accident Condition [Post DBE - 1 year]

Temperature	5.0 to 60°C
Relative Humidity	20 to 95%, 95% normally
Pressure	-1.0 to +1.0 in. water

Radiation Dose

Normal and Accident: 2×10^5 rads* (total integrated dose)

* This accident dose rate applies to all components except:

a) SC1302-323
b) SC1326-323
c) SC1326W-323
d) SC-1372-323
e) SC-1373-323

The total integrated dose for these five (5) components is 1.0×10^4 rads.

6.0 INSPECTION AND FUNCTIONAL TESTING

6.1 Pre-Test Inspection

Inspection of the test units was performed upon their delivery to Acton Environmental Testing Corporation to ensure that the equipment was not damaged due to handling and shipping. No such damage was noted.

6.2 Functional Testing

The purpose of these tests was to check operational characteristics of the test items at the beginning of the program and after humidity, aging, and seismic testing. The parameters were as follows:

1. Dielectric Strength
2. Device Operability

The test items described in Section 3.0 underwent baseline functional testing as described herein with acceptance criteria described specifically for each item listed.

6.2 Functional Testing (continued)

NOTE: Section 8.6.3 of the Acton Environmental Quality Control Manual states the following:

"All measuring standards used in the calibration system shall show traceability to the National Bureau of Standards by means of a CERTIFICATION or TEST DATA REPORT."

The general dielectric strength test procedures are described below. More specific application of these general procedures are given for individual components when applicable.

Dielectric Withstanding Voltage (General)

This test involves the application of a voltage higher than rated voltage, for a specific time, between mutually insulated points or between insulated points and ground. It is used to prove that the component can operate safely at rated voltage and withstand momentary surges due to switching, etc. This test was conducted to determine whether insulating materials and spacings in the component are adequate. The dielectric withstanding voltages are given in the following paragraphs and are applied as specified by MIL-STD-202F, Method 301.

The components were electrically connected to a dielectric voltage tester. The test voltage was increased gradually to the

6.2 Functional Testing (continued)

voltages specified below and maintained for one (1) minute.

Acceptance Criteria

No arcing, breakdown or current flow in excess of 2.0 milliamps.

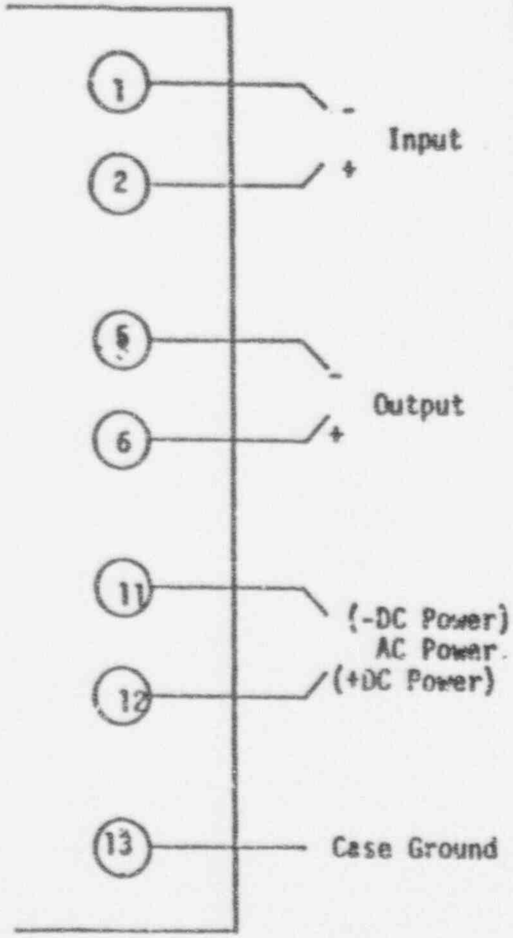
6.3 Signal Transmitters and Electronic Trips

6.3.1 SC-1302

Dielectric strength was performed in accordance with Section 6.2 and Figure 3. The general acceptance criteria specified in 6.2 are applicable for the SC-1302 unit.

Device operability was determined for this unit (including options) by applying the appropriate power input and signal input voltage and monitoring the output drive capability against a given load (see Table I).

For acceptance criteria see Table I.



Dielectric Testing

Equipment Used: Milwaukee Electronics Corp.
Model 49, ME-2.5KV

1. Terminal 13(-) to Terminal 11,12(+) (1000 VAC)
2. Terminal 13(-) to Terminal 1,2(+) (1000 VAC)
3. Terminal 13(-) to Terminal 5,6(+) (1000 VAC)
4. Terminal 1,2(-) to Terminal 5,6(+) (NOTE: 600 VAC) (Not to be performed on Model No. SC-1330-323)
5. Terminal 11,12(-) to Terminal 1,2,5,6,(+) (Note: 600 VAC)

FIGURE 3

TERMINAL LOCATIONS FOR
SC-1302-323, 1326-323, 1326W-323,
SC-1330-323, 1372-323

TABLE I

DEVICE	INPUT SIGNAL	OUTPUT LOAD	ACCEPTANCE CRITERIA
SC-1302	1-5V	250Ω	Output signal must be between 4 and 20mA.*
SC-1326	10-100 mV	250Ω	
SC-1326W	Thermocouple Input	250Ω	
SC-1330	1-5 VDC	250Ω	

NOTES: (1) Linearity:

(a) ±0.1% of span maximum for SC-1302, SC-1326, 1326W

(b) ±0.1% of span from 10 to 100% of input maximum for SC-1330

(2) Power Supply Effect:

(a) SC-1302 - ±0.15% with 20% power variation
(b) SC-1326/1326W - ±0.15% with ±20% power variation
(c) SC-1330 - ±0.15% with ±20% power variation

* Since the current is being measured across a 250Ω resistor, acceptable voltage drops across these resistors would be in the range of 1 to 5 VDC.

6.3.2 SC-1326

Dielectric strength was performed in accordance with Section 6.2. The general acceptance criteria specified in 6.2 are applicable for the SC-1326 unit.

Device operability was determined for this unit (including options) by applying the appropriate input voltage and monitoring the output drive capability against a given output load (see Table I). Response time will also be recorded.

For acceptance criteria see Table I.

6.3.3 SC-1326W

Dielectric strength was performed in accordance with Section 6.2 and Figure 3. The general acceptance criteria specified in 6.2 are applicable for the SC-1326W unit.

Device operability was determined for this unit (including options) by applying the appropriate input voltage and monitoring the output drive capability against a given output load (see Table I).

For acceptance criteria see Table I.

6.3.4 SC-1372

Dielectric strength was performed in accordance with Section 6.2 and Figure 3. The general acceptance criteria specified in 6.2 are applicable for the SC-1372 unit.

Device operability was determined for this unit (including options) by utilizing a 5 to 2000 ohm variable resistor to simulate RTD input (see-Table II). The output was also monitored and recorded versus a resistance value input and specified output load.

For acceptance criteria see Table II.

TABLE II

DEVICE	INPUT SIGNAL	OUTPUT LOAD	ACCEPTANCE CRITERIA
SC-1372	two-, three- or four-wire RTD (5-2000Ω)	0-250Ω	The output signal shall be between 4 and 20mA. (or 1-5 VDC across the 250Ω resistor)
SC-1373	Dual RTD inputs	0-250Ω	*
Overall	278.22Ω-480.46Ω		
Expanded	384.20Ω-444.84Ω		

NOTES: (1) Linearity:

(a) SC-1372 - ±0.1% of span maximum ±0.05% typical

(b) SC-1373 - ±1°C maximum

(2) Power Supply Effect:

(a) SC-1372 - ±0.15% with ±20% power variation

(b) SC-1373 - ±0.15% with ±20% power variation (±10% for H3 option)

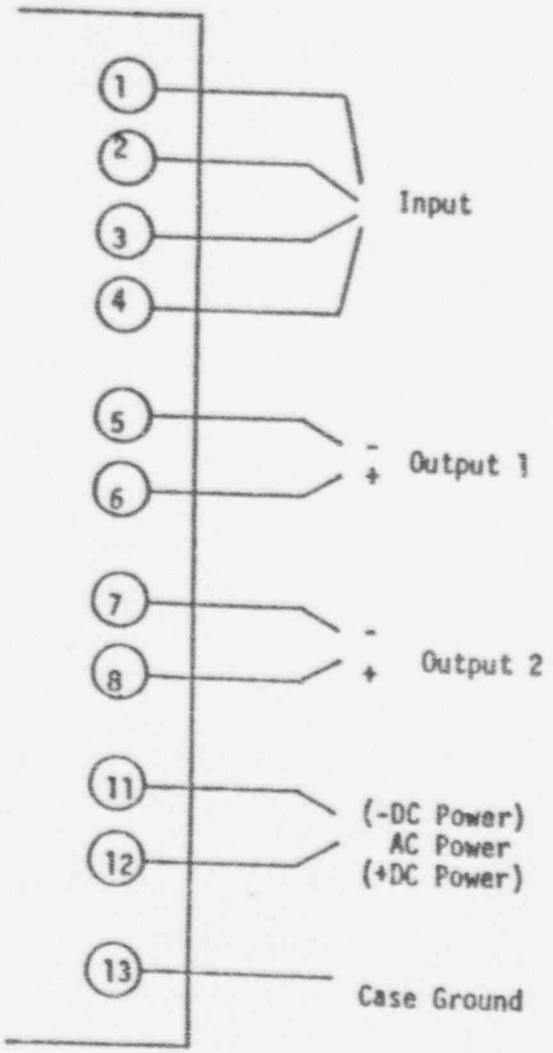
*Table III shows a derivation of the acceptable values which apply to the SC-1373-323.

6.3.5 SC-1373

Dielectric strength measurements were performed in accordance with Section 6.2 and Figure 4. The general acceptance criteria specified in Section 5.2 applied to the SC-1373 unit.

Device operability was determined for this unit (including options) by utilizing a 5-2000 ohm variable resistor to simulate each RTD input (see Table II). The output was also monitored and recorded versus a resistance value input and specified output load. The acceptance criteria are also given in Table II.

ACTON ENVIRONMENTAL TESTING CORPORATION



Dielectric Testing (500 VDC @ <2mA)

Equipment Used: AETC 10K VDC Power Supply and Fluke 8050A (to measure mA draw)

1. Terminal 13(-) to Terminal 1-12(+)
2. Terminal 7,8(-) to Terminal 1-6(+)
3. Terminal 5,6(-) to Terminal 1-4(+)
4. Terminal 11,12(-) to Terminal 1-8(+)

Note: The test voltage between Terminals 13 and 12 was 500 VDC. All other test voltages were 1000 VDC.

FIGURE 4

TERMINAL LOCATIONS FOR SC-1373-323

BY ________ DATE ________
CHKD. ________ DATE ________
JOB NO. ________

Report No. 16376

ACTON ENVIRONMENTAL TESTING

TABLE III

SC-1373-323

Input (Narrow Range)

°F	°C	IDEAL OHMS VALUE	IDEAL OUTPUT
465	240.55	384.20	4.0mA
502.5	261.38	399.51	8.0mA
540	282.22	414.72	12.0mA
577.5	303.055	429.84	16.0mA
615	323.88	444.84	20.0mA

Input °F Range: Δ150°F

Input °C Range: Δ83.3°C

Input Ω Range: 60.64Ω

Output Span (maximum output - minimum output) = 16mA

$60.64\Omega \div 150°F = .40426\Omega/°F$

$60.64\Omega \div 83.33°C = .72768\Omega/°C$

Acceptance Linearity = $\pm 1°C$

$16mA \div 83.33°C = .192mA/°C$

Therefore, the output may be off $\pm$.192mA from the ideal output.*

$(.01\Omega \div 60.64\Omega) \times 100 = .016490\%$ error/.01Ω shift.

*Since the current was measured as a voltage drop across a 250Ω resistor, the allowable voltage drift was 0.048 VDC.

TABLE III
(continued)

AVAILABLE OHMS VALUE	IDEAL OUPUT FOR AVAILABLE OUTPUT	TOLERANCE ALLOWED
384.2	4.00mA	±.192mA
399.5	7.9973614mA	±.192mA
414.7	11.994723mA	±.192mA
429.8	15.989446mA	±.192mA
444.8	19.989446mA	±.192mA

Input (Wide Range)

°F	°C	IDEAL OHMS VALUE	IDEAL OUTPUT
212	100	278.22	4.0mA
335.25	168.47	330.425	8.0mA
458.5	236.94	381.53	12.0mA
581.75	305.42	431.54	16.0mA
705	373.88	480.46	20.0mA

Input °F Range: Δ493°F

Input °C Range: Δ273.88$\overline{8}$°C

Input Ω Range: 202.24Ω

Output Span (maximum output - minimum output) = 16mA

202.24Ω ÷ 493°F = .41022Ω/°F

Report No. 16376

TABLE III
(continued)

202.24Ω ÷ 273.888°C = .73840Ω/°C

Acceptance Linearity = ±1°C

16mA ÷ 273.888°C = .05842mA/°C

Therefore, the output may be off ±.05842mA from the ideal output.*

(.01Ω ÷ 202.24Ω) x 100 = .0049446% error/.01Ω shift.
(.000049466) (16mA) = .000791136mA/.01Ω shift.

AVAILABLE OHMS VALUE	IDEAL OUPUT FOR AVAILABLE OUTPUT	TOLERANCE ALLOWED	
278.2	3.998417728mA	±.05842mA	.9996044V
330.4	7.99802216mA	±.05842mA	1.9995055V
381.5	11.9976266mA	±.05842mA	2.9994065V
431.5	15.99683546mA	±.05842mA	3.9992087V
480.4	19.99525319mA	±.05842mA	4.9988132V

Ideal Output for Avail. Input =

$$\text{Ideal Output} - \frac{(\text{Ideal ohms value} - \text{Avail. ohms value}) \times (.000791136\text{mA})}{.01\Omega}$$

*Since the current was measured as a voltage drop across a 250Ω resistor, the voltage tolerance was .0146 VDC.

6.3.6 SC-1330

Dielectric strength was performed in accordance with Section 6.2 and Figure 3. Device operability was determined for the SC-1330 unit (including options by applying the appropriate input voltage and monitoring the output drive capability against a given output load (see Table I).

The acceptance criteria are found in Table I.

6.3.7 ET-1214

Dielectric strength was performed in accordance with Section 6.2 and Figures 5 and 5A. The general acceptance criteria specified in 6.2 are applicable for the ET-1214 unit.

Contact resistance for the DPDT output relay was determined by utilizing the volt-amp method, using a known current and measuring the voltage drop across the contacts. All contacts were tested.

A resistance value of greater than one ohm constituted a failure.

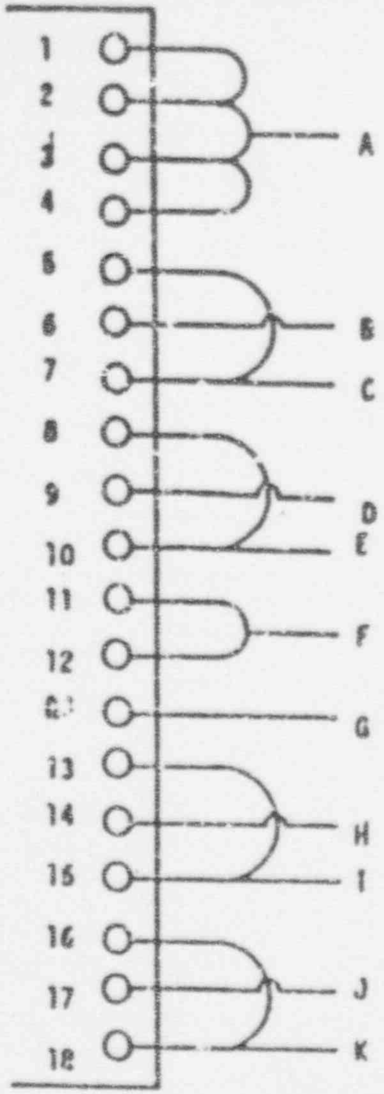


FIGURE 5

TERMINAL LOCATIONS FOR

ET-1214-H-323, ET-1214-323, ET-1215-323, ET-1215-T2-323

Report No. 16375

FIGURE 5A

DIELECTRIC STRENGTH TESTING

	ET-1214-H-323		ET-1214-323		ET-1215-323		ET-1215-T2-323	
1. 1000 VAC	-Lead	+Lead	-Lead	+Lead	-Lead	+Lead	-Lead	+Lead
	G	A-F	G	A-F	G	A-F	G	A-F, H-K
2. 600 VAC								
	A	B-E	A	B-E	A	B-E	A	B-E, H-K
	F	B,C,E,D	F	B,C,D,E,A	F	B,C,D,E,A	F	A-E, H-K

1. Record the input voltages that cause relay to change state approximately equal to 3.000V and 2.980V (High trip-K1) approximately equal to 3.500V and 3.520V (Low trip-K2 on 1215) approximatley equal to 3.500V and 3.480V (for high trip on ET-1215)

<1Ω across term.	5-7 (1214,15,15-T2) 8-10 (1214) 13-15 (1215-T2)	6-7 (1214,15,15-T2) 9-10 (1214) 14-15 (1215-T2)	8-10 (1215,15-T2) 16-18 (1215-T2)	9-10 (1215,15-T2) 17-18 (1215-T2)
<1Ω across term. (power supply effect)	5-7 (1214,15,15-T2) 8-10 (1214) 13-15 (1215-T2)		8-10 (1215,15-T2) 16-18 (1215-T2)	

6.3.7 ET-1214 (continued)

NOTE: In the case of multiple output relay options, all relays were tested.

Device operability was determined for this unit (including options) by applying the appropriate input signal necessary to trip the unit resulting in the output relay change of state. The output relay contacts were monitored. For acceptance criteria see Table IV.

Device deadband was preset, recorded and verified during the device operability testing.

6.3.8 ET-1215

Dielectric strength was performed in accordance with Section 6.2 and Figures 5 and 5A. The general acceptance criteria specified in 6.2 are applicable for the ET-1215 unit.

Contact resistance for the two (2) SPDT output relays was determined by utilizing the volt-amp method, using a known current to measure the voltage drop across the contacts. All contacts were tested.

ACTON ENVIRONMENTAL TESTING

TABLE IV

DEVICE	INPUT SIGNAL	OUTPUT SIGNAL	ACCEPTANCE CRITERIA
ET-1214 ET-1215	1 - 5V (into 5 MΩ)	Relay contact rated 5 amps at 30 VDC	The relay contacts must transfer

NOTES: (1) Power Supply Effect - less than ±0.15% of span for a ±20% change

(2) Deadband - ET-1214/1215, fixed 0.5% ±0.1% of span

Report No. 16376

Rev. 1

6.3.8 ET-1215 (continued)

A resistance value of greater than one ohm would have constituted a failure.

Device operability was determined for this unit (including options) by applying the appropriate input signal necessary to trip the unit resulting in the output relay change of state. The output relay contacts were then monitored.

For acceptance criteria see Table IV.

Device deadband was periodically preset, recorded and verified during the device operability testing.

6.4 Analog Isolator System

6.4.1 Analog Isolator Module (EI-4420) and Chassis (EI-4481/4482)

Dielectric strength tests were performed in accordance with Section 6.2.

Input/output isolation was tested by means of the dielectric withstand voltage test as specified in

6.4.1 Analog Isolator Module (EI-4420) and Chassis (EI-4481/4482) (continued)

Section 6.2. A 1.5 KV AC voltage was applied between the input to output, input to ground, output to ground, power to input/output, and power to ground.

The test results were acceptable if the current leakage was less than 2 milliamps.

A. Operability

The analog isolator module and chassis was tested to verify device operation and performance specifications. An input test signal was applied to the test samples as shown in Figure 6.

Acceptance Criteria

Operation of the analog isolator was acceptable if the output voltage was 1 to 5 VDC or 4 to 20mA when the input voltage or current was varied between 1 to 5 VDC or 4 to 20mA.*

Input/output signal difference shall not exceed $\pm.25\%$. Power supply effect shall be less than $\pm0.15\%$ of span for a ±10 change.

*Since the output currents in the current input/output analog isolators were measured as voltage drops across a 250Ω resistor, the acceptable output range for these test items was also 1-5 VDC.

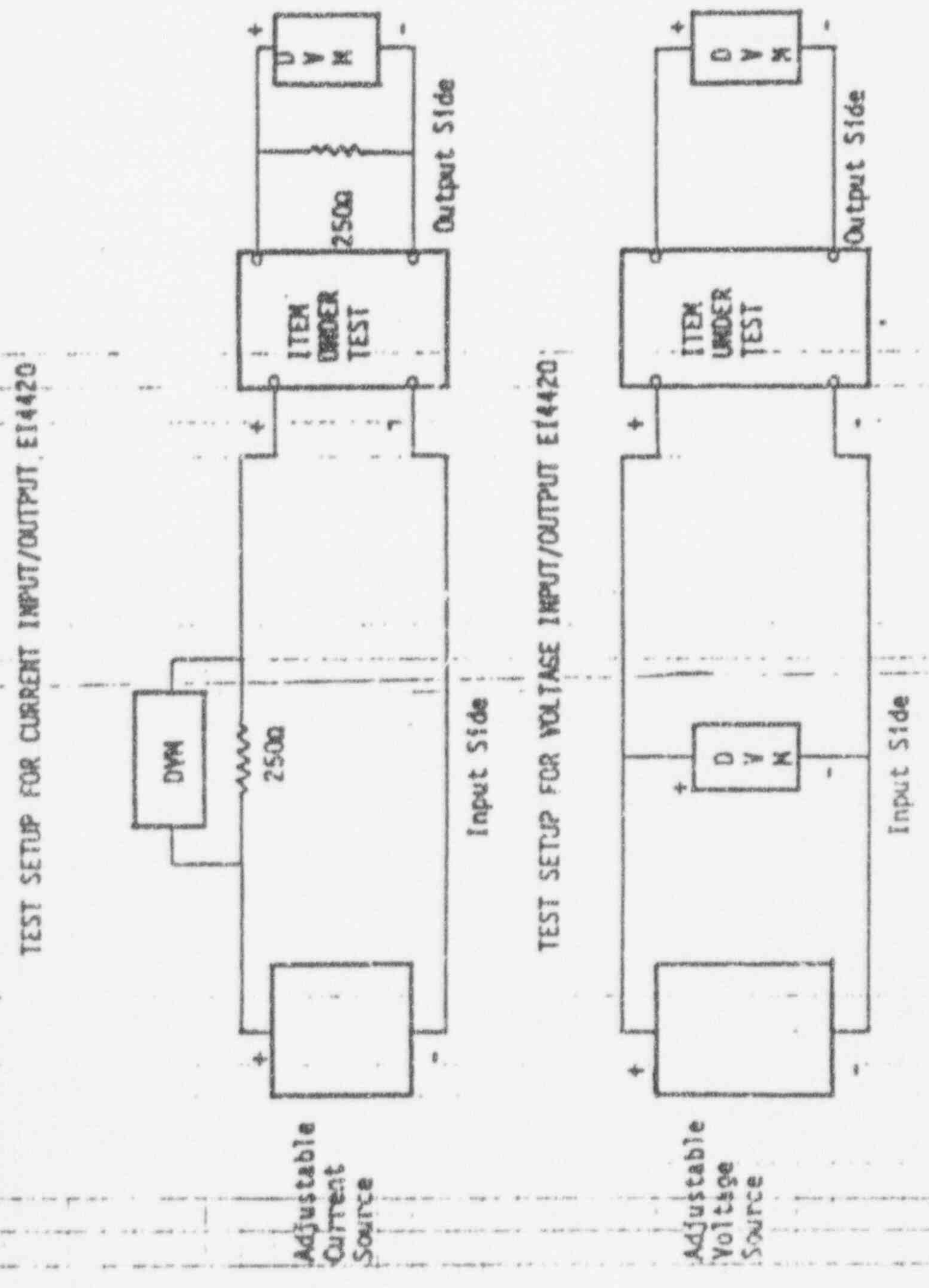


FIGURE 6

Report No. 16376

6.4.2 EI-4477 Power Supply

The baseline functional testing included dielectric strength and device operability.

A. Dielectric Strength

Dielectric strength was measured for all pins of J1 and J3 to ground and J1 to J3 using 1,500 VAC for one (1) minute.

Acceptance Criteria

There could be no arcing or breakdown with a resultant current flow in excess of two (2.0) milliamps.

B. Device Operability

The EI-4477 power supply accepts 120 $\pm$10% VAC, 60 Hz and outputs 12 VDC, 24 VDC, and 125 VDC. During this test, a 0.1µf capacitor was connected across Terminals 3 and 6.

Acceptance Criteria

Output voltages were verified by observing operation of LED 1 and 2. The output voltages on the power supply converter J3 (DC return on Pin 8) were then measured.

6.4.2 EI-4477 Power Supply (continued)

B. Device Operability (continued)

(See diagram of connector for pin locations on Page 6-22.) Pins 2, 3, 4, and 10 are described below:

Pin 10: 125 VDC +20%, -32% @ 0 to 0.2A load

Pins 2 and 4: 24 VDC ±20% @ 0 to 2A load

Pin 3: 12 VDC +5%, -15% @ 0 to 0.2A load

6.4.3 EI-4479 Power Supply

The baseline functional testing included dielectric strength and device operability.

A. Dielectric Strength

Dielectric strength was measured as follows:

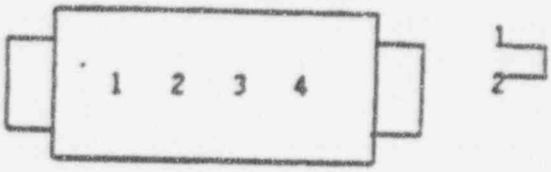
- Case to terminals 1, 2; 1500 VAC
- Case to terminals 4, 5, 6, 7, 8; 500 VAC
- Terminals 1, 2 to 7, 8; 1500 VAC
- Terminals 7, 8 to 5, 6; 500 VAC

Acceptance Criteria

There could be no arcing or breakdown with a resultant current flow in excess of two (2.0) milliamps.

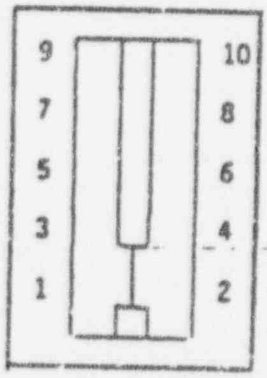
EI-4477 CONNECTORS

J_1



AC INPUT

J_3



1 + Power Monitor

2 + 24 Vdc

3 + 12 Vdc

4 + 24 Vdc

5 Ext Led + 12 Vdc

6 Common

7 - Power Monitor

8 Common

9 Ext Led + 125 Vdc

10 + 125 Vdc

FIGURE 7

Report No. 16376

ACTON ENVIRONMENTAL TESTING

6.4.3 EI-4479 Power Supply (continued)

B. Device Operability

The EI-4479 accepts a 120 VAC, 60 Hz input and outputs 24 VDC.

Acceptance Criteria

The output voltage at Terminals 7 and 8 was measured. Output 24 VDC $\pm$.1V at 4.0A. Line/load effect at 120 VAC $\pm$10% input/output 24 VDC $\pm$5% maximum. For power monitor output, the relay contactor should have been closed with the power on and open with the power off.

7.0 AGING PROGRAM

7.1 Thermal Aging

7.1.1 General Aging Program

The purpose of this program was to reproduce the physical stresses, thermal, mechanical and electrical which a component would most likely see in a 20-year service period. This program consisted of one or more applied stresses including thermal, mechanical and electrical. Upon the successful completion of an aging program, the component would have a qualified life of 20 years or a maintenance cycle as listed in Table VIII. In order to accomplish this, it was necessary to analyze the overall unit and divide component parts into three (3) different aging categories: mechanical, thermal and electrical. At this time components which wer previously proven not to have age-related failure mechanisms were eliminated.

7.1.2 Rationale for Normal Thermal Aging

Polymeric materials undergo degradation reactions which cause loss of strength and insulative abilities. There is a potential for failure with age for these materials. These degradation reactions are accelerated thermally by placing the test units in an environmental chamber at an elevated temperature. The time and temperature for accelerated aging of a test unit with several materials is determined for the material in the test units with the lowest activation energy. If the activation energy for that material is known, the Arrhenius equation is used to determine the temperature and time period at which the test unit is aged. The specific methods by which each type of test unit component set is aged is discussed in the following sections.

7.1.2 Rationale for Normal Thermal Aging (continued)

If thermal degradation is determined by a simple temperature-dependent reaction that follows the Arrhenius law, this law can be used as the basis for thermal aging. This law is expressed by the following equation:

$$\frac{d\ln k}{T} = \frac{Ea}{BT^2} \qquad (1)$$

where:

k = Reaction Rate

B = Boltzmann's Constant

T = Absolute Temperature (°K)

Ea = Activation energy of the reaction (eV)

It is assumed that Ea is independent of temperature. Rearrange equation (1).

$$d\ln k = \frac{Ea}{B}\frac{dT}{T^2} \qquad (2)$$

Integrate between limits of K_2, T_2 and K_1, T_1

7.1.2 Rationale for Normal Thermal Aging (continued)

$$\int_{K_2}^{K_1} d\ (\ln k) = \frac{Ea}{B} \int_{T_2}^{T_1} \frac{dT}{T^2} \qquad (3)$$

$$\ln k \Big|_{K_2}^{K_1} = \frac{Ea}{B} \quad \frac{1}{T} \Big|_{T_2}^{T_1} \qquad (4)$$

$$\ln k_1 - \ln k_2 = \frac{Ea}{B} \left(\frac{1}{T2} - \frac{1}{T1}\right) \qquad (5)$$

$$\ln \frac{k_1}{k_2} = \frac{Ea}{B} \left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

where:

k_1, T_1 = service conditions

k_2, T_2 = aging conditions

$$\ln \frac{k_1}{k_2} = \frac{Ea}{B} \left(\frac{1}{T_1} - \frac{1}{T_1}\right) \qquad (6)$$

Multiply equation (G) by -1

$$\ln \frac{k_2}{k_1} = \frac{-Ea}{B} \left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad (7)$$

7.1.2 Rationale for Normal Thermal Aging (continued)

Assuming the reaction rate is constant at a given temperature, then t_1 and t_2 may be substituted for the reaction rates at those temperatures.

$$\ln \frac{t_2}{t_1} = \frac{-Ea}{B} \quad \frac{1}{T_1} - \frac{1}{T_2} \qquad (8)$$

$$\frac{t_2}{t_1} = \exp \quad \frac{-Ea}{B} \quad \frac{1}{T_1} - \frac{1}{T_2} \qquad (9)$$

$$t_2 = \exp \quad \frac{-Ea}{B} \quad \frac{1}{T_1} - \frac{1}{T_2} \quad t_1 \quad .$$

$$= t_1 \exp \quad \frac{-Ea}{B} \quad \frac{1}{T_1} - \frac{1}{T_2}$$

The aging time required (t_2) at T_2 may be calculated based upon knowledge of the activation energy Ea and the desired qualified life (t_1) at T_1.

The aging time has been calculated for each component based upon the lowest activation energy found for materials in that device, and a table of these values follows the sample calculation.

7.1.3 Aging Analysis

NOTE: Each module was evaluated using activation energy to determine the lowest value or weak link. The module was then aged to end of life condition base upon the lowest, most conservative,

7.1.3 Aging Analysis (continued)

activation energy. Components in the module that were not judged to be the weak link were exposed to the same thermal aging and mechanical cycling as the weak link component.

The qualified life for each module is limited by the qualified life of the weak link.

The components contained in the test item may consist of various materials. The weak link approach dictates that we select a component with the lowest activation energy and apply the Arrhenius equation to determine an appropriate aging time based on a desired qualified life. From Appendix A the weak link material is the semiconductor material contained in the electronics components (Ea = 1.0). It should also be noted that using the Arrhenius equation one can obtain the aging time required to simulate twenty (20) years service based on a 100°C aging temperature.

7.1.3 Aging Analysis (continued)

The following is a sample calculation:

$$t_2 = t_1 \exp\left[\frac{-Ea}{B}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

Where:

Ea = Activation energy of the semiconductor devices (1.0 eV)

B = Boltzmann's Constant (8.617×10^{-5})

T_2 = Aging temperature = 100°C = 373°K

T_1 = Environmental temperature being simulated

t_1 = Duration at T1 (see table below)

t_2 = Required aging time

exp [x] = e^x

	NORMAL CONDITIONS	ACCIDENT CONDITIONS
T_1 (Env. Temp.)	51.5 (324.5°K)	60°C (333°K)
t (Duration)	175,200 hours	8760 hours

7.1.3 Aging Analysis (continued)

To simplify the aging calculations and all references to the service environmental temperature, a weighted average for the normal and accident temperatures was derived as follows:

$$T_1 = 51.5 \frac{175,200}{175,200 + 8,760} + 60 \frac{8,760}{175,200 + 8,760} = 51.9°C$$

In addition, the total service time being simulated (t_1) is hereafter defined as:

t_1 = 175,200 + 8,760 = 183,960 hours

Then:

$$t_2 = 183,960 \exp\left[\frac{-1.0}{8.617 \times 10^{-5}} \left(\frac{1}{324.9} - \frac{1}{373}\right)\right]$$

t_2 = 1,837.95 hours

Add 10% margin:

t_2 = 2,021.7 hours

Calculated by: William J. Lanier
William J. Lanier, Project Engineer

Reviewed by: N. J. Fredkin Jr.
N. J. Fredkin, Jr., Project Engineer

Report No. 16376

7.1.3 Aging Analysis (continued)

From this sample calculation, the semiconductor PC board components were aged for 2,022 hours to simulate twenty (20) years of service under normal conditions plus one (1) year of postulated accident condition with 10% margin.

In addition, several of the test items contain polymeric parts as well as relays and transformers which experience a temperature rise during operation.

The general strategy of the aging program, based on the activation energies found in Appendix A, was to age all components being qualified at 100°C for 2,072 hours. A sample of each item being qualified which had either a relay or a transformer (except the power supplies) was energized during aging. The coil rises seen would increase the qualified lives. As a backup, an identical sample of each energized item was aged at 100°C in a de-energized state. The qualified lives of the transformers and relays in these items were extended by aging spare transformers at 130°C and spare relays

7.1.3 Aging Analysis (continued)

at 120°C. The spare parts were installed into the backup units whenever a failure occurred in the energized units. All items were aged for 2,072 hours because this period of time was more than enough to fully qualify the electronic components and the time available to complete the aging program was limited because of scheduling problems.

Table VI lists all the fully assembled units originally supplied to Acton for qualification. Those items that were energized during aging are noted. Table VII lists the spare parts that were aged.

Several items were dropped from the program and qualified by similitude to other items. Other items were changed in terms of the options they contained so that a sample of each option would be tested. Table VIII contains a finalized list of all the items qualified by testing and all the qualified lives are based on this list. Justifications for those items not tested further are found in Section 11.0.

7.1.3 Aging Analysis (continued)

These qualified lives also take into account the aging analyses performed on all the capacitors. Qualification of the capacitors presents some unique considerations. The most significant aging/stress mechanisms are those which result from a combination of voltage stressing, ripple current, and in some cases thermal degradation of polymeric materials. No thermal aging program can properly address all of these stress mechanisms. This program addresses this problem by using manufacturers' data to establish a qualified life by analysis. Appendix D contains the manufacturers' data used and Table IX gives the qualified lives of the capacitors used in the program as derived from this data.

ACTON ENVIRONMENTAL TESTING

TABLE VI

AETC ITEM NO.	MODEL NO.	SERIAL NO.	DESCRIPTION		OPTION INCLUDED
18.	SC-1326-323-I-C	95448-7	Isolated RTD Transmitter	*	I, C
19.	SC-1372-323	9448-11	Isolated mV Transmitter	*	H1
20.	SC-1330-323	723614-3	Square Root Extractor	*	H1
21.	SC-1330-323	723614-4	Square Root Extractor		H1
25.	ET1214-H-323	95448-1	Voltage Alarm	*	H
26.	ET1214-323	95448-2	Voltage Alarm		-
27.	ET-1215-T2-323	95448-3	Voltage Alarm	*	T2
28.	ET-1215-323	95448-4	Voltage Alarm		-
29.	SC1302-323-H0	95448-5	Isolator Transmitter	*	H0
30.	SC1302-323	95448-6	Isolator Transmitter		H1
31.	SC1326-[illegible]23	95448-8	Isolator Millivolt Transmitter		H1
32.	SC-1326W-323-I1	95448-9	Isolated T/C Transmitter	*	I1
33.	SC-1326W-323	95448-10	Isolated T/C Transmitter		H1
34.	SC-1372-323	95446-12	Isolated RTD Transmitter		H1
35.	SC-1373-323-H3	723614-1	Dual Isolated RTD Transmitter	*	H3

* Energized during aging

Report No. 16376

ACTON ENVIRONMENTAL TESTING

TABLE VI
(continued)

AETC ITEM NO.	MODEL NO.	SERIAL NO.	DESCRIPTION	OPTION INCLUDED
36.	SC-1373-323-I1	723614-2	Dual Isolated RTD Transmitter	I1
37.	EI-4477	521104-W	Power Supply	-
38.	EI-4477	521104-X	Power Supply	-
39.	EI4481/EI4482	521104-U	Analog Isolator Chassis	-
40.-59.	EI4420	521104-A through 521104-T	Analog Isolators **	-
60.	EI4479	521104-Y	Power Supply	-
61.	EI4479	521104-Z	Power Supply	-

** Energized as noted below

Items Energized	Items Non-energized
40,41,51,52,53	42-50,54-59

Report No. 16376

831191

TABLE VII

SPARE COMPONENTS AGED

AETC NO.	MODEL NO.	DESCRIPTION	CONTAINED IN
1,2,3,72, 72A-C	MC2ED	Aromat Relay	ET1214 & ET1215
13,4,5,62, 62A,65	1041-045		HO Option
6,7,8,66, 66A-66G	1041-249	Tabtronics Transformer	SC1302, SC1326, SC1326W, SC1372, SC1373, SC1330
65A,9,11	1040-059		I1 Option
12,14	1024-610 (Same as 1041-058)		I Option
15,16,17	1016-336 (Same as 1041-050)	Tabtronics Transformer	H1, H2 Options
63,63A-63I	B1041-050 (Same as 1016-336)	Tabtronics Transformer	H1, H2 Options
10,64,64A	B1041-058 (Same as 1024-610)	Tabtronics Transformer	I Option
67A-D	1045-358	Tabtronics Transformer	H3 Option

Report No. 16376

TABLE VII
(continued)

SPARE COMPONENTS AGED

AETC NO.	MODEL NO.	DESCRIPTION	CONTAINED IN
68A,68B	1047-535	Tabtronics Transformer	EI-4477
69,69A-G	1049-139	Tabtronics Transformer	SC1372, ET1214, ET1215, SC1330, SC1373
70,70A-70H	1048-128	Tabtronics Transformer	EI4420
71,71A	503277	Power One Transformer	EI4479
73,73A	MRRN1A	Struthers-Dunn Relay	EI4479

TABLE VIII - LIST OF ITEMS QUALIFIED THROUGH TEST

TC ITEM NO.	DESCRIPTION	UNIT QUALIFIED LIFE	LIMITING COMPONENT ACTIVATION ENERGY	OPTION INCLUDED	MAINTENANCE ITEMS: ITEM	TEMP RISE OR LIMITING COMPONENT	QUALIFIED LIFE (YEARS)
18	SC-1326-323-I-C	11.79 years	PVC (Wire)* 0.88eV	I, C	a) C1 b) C4, C5, C14, C16	Electrolytic	a) 18.10 b) 18.10
19	SC-1372-323-I-1, Isolated Transmitter	11.79 years	PVC (Wire)* 0.88eV	I1	C1	Electrolytic	18.10
20	SC-1330-323	11.79 years	PVC (Wire)* 0.88eV	H1	a) Transformer (1049-139) b) C1 c) C3, C1, C9, C7	PVC Wire Insulation Electrolytic Electrolytic	a) 11.79 b) 18.10 c) 18.10
27	ET1215-T2-323	11.79 years	PVC (Wire)* 0.88eV	T2 H1	a) Transformer (1049-139) b) C1 c) C4 d) C101, C104, C105 (HO Option)	PVC Wire Insulation Electrolytic Electrolytic Electrolytic	a) 11.79 b) 18.10 c) 18.10 d) 9.06
29	SC-1302-323-HO	11.79 years	PVC (Wire)* 0.88eV	HO	a) Transformer (1044-249) b) C1 c) C4, C5, C14 C16	PVC Leads Electrolytic Electrolytic	a) 11.79 b) 18.10 c) 18.10
32	SC-1326W-323-I1	11.79 years	PVC (Wire)* 0.88eV	I1	a) C1 b) C4, C5, C6, C14, C16	Electrolytic Electrolytic	a) 18.10 b) 18.10

*RIS has indicated that they will replace these wires in the design with irradiated X-linked polyethylene to increase the qualified life of these units to 20 years.

TABLE VIII - LIST OF ITEMS QUALIFIED THROUGH TEST (continued)

AETC ITEM NO.	DESCRIPTION	UNIT QUALIFIED LIFE	LIMITING COMPONENT ACTIVATION ENERGY	OPTION INCLUDED	MAINTENANCE ITEMS: ITEM	MAINTENANCE ITEMS: TEMP RISE OF LIMITING COMPONENT	MAINTENANCE ITEMS: QUALIFIED LIFE (YEARS)
35	SC 1373-323-H3	11.79 years	PVC (Wire)* 0.88eV	H3	a) Transformer (1049-139 & 1044-358) b) C1 c) C19	PVC Wire Insulation Electrolytic Electrolytic	a) 11.79 b) 18.10 c) 18.10
37, 38	EI 4477 Power Supply	20 years	Electronics (1.0eV)	--	a) Fuse Holder b) C1 c) C2 d) Transformer	Limited by .96eV activation energy 22.09°C 1.31°C PVC Leads	a) 17.00 b) 1.71 c) 7.24 d) 11.79
39	EI4481/EI4482 Chassis Assembly	20 years	Nylon Terminal Block (1.0eV)	--			
42, 45, 53, 55	EI4420 Analog Isolators	20 years	Electronic Components (1.0eV)	--			
60, 61	EI4479 Power Supply	20 years	Electronics (1.0eV)	--	a) Transformer (Power One) b) C1 c) C2 d) C5 e) Terminal Blocks f) C4	44.20°C Electrolytic Electrolytic Electrolytic Phenolic (0.96 eV) Electrolytic	a) 16.10 b) 3.61 c) 1.13 d) 2.26 e) 17.00 f) 9.06

* RIS has indicated that they will replace these wires in the design with irradiated x-linked polyethylene to increase the qualified lives of these units to 20 years.

7.1.4 Capacitor Life Analysis

The primary failure mechanism for electrolytic capacitors over a long period of time is loss of electrolyte due to evaporation. As more and more electrolyte is lost, the capacitance is reduced and the equivalent series resistance (ESR) increases. Eventually one or both of these properties reaches an intolerable level.

One parameter that will accelerate this process is an increase in temperature. In this situation, the 10°C rule is applicable. This rule states that every 10°C increase in the environmental temperature will cut the capacitor life in half. There are two parameters that will dictate the effective environmental temperature. One is the temperature of the surrounding environment and the other is the heat generated by ripple current.

This analyis was based on manufacturer's data and an agreed upon acceptance criterion. This yielded a specific life at a specific temperature. The acceptance criteria was a 20% change in capacitance or a change in

ACTON ENVIRONMENTAL TESTING

7.1.4 Capacitor Life Analysis (continued)

the ESR that would result in an increase in the power dissipation of the capacitor above its rated power dissipation capability. In no case, however, will a change in ESR greater than 50% be acceptable.

The first step in the analysis was to determine the temperature rise due to ripple current. This was done using the following relationship.

$$T = I^2(ESR)/KA$$

Where:

T = The temperature rise at the core (°C)
I = Measured ripple current in amperes
ESR = Equivalent Series Resistance (ohms)
K = Core constant equal to 0.006W-in²/°C (ref. 2.8 in Section 2.0)
A = Case area (in²)

An example calculation would be as follows:

Capacitor Manufacturer, P/N: CDE, WBR 100-150
Used In: EI4477 Power Supply
Measured Ripple Current: 0.113 Amps

Case Area = $\pi DL + 2\pi\, D^2/4 = \pi(.760)(1.723) + 2\pi \frac{(.760)^2}{4} = 5.02\ In^2$
ESR (from mfr's data): 3.1Ω
$T = (.113)^2(3.1)/(.006)(5.02) = 1.31°C$

Calculated by: William J Lanier
William J. Lanier, Project Engineer

Reviewed by: N. J. Fredkin
N. J. Fredkin, Jr., Project Engineer

Report No. 16376

Rev. 1

7.1.4 Capacitor Life Analysis (continued)

The next step in the analysis is to determine the acceptance criteria and aging characteristics based on manufacturer's data. From data found in Appendix D a similar capacitor (WBR500-50) retains 87.3% its capacitance at the end of 7000 hours at 85°C. This time period will be considered to be the qualified life at 85°C even though the capacitance is still above the mandatory 80%, because there is no test data beyond this point.

The final step in the analysis is to determine the qualified life using all of the parameters discussed above. This is done by using the 10°C rule as follows (This is justified in Reference 2.8 in Section 2.0).

$$t_2 = t_1 2^{(T_1 - T_2)/10}$$

Where:

t_2 = Qualified Life at T_2
t_1 = Life derived through test data at T_1 = 7000 hrs.
T_1 = Test Temperature in mfr's data = 85°C
T_2 = Environmental Service Temperature + Temperature Rise = 51.9 + 1.31°C = 53.21

$$t_2 = 7000 \times 2^{(85-53.21)/10} = 63397.50 \text{ hrs} = 7.24 \text{ yrs.}$$

Calculated by: *William J. Lanier*
William J. Lanier, Project Engineer

Reviewed by: *N.J. Fredkin*
N. J. Fredkin, Jr., Project Engineer

Table IX tabulates the qualified lives given to the capacitors used in the test samples.

TABLE IX - CAPACITOR LIFE ANALYSIS

MANUFACTURER & MFR'S P/N	RIS P/N	RIS DESIG-NATION	USED IN	CAPACITOR VALUE	DC VOLTS ACROSS CAP	RIPPLE CURRENT (AMPS)	CASE AREA (in²)	ESR AT 120 Hz (Ω)	TEMP. RISE FROM RIPPLE CURRENT (°C)	RATED LIFE AT ____ °C	QUALIFIED LIFE (YEARS)
Mallory TCX102U040L1L	1044-239	C1	SC-1302, SC-1326, SC-1326W, SC-1330, SC-1372, SC-1373, ET-1214, ET-1215	1000μF 40V	26 V	0.173 (Note 1)	6.1	0.078	0.67	4000 Hrs @ 105°C	18.10
Sprague 672D476H025CC5C	1044-244	C2 C2,C18	SC-1326, SC-1326W SC-1302	47μF 25V	15 V	0.002 (Note 2)	1.146	2.35	0.001	6250 Hrs @ 105°C	23.77
Illinois 107THA-PX025A	1044-262	C4,C5 C3 C4	SC-1302, SC-1326, SC-1326W SC-1330 ET-1214, ET-1215	100μF 25V	14 V	0.007 (Note 2)	1.464	2.25	0.0125	1000 Hrs @ 125°C	18.10
Illinois 335THA-100APX	1049-135	C16	SC-1302, SC-1326, SC-1326W	3.3μF 100V	23 V (49 when used with HO Option)	Negli-gible	.8708	1.32	Negli-gible	1000 Hrs @ 125°C	18.10
Illinois 105THA-100APX	1049-137	C14	SC-1302, SC-1326, SC-1326W, SC-1330	1MF 100V	23 V	Note 3	.779	132.7	Note 3	1000 Hrs @ 125°C	18.10

TABLE IX - CAPACITOR LIFE ANALYSIS
(continued)

MANUFACTURER & MFR'S P/N	RIS P/N	RIS DESIG-NATION	USED IN	CAPACITOR VALUE	DC VOLTS ACROSS CAP	RIPPLE CURRENT (AMPS)	CASE AREA (In^2)	ESR AT 120 Hz (Ω)	TEMP. RISE FROM RIPPLE CURRENT (°C)	RATED LIFE AT ____ °C	QUALIFIED LIFE (YEARS)
Illinois 225THA-PX100A	1045-357	C9 C19	SC-1330 SC-1372, SC-1373	2.2µF 100V	23 V (49 when used with HO Option)	Note 3	.701	60.3	Note 3	1000 Hrs @ 125°C	18.10
Illinois 475THA063APX	1049-138	C7	SC-1330	4.7µF 63V	5 V	Note 3	.779	26.3	Note 3	1000 Hrs @ 125°C	18.10
Illinois 476RMR050MPX	1049-136	C101, C104, C105	HO Option	47µF 50V	25 V	0.004	0.604	2.82	0.012	2000 Hrs @ 105°C	9.06
Sprague 672D156H06CD5C	1045-514	C100	I1 Option	15µF 60V	33 V	0.023	1.228	7.0	0.502	5250 Hrs @ 105°C	22.96
CDE WBR-3000-35	1046-862	C1	EI-4477	3000µF 35V	24 V	2.920	9.649	0.15	22.09	7000 Hrs @ 85°C	1.71
CDE WBR-100-150	1046-861	C2	EI-4477	100µF 150V	125 V	0.113	5.02	3.1	1.31	7000 Hrs @ 85°C	7.24
Mallory CGS133U050V4C3PH	1050-284	C1	EI-4479	13000µF 50V	40 V	5.08	34.53	0.033	4.11	5000 Hrs @ 85°C	4.26
Nichicon ULB1E100M	1050-285	C2	EI-4479	10µF 25V	8 V	Note 3	0.329	1.132	Note 3	1000 Hrs @ 85°C	1.13
Illinois 227RMR016MPX	1050-282	C4	EI-4479	220µF 16V	8 V	Note 3	0.853	1.020	Note 3	2000 Hrs @ 105°C	9.06
United Chemi-Con SL35VB330	1050-287	C5	EI-4479	330µF 35V	24 V	Note 3	2.61	5.360	Note 3	2000 Hrs @ 85°C	2.26

ACTON ENVIRONMENTAL TESTING

Notes to Table IX

CAPACITOR LIFE ANALYSIS

1. This ripple current was measured by RIS personnel as part of the SC-1330-323. This value is assumed to apply to all locations where it is used because the other circuits result in similar application. (See Appendix E).

2. This ripple current was measured while installed in the SC-1302-323-HO. (See Appendix E). This value is also assumed to be applicable in all other applications in this report because they are all similar.

3. The ripple current was not measured because the capacitor is located in a signal circuit rather than in a power circuit so it does not see any significant amount of ripple current. The measurements taken of many of the capacitors in the SC-1302-323-HO tend to support this assumption. Because of this, the temperature rise associated with ripple current is also assumed to be negligible.

Report No. 16376

ACTON ENVIRONMENTAL TESTING

7.2 Mechanical Aging

Relays are electromechanical devices and as such, have two (2) basic factors that contribute to their aging. The first is deterioration of a resource factor (h) with time as a result of electrical and thermal stresses. The second is a fatigue-related factor of cyclic stresses on the mechanical system. The aging methods used for these types of devices consisted of cycling the devices a specified number of actuations to simulate normal operations.

The mechanical aging program used was based on a maximum number of actuations with a maximum load. The following table details the aging program used.

ITEM NO.	DESCRIPTION	CONTAINED IN	NO. OF CYCLES	LOAD
1,2,3,72, 72A-C (Aged at 120°C)	Aromat NC2ED Relay	ET1214,ET1215	2300	5A @ 20 VDC
			5730	2.5A @ 25 VDC
73,73A (Aged at 120°C)	Struthers-Dunn MRRN1A Relay	EI4479 Power Supply	2300*	0.5A @ 24 VDC
Original Relays (Aged at 100°C)			520	150mA @ 30 VDC

Only one set of contacts were loaded during cycling of the relays.

*These relays were also aged an indeterminate number of cycles with a 0.25A load before they failed. Failure occurred before 1080 cycles at 0.25A.

7.3 Radiation Aging

Radiation aging was performed in two stages. During the first stage, the test items that were still considered to be in the program as well as the spare transformers were irradiated to a TID (gamma) of 3.0×10^5 rads.

Some of the electronics components failed in a number of the test items and replacement parts were subsequently irradiated to a TID of 1.15×10^4 rads.

Table X lists the items that were irradiated to a TID of 3.0×10^5 rads and Table XI lists the items irradiated to a TID of 1.15×10^4 rads.

Radiation aging was conducted at Isomedix, Inc. The test items were exposed to the levels shown in Tables X and XI. Halfway through the exposure, the test items were rotated 180° to give a more uniform dose distribution and eliminate any shielding problems resulting from test item geometry. The test item temperature was also monitored and did not exceed 100°F during the exposure.

7.3 Radiation Aging (continued)

Dosimetry was performed using a Harwell Red 4034 Perspex dosimeter, utilizing a Bausch and Lomb Model 710 spectrophotometer as the readout instruments. The dosimetry system is calibrated directly with NBS.

The irradiation was conducted in air at ambient temperature and pressure for the facility. Radiant heat from the source was determined to impose less than a 30°F temperature rise (air), as indicated by previous measurements on an oil solution in the same relative position.

TABLE X

ITEMS IRRADIATED TO 3 x 10^5 RADS

ITEM NO.	QUANTITY	TYPE NO.	DESCRIPTION
20	1	SC-1330	Square Root Extractor
4,5,10-14,62, 62A,64,64A	11	N/A	Transformers
70A,C,D,E,F,H	6	N/A	Transformers
33,33 from 1326W	2	N/A	Transformers
63A,B,C,G,H,I	6	N/A	Transformers
16,17	2	N/A	Transformers
67A,B,C,D	4	N/A	Transformers
39, 40-59	21	N/A	Analog Isolator/ Plus All PC Boards
27, 28	2	ET 1215	Dual Duplex Current/ Voltage Alarms
18	1	SC-1326	Isolated Millivolt Transmitter
33	1	SC-1326W	Isclated Millivolt Transmitter
29	1	SC-1302-HO	Isolator Transmitter

Report No. 16376

TABLE X
(continued)

ITEM NO.	QUANTITY	TYPE NO.	DESCRIPTION
36	1	SC-1373	Dual Isolated RTD Transmitter
19	1	SC-1372	Isolated RTD Transmitter
42	1	EI 4420	Analog Isolator
53	1	EI 4420	Analog Isolator
55	1	EI 4420	Analog Isolator
45	1	EI 4420	Analog Isolator
37, 38	2	EI 4477	Power Supply
60, 61	2	EI 4479	Power Supply

ACTON ENVIRONMENTAL TESTING

TABLE XI

ITEMS IRRADIATED TO 1.15 x 10^4 RADS

ITEM NO.	TYPE NO.	DESCRIPTION	CONTAINS SPARE PARTS FOR:
30	N/A	P.C. Board from SC-1302 Signal Transmitter	Item No. 29, SC-1302-HO
31	N/A	P.C. Board from SC-1326 Signal Transmitter	Item No. 18, SC-1326
32	N/A	SC-1326W Signal Transmitter	---
24	N/A	HO Option Board	Item No. 29, SC-1302-HO
35	N/A	SC-1373 Dual Isolated RTD Transmitter	---
34A	LM337T	Voltage Regulator from SC-1372 (Item No. 34)	---
34B	4N36	Optical Coupler from SC-1372 (Item No. 34)	---

As a result of this program, Items 18, 19, 29, 32, and 35 are qualified to a TID of 1.0 x 10^4 rads and all other items are qualified to a TID of 2.7 x 10^5 rads. These figures take margin into account. Section 10.0 provides more details concerning the components that failed and were replaced in each unit. Radiation certificates are found in Appendix A.

8.0 SEISMIC TESTING

The purpose of this test was to subject the components described in Section 3.0 of this test report to seismic vibration testing (as specified below) to determine their ability to withstand such vibration without evidence of mechanical damage, deterioration, or loss of its ability to perform Class 1E functions during and after the simulated seismic event. Because of the number of test items involved, these items were tested in three (3) groups.

8.1 Test Mounting

The items specified in Section 3.0 were mounted in three (3) groups to a test fixture fabricated from structural steel as shown in the sketches in Appendix H. Each test item was mounted in its vertical position to simulate its most likely field mounting configuration. The mounting fixture was rigid and without resonances up to 33 Hz. This was verified by a resonance survey (see Paragraph 8.4). The test fixture was then securely attached to a dependent biaxial table which resulted in equal horizontal and vertical components.

8.2 Test Monitoring

All test components were energized in a manner which simulated as closely as possible normal operating conditions. The system output signals/alarms were monitored along with output relay contacts for chatter on visicorder tape which is supplied with this report. Figures 8 through 16 are schematics which detail the monitoring setups used.

8.3 Test Conditions

The seismic test was run at ambient temperature and pressure for the test facility.

8.4 Resonance Survey

A resonance survey was conducted for the test fixtures with attached test samples. The purpose of the test was to demonstrate and verify the rigidity of the fixture/test item system. The test consisted of a dependent biaxial sinusoidal input with peak horizontal and vertical accelerations of 0.2g at frequencies from 1 to 40 Hz swept at a rate of one octave-per-minute. One biaxial group of accelerometers was mounted on the test fixture to monitor input levels. Accelerometers were also mounted on the test fixture at appropriate points to monitor the response to vibration. Data from all accelero-

ACTON ENVIRONMENTAL TESTING CORPORATION

BY ____________ DATE ____________
CHKD. ____________ DATE ____________
JOB NO. ____________

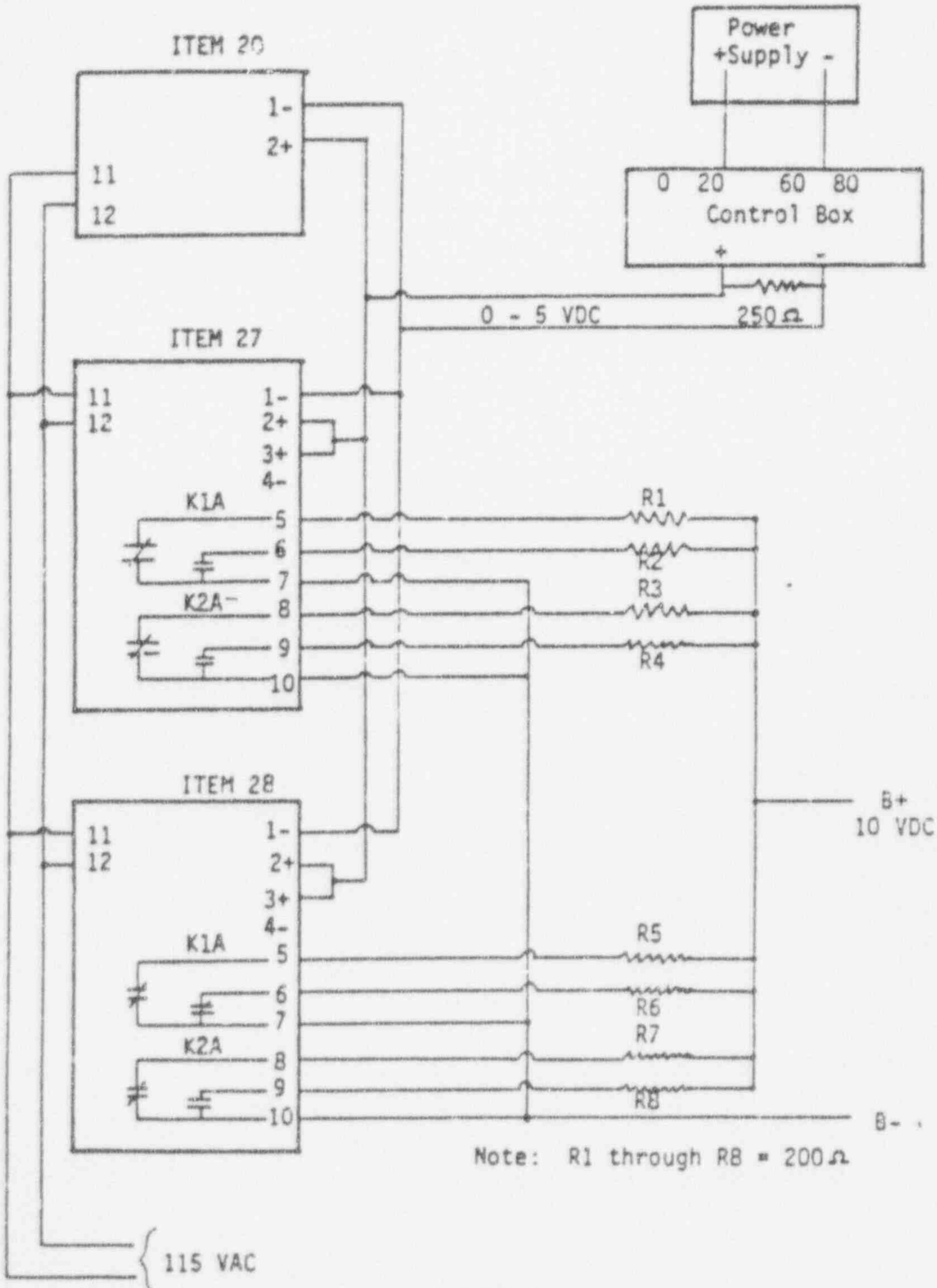
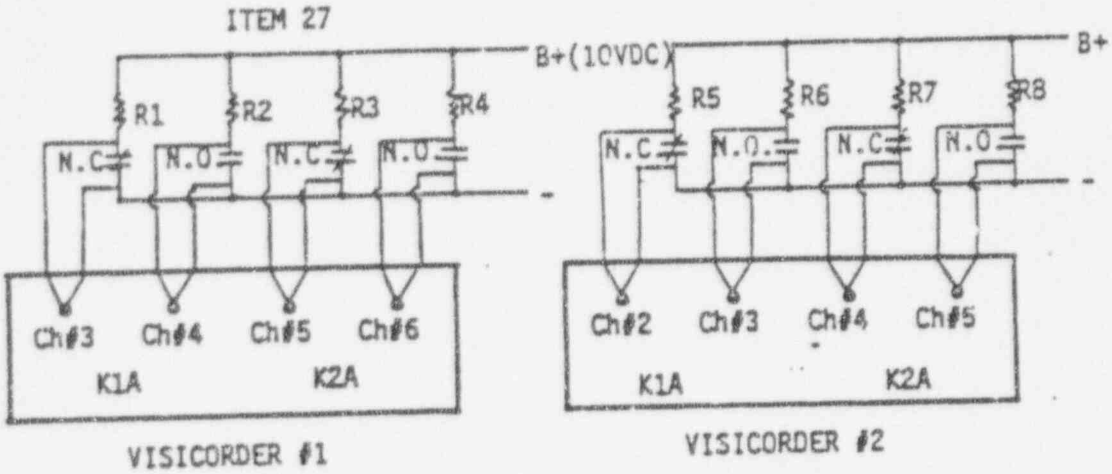


FIGURE 8

POWER SUPPLY CONNECTIONS



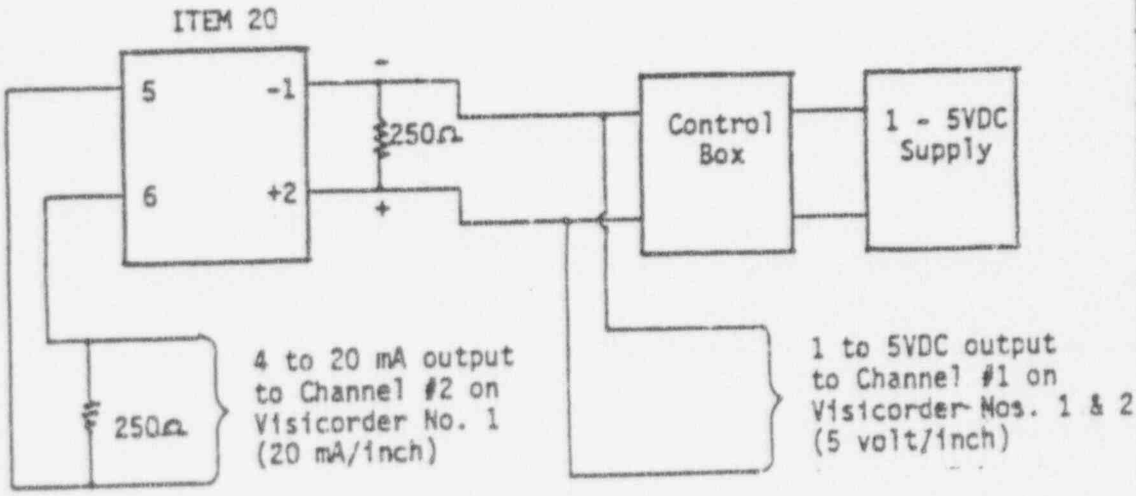


FIGURE 9
MONITORING SETUP

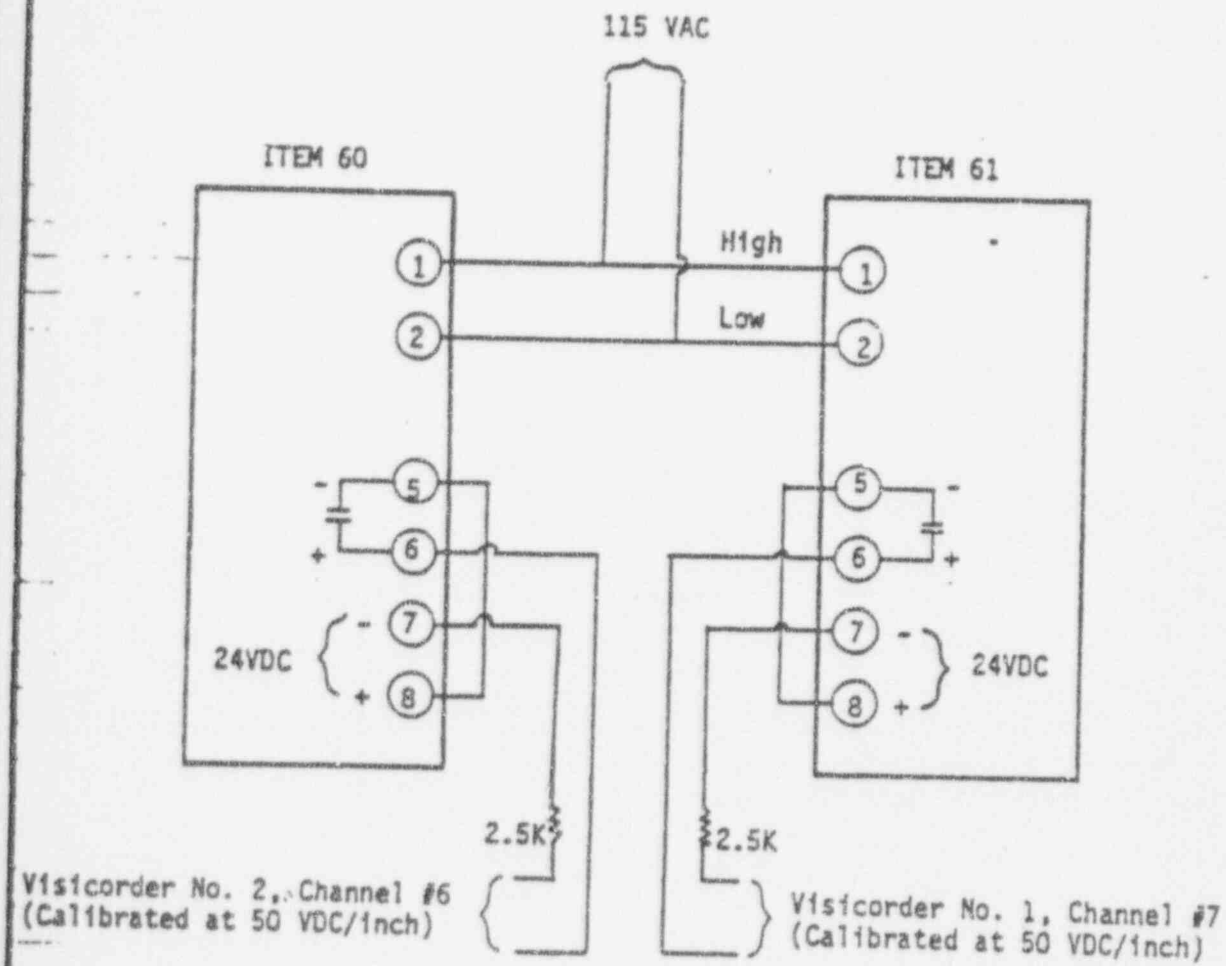


FIGURE 10
MONITORING SETUP

ACTON ENVIRONMENTAL TESTING CORPORATION

BY ______ DATE ______
CHKD. ______ DATE ______
JOB NO. ______

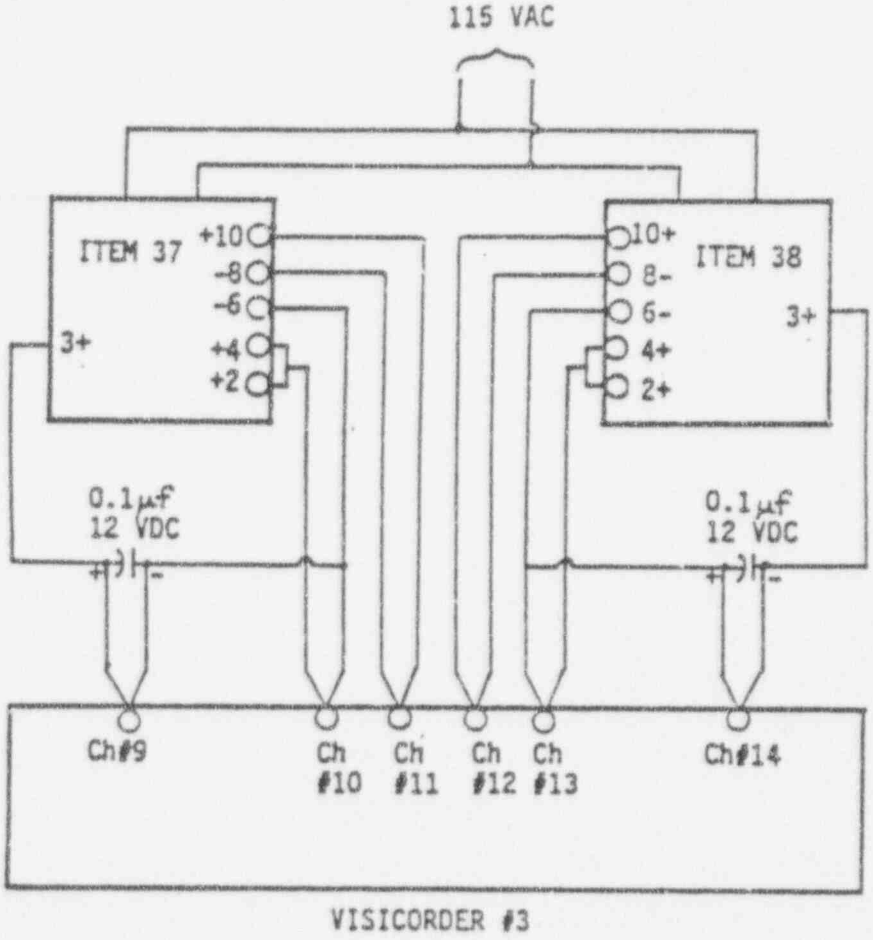


FIGURE 11
MONITORING SETUP

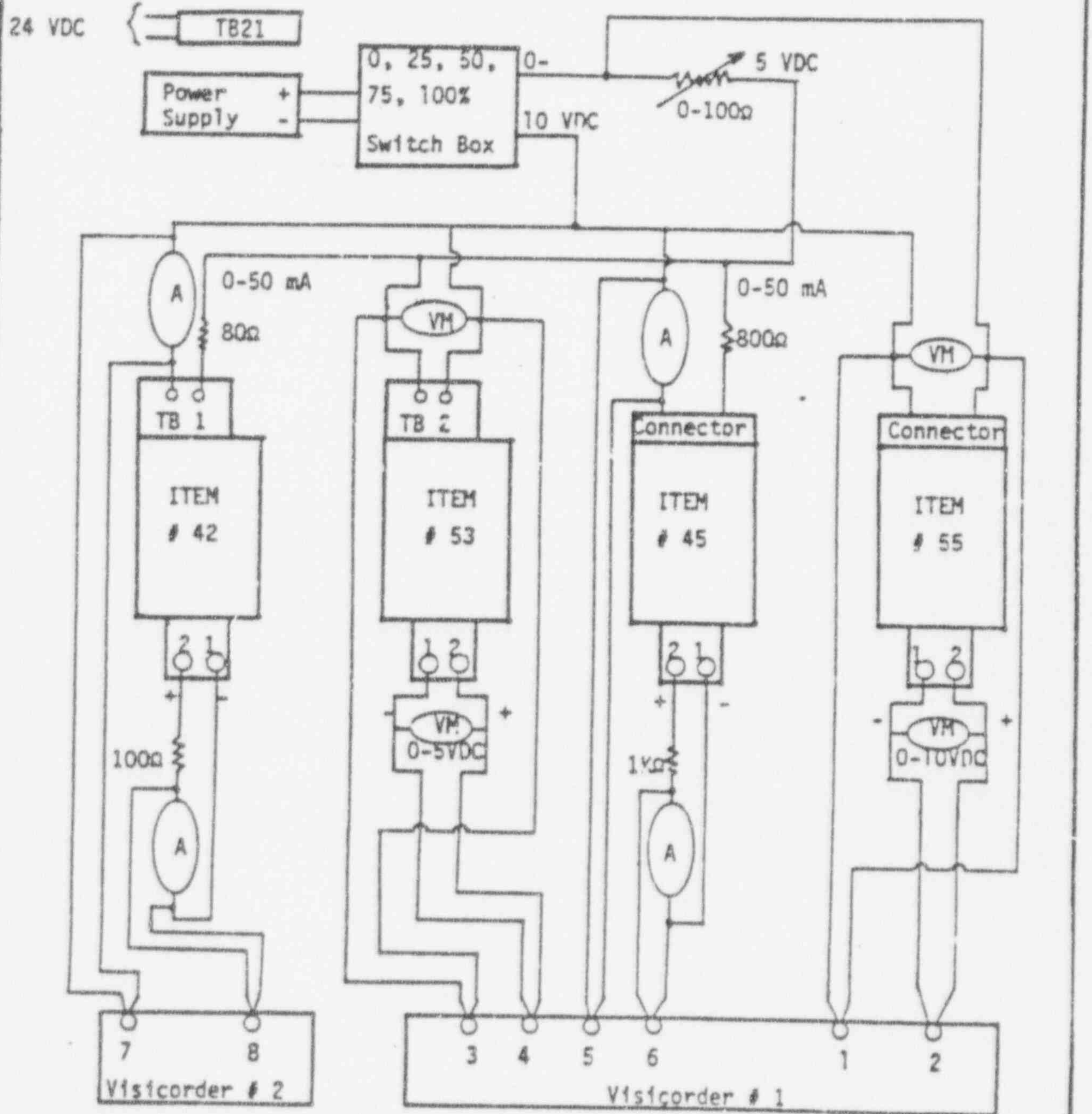


FIGURE 12

MONITORING SETUP

Report No. 16376

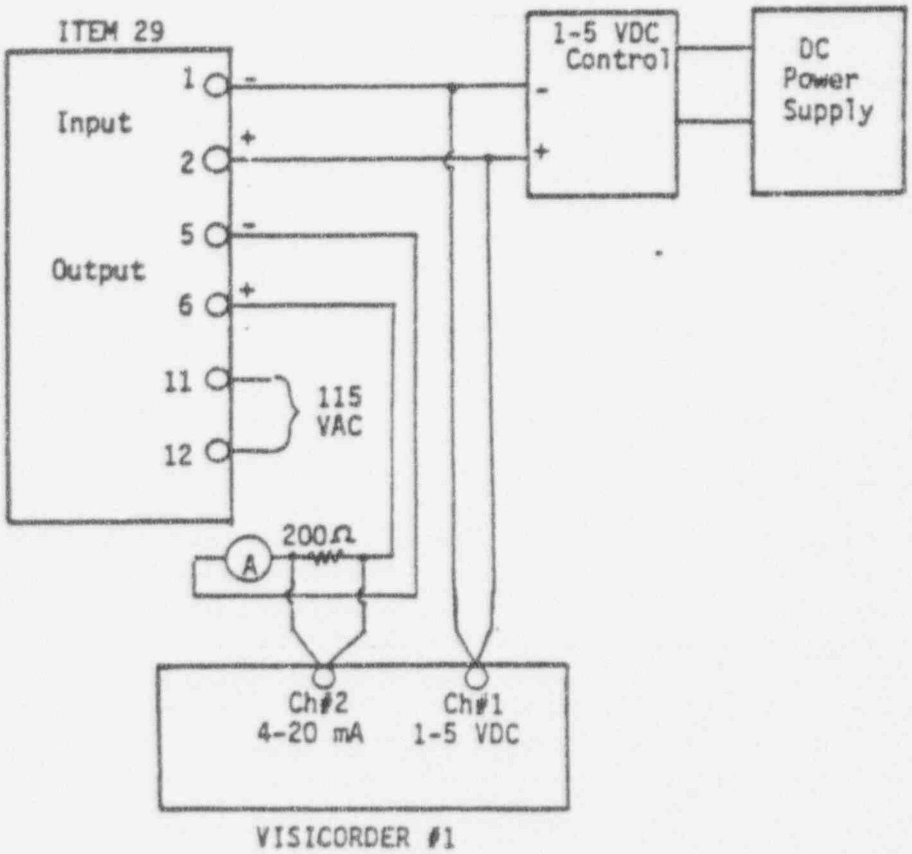


FIGURE 13

MONITORING SETUP

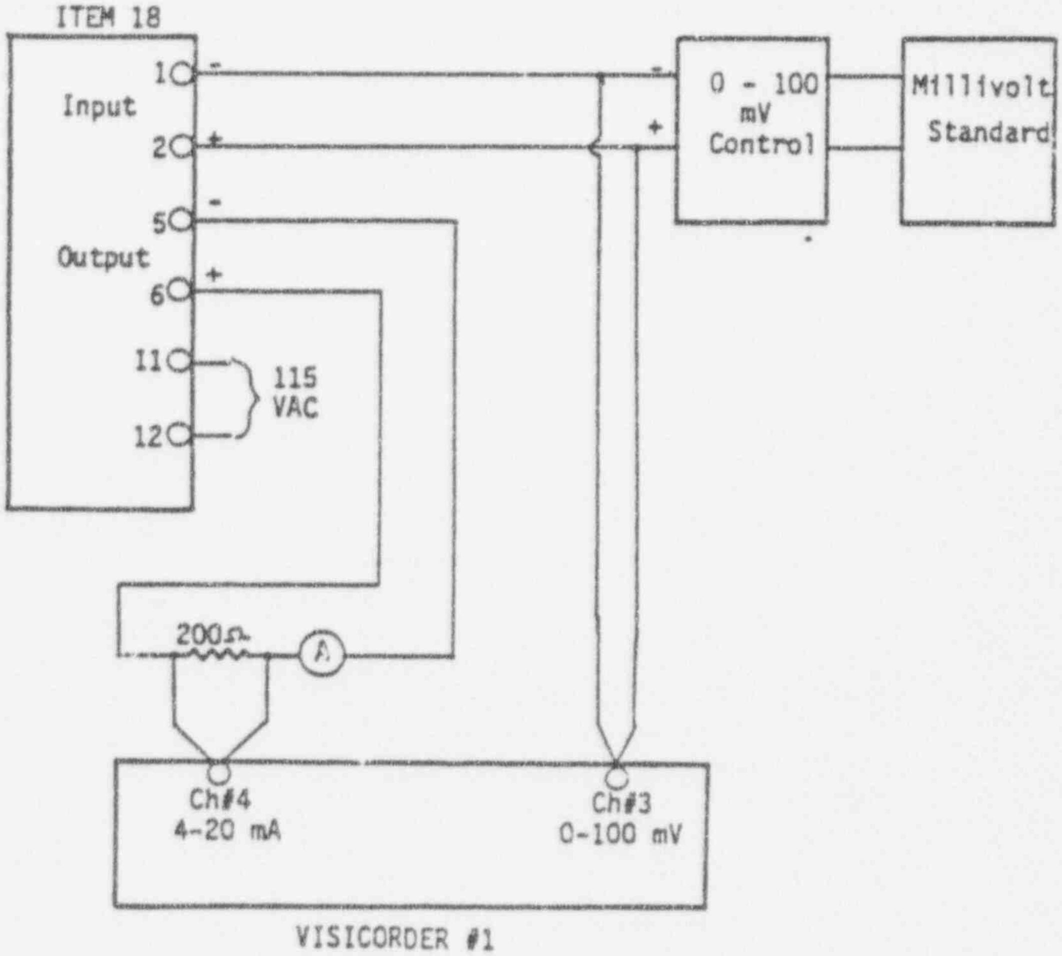
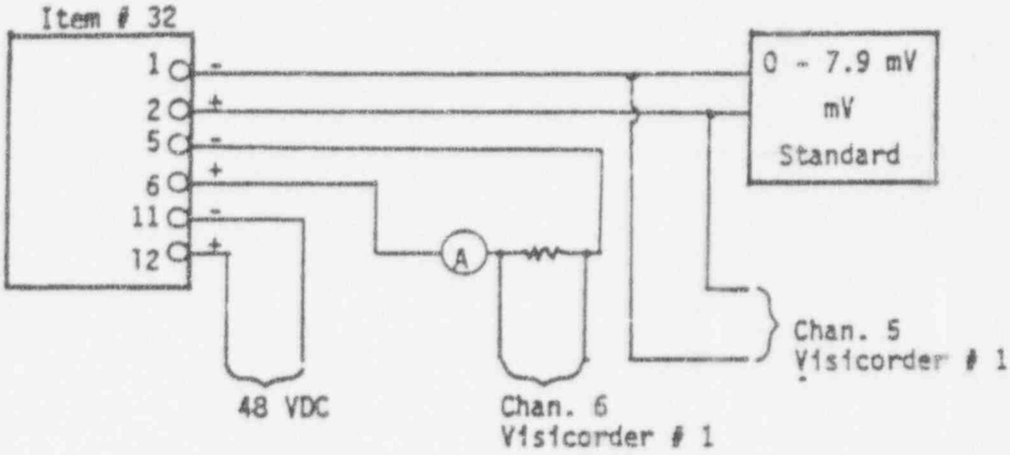


FIGURE 14
MONITORING SETUP



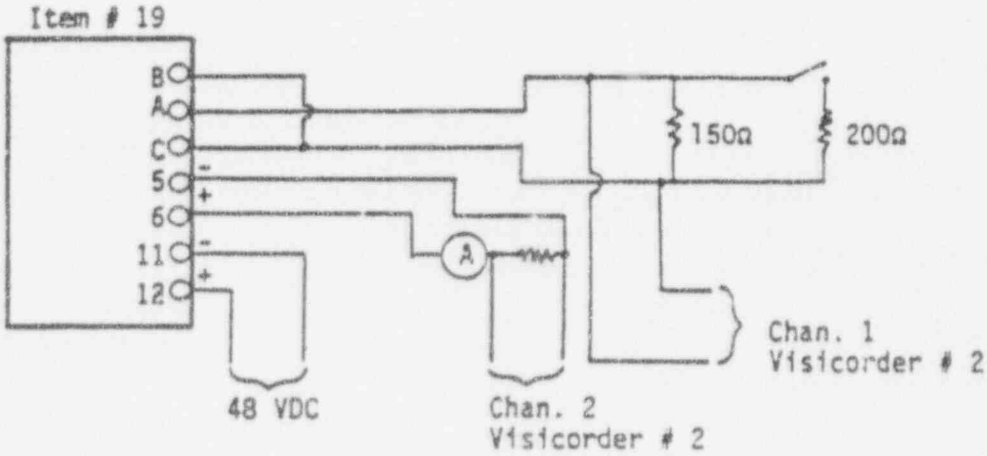


FIGURE 15

MONITORING SETUP

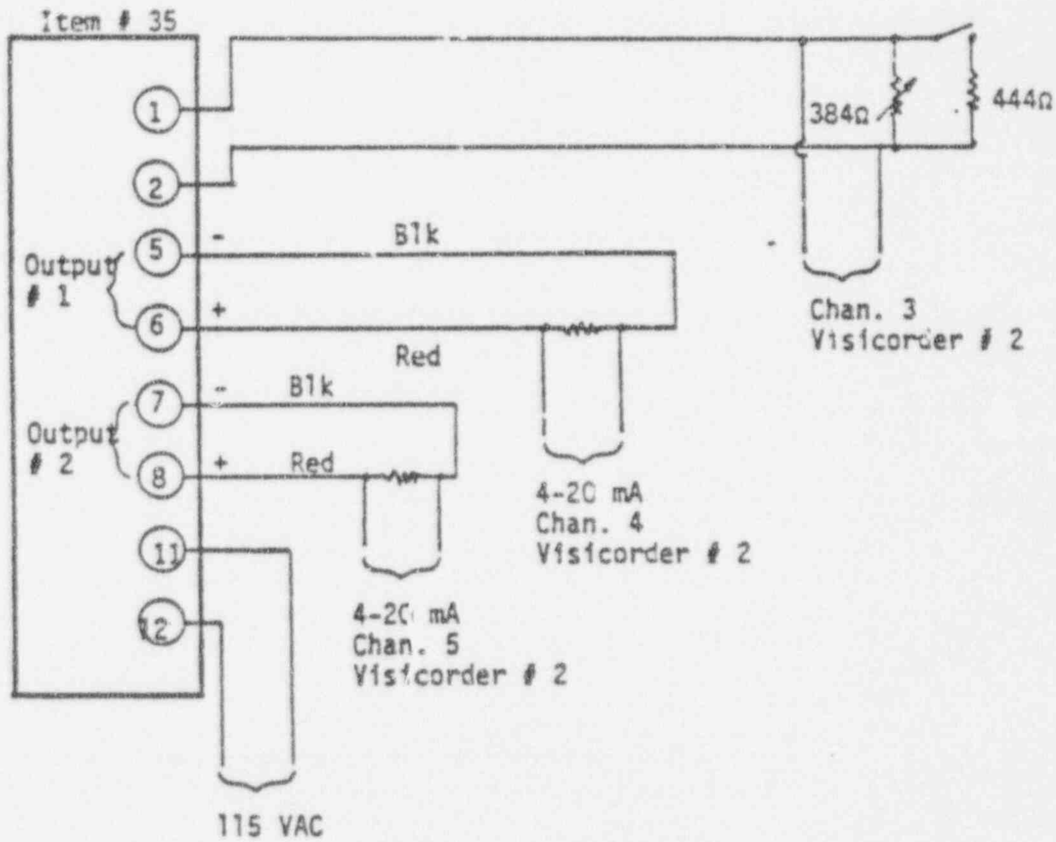


FIGURE 16

MONITORING SETUP

Report No. 16376

8.4 Resonance Survey (continued)

meters was processed through appropriate signal conditioning and recorded on an oscillographic recorder device. The recorder output is included with this test report. No resonances were found.

8.5 Multiple Frequency Test

A dependent biaxial multiple frequency excitation was applied. The test input was recorded on a 14-channel tape recorder, each track having discrete frequency sine beats recorded at a different frequency and delay between beats. All frequencies were recorded at maximum levels.

The input was played back through a 14-channel tape recorder. The outputs of the 14 channels were then combined in a 14-channel mixer which resulted in a multiple frequency output. The individual mixer channels had gain controls so that the level of each output tape channel passing through the mixer could be controlled. In this manner, the required test spectrum was shaped by controlling the level of individual frequencies in 1/3-octave intervals. Qualification tests, consisting of dependent biaxial periodic random excitation, 8.5 Multiple Frequency Test (continued)

were performed. The level of periodic random excitation was such that the Test Response Spectrum (TRS), from the control accelerometers, was shaped as shown in the curves in Appendix C. The curves all enveloped the curves shown in Figure 16A. The items received the input . (6) times in each of four (4) biaxial directions of excitation for a 30-second duration:

Right-to-left & vertical
Back-to-front & vertical
Left-to-right & vertical
Front-to-back & vertical

The level of the first five (5) inputs in each biaxial direction were designated as the OBE inputs and the sixth input was designated as the SSE input. The OBE levels are 2/3 of the SSE levels. Output from the control accelerometers was analyzed on line by a Spectral Dynamics SD321 shock spectrum analyzer in 1/3-octave intervals. The X-Y plots of the Test Response Spectra (TRS) from the control accelerometers are shown in Appendix C of this test report.

During testing of Group I the TRS plot for Run No. 4D (OBE) in the vertical direction was lost due to a faulty monitoring cable. Since the test was conducted on a dependent biaxial table and the other horizontal-vertical pairs of plots were roughly the same, it can be assumed that the horizontal plot generated for Run 4D is applicable to the vertical direction.

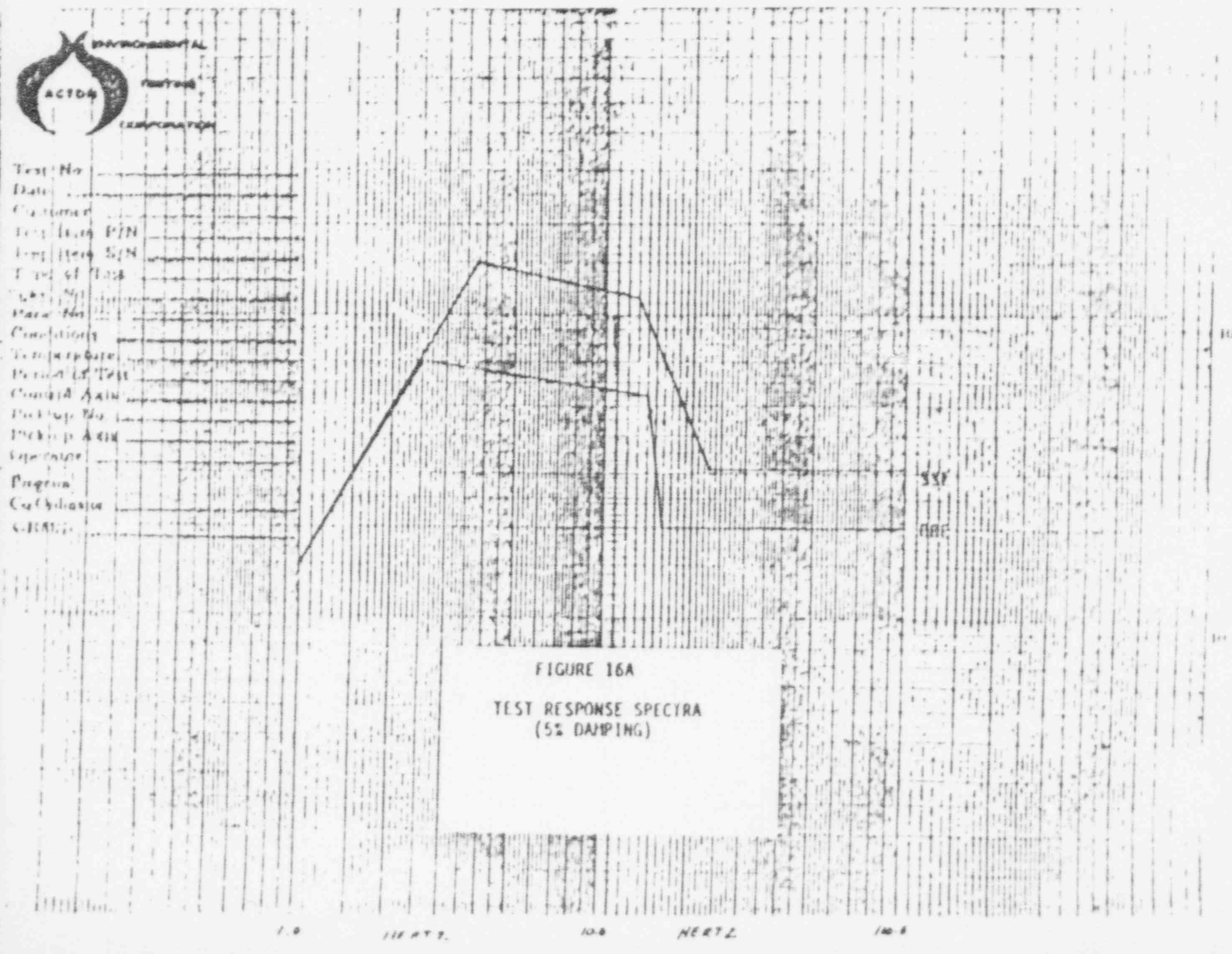


FIGURE 16A

TEST RESPONSE SPECTRA
(5% DAMPING)

9.0 HUMIDITY TEST

In order to demonstrate operability of the test items under postulated abnormal environment conditions (outside of containment) the test items were operated while subjected to a humidity test based on the environmental profile given in IEEE Std. 650-1979. The actual profile used is shown in Figure 17.

The humidity test was conducted as follows:

1. The chamber temperature and humidity were maintained at 140°F and 95 to 100% relative humidity for 21 hours. During this time the test items were energized with their nominal supply voltages. Steps 2 through 7 were performed while these conditions were maintained.
2. The input signal voltage to the ET-1215 was set at 2.5 VDC and the input signals to all the other units, except the power supplies, were set to ≈ 20% of full scale.
3. The output signals of all units, including the power supplies, were measured and the status of the alarm relays were monitored.
4. The input signal voltage to the ET-1215 was set to 4.5 VDC and the input signals to the other units, except the power supplies, were set to 80% of full scale.
5. The outputs of all units, except the power supplies, and the status of the alarm relays in the ET-1215 were monitored.
6. The supply voltages to the units were reduced to 90% of their nominal value and Steps 2 through 5 were repeated.

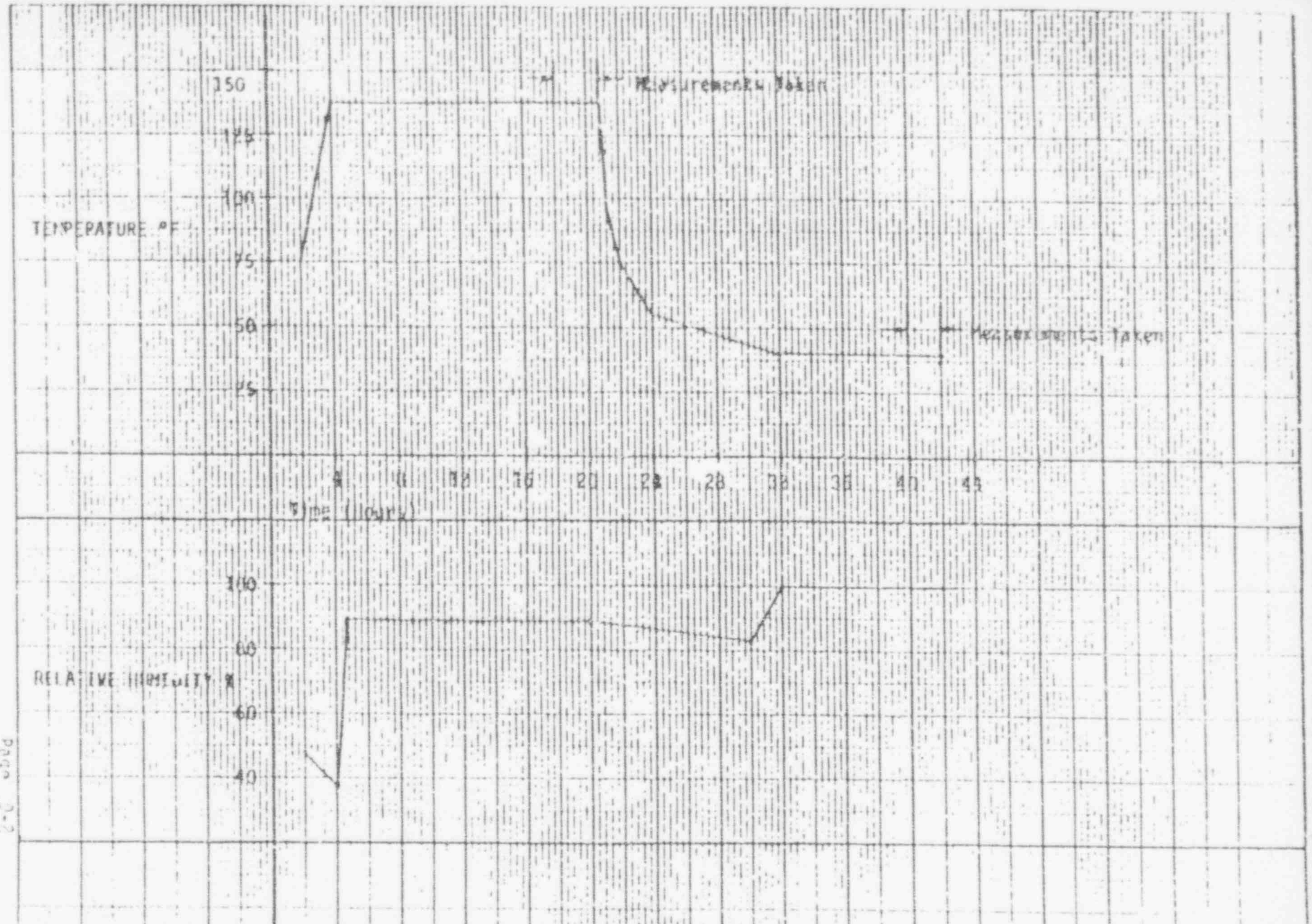


FIGURE 17 DBE PROFILE

9.0 HUMIDITY TEST (continued)

7. The supply voltages to the units were increased to 110% of their nominal value and Steps 2 through 5 were repeated.

8. The chamber temperature and humidity were maintained at 40°F and 95 to 100% relative humidity for 8 hours. During this time the units were supplied with their nominal voltages.

9. Steps 2 through 7 were repeated while these conditions were maintained.

During a lengthy (30 days or more) LOCA test, the normal way to justify a 1-year accident period would be to elevate the temperature during the test so that the balance of the accident period is justified using Arrhenius methodology. In order to use the same methodology for an outside of containment environment during the extremely short test time used in this program, however, it would have been necessary to operate the test items at temperatures far in excess of their design operating temperatures. This is especially true in the case of P.C. board components and other electrical components.

To operate this equipment under these conditions would have constituted a severe over-test, and for this reason this methodology was not used. Instead, this justification consisted of a

9.0 HUMIDITY TEST (continued)

two-phase alternative. The first phase consisted of simulating the degradation (chemical, mechanical, and radiation) that occurs during the entire accident period during the aging program. The second phase involved subsequent operation of the equipment under postulated DBE conditions. The cumulative effect of these two phases was to prove that the equipment could operate during the entire length of the accident period. This was accomplished because operability of the test item was demonstrated under DBE conditions after the equipment had seen the cumulative effects of the entire accident period. This approach is specifically recommended in IEEE Std. 650-1979.

ACTON ENVIRONMENTAL TESTING

10.0 TEST RESULTS

1. SC-1302-HO-323 (Item 29)

This unit, which was energized during aging, has a qualified life of 11.79 years with the exception of the maintenance items in Table VIII. The unit is also qualified for radiation dosage up to 1×10^4 rads (TID).

After the test item was irradiated to a TID of 3×10^5 rads, it was found to be inoperative. RIS personnel discovered that the two (2) LM337T voltage regulators and the four (4) VN10KM FET's were damaged due to the high radiation dose. To correct this problem it was decided to irradiate spare, identical aged voltage regulators and FET's to a TID of 1.15×10^4 (this includes margin) and derate the entire unit to a dose of 1×10^4 rads. To this end, the aged P.C. board from Item 30 and the unaged HO board were irradiated to a TID of 1.15×10^4 rads. The voltage regulators and FET's were removed after irradiation and installed in Item 29. (The unaged HO components are justified because they are identical to the components in Item 30 that were aged.) The unit was tested after being

10.0 TEST RESULTS (continued)

1. SC-1302-HO-323 (Item 29) (continued)

recalibrated and an anomaly occurred during the 2 VDC input-to-output linearity measurement. The measured output was 7.964 mA. The ±0.016 mA tolerance was not enough to bring this up to the nominal 8.000 mA requirement. Testing was continued per the customer's instructions and measurements showed that this particular data point drifted back into the range of acceptable limits during subsequent testing. Otherwise, the test item performed satisfactorily afterwards.

2. SC-1302-323 (with H1 Option)

This unit is qualified by similarity to the SC-1302-HO-323 and by the qualification tests performed on Item 21 which also contained the H1 Option.

3. SC-1326-I-C (Item 18)

This unit has a qualified life of 11.79 years with the exception of the maintenance items in Table VIII. The unit is also qualified to a TID of 1.0×10^4 rads.

After the unit was irradiated to a TID of 3.0×10^5 rads it was found to be inoperative. RIS personnel later discovered that the LM337T voltage regulators and the two VN10KM FET's were damaged due to irradiation. In order to

10.0 TEST RESULTS (continued)

3. SC-1326-I-C (Item 18) (continued)

produce a qualified unit, it was decided to irradiate the P.C. board from Item 31 to a TID of 1.15×10^4 rads and subsequently replace the damaged components in Item 18 with their counterparts from Item 31. After the unit was recalibrated it worked satisfactorily throughout the rest of the test program. It should be noted that prior to seismic testing, the RIS personnel removed Option C from Item 18 and installed it on Item 32 (SC-1326W-323-I1). This was done in order to facilitate testing of Item 32. Since Option C performed satisfactorily during the remainder of the test, and is mounted in an identical manner, Item 18 is also qualified with Option C.

It should also be noted that this unit needed to be recalibrated before and after humidity testing.

4. SC-1326-323-H1

This unit is qualified by similitude to Item 18. The same qualified life and radiation doses also apply. Option H1 is qualified by similitude to Option H1 test as part of Item 21.

10.0 TEST RESULTS (continued)

5. SC-1326W-323-I1 (Item 32)

This unit has a qualified life of 11.79 years with the exception of the maintenance items listed in Table VIII and is rated to a TID of 1.0×10^4 rads.

This unit, which was powered during thermal aging, failed during post-thermal aging tests (no output response to input signals) because a screw was loose on the terminal block at Terminal #4 inside the housing. This caused an open circuit at the terminal point which interfered with the output signal. Later, the loose screw was tightened by RIS personnel and the unit was immediately irradiated to a TID of 1.5×10^4 rads. Functional testing was not done prior to irradiation due to time constraints. Since the unit performed satisfactorily after irradiation and subsequent recalibration, by implication the unit operated satisfactorily before irradiation.

The unit performed well during seismic and humidity testing although it had to be recalibrated following seismic* and humidity testing.

*The unit was recalibrated by RIS and was not tested again by Acton prior to humidity testing.

10.0 TEST RESULTS (continued)

6. SC-1326W-323-H1 (Item 33)

After thermal aging this item passed all of its functional tests, including dielectric strength testing. Since this unit was not energized during thermal aging, the two 1044-249 transformers were replaced with Items 6 and 66. Both of these items failed dielectric strength testing after being installed in the unit. Items 8, 66A, and 66C-G were tested for dielectric strength outside the unit and all passed. ITems 69 and 69A-F were also tested since they were of similar construction. An RIS representative replaced Items 6 and 66 with Items 66C and 69B (Item 69B was used in error). Item 69B failed subsequent dielectric testing and was replaced with Item 69 (also in error). The unit worked satisfactorily after these changes were made.

After radiation aging, Items 69A, 69C-F, and Items 8, 66A and 66D-G were tested for dielectric strength and all passed.

It is believed that the installation process itself caused the failures seen by the transformers. This process was especially stressful considering that the transformer insulation was at its end-of-life condition. This theory is

10.0 TEST RESULTS (continued)

6. SC-1326W-323-H1 (Item 33) (continued)

further supported by the fact that the transformers that failed did so after being installed in the unit and one of them performed satisfactorily just prior to installation. In view of these circumstances, these failures are not considered to be common mode in nature, although special care should be taken during installation of the transformers during manufacturing.

After irradiation to a TID of 3.0×10^5 rads, the unit was inoperative because the LM337T voltage regulator and the two VN10KM FET's were damaged by radiation. At this point, Item 33 was dropped from the program and qualified instead to a lower TID (1.0×10^4 rads) by similiarity to Item 32. This unit is also assigned the same qualified life. It is qualified with Option H1 because Item 21, which also contained Option H1, was fully tested and qualified.

7. SC-1330-323-H1 (Item 20)

This test unit has a qualified life of 11.79 years, with the exception of the maintenance items listed in Table VIII, and is qualified to a dose of 3.0×10^5 rads TID.

10.0 TEST RESULTS (continued)

8. SC-1372-323-I1 (Item 19)

The test unit has a qualified life of 11.79 years, with the exception of the maintenance items listed in Table VIII, and is rated to a TID of 1.0×10^4 rads.

This unit failed during post-radiation functional tests (no response to input signals). RIS personnel discovered that one LM337T voltage regulator and 4N36 optical coupler were damaged from being irradiated to a TID of 3.0×10^5 rads. To correct this failure, an identical voltage regulator and optical coupler were removed from Item 34, irradiated to a TID of 1.15×10^4 rads and installed in Item 19 in place of the failed components.

In addition, Option I1 was removed from Item 36, irradiated to a TID of 1.15×10^4 rads and then installed into Item 19.

Prior to radiation, one of the replacement transformers (aged at 130°C), Item 9 was installed into the I1 board and was subsequently found to have an open primary. Item 65A was subsequently installed into the I1 board in place of

10.0 TEST RESULTS (continued)

8. SC-1372-323-I1 (Item 19) (continued)

Item 9 and the unit performed satisfactorily. It was also noted that an identical transformer (Item 11) and a similar transformer (Item 10) were tested for continuity at the pins. Both Items 10 and 11 had open primaries. This problem was caused by handling rather than aging. The connections between the transformer coils and the pins are all metal and extremely delicate. Since they did not receive any special handling, the spare transformers were especially vulnerable to damage. Since the original transformer in Option I1 worked well after thermal aging and the other Option I1 tested (from Item 32) worked well throughout the program, the problem can be attributed exclusively to being handled outside the unit. It is recommended that all units containing this type of transformer be tested prior to leaving the factory.

10.0 TEST RESULTS (continued)

9. SC-1372-323-H1 (Item 34)

Testing of this unit was terminated prior to irradiation because it was needed for spare parts. It is, however, qualified by similitude to Item 19. Option H1 is further qualified by similitude to the H1 option in Item 21 which was fully tested.

10. SC-1373-323-H3 (Item 35)

This unit has a qualified life of 11.79 years. The unit is also qualified to a TID of 1.0×10^4 rads.

The unit which was energized during thermal aging failed during post-thermal aging dielectric withstand voltage tests. This failure was determined to be a result of improper alignment between the P.C. board and the spacers in the housing. As a result, one of the P.C. board mounting screws was extremely close to one of the PCB etchings. After the P.C. board was properly aligned, the unit performed satisfactorily. It should be noted that the

10.0 TEST RESULTS (continued)

10. SC-1373-323-H3 (Item 35) (continued)

Humiseal removed during the process of repairing this unit was replaced. This was the case in all the units where a component was changed out (for example when a transformer was replaced with another which was aged at a higher temperature). Since the Humiseal was replaced in small localized areas and the majority of the aged Humiseal was undisturbed the new Humiseal is justified in terms of the other Humiseal used in the test items. The aged Humiseal is polyurethane based and, therefore, has an activation energy of 1.14eV (AETC File No. M32-3) and a qualified life of 20 years. It should be noted, also, that these units required calibration after humidity testing.

11. SC-1373-323-I1 (Item 36)

This unit was tested until it failed as a result of being irradiated to a TID of 3.0×10^5 rads. This unit is qualified to a TID of 1.0×10^4 rads by similitude to Item 35. Option I1 was qualified as part of Item 19.

10.0 TEST RESULTS (continued)

12. ET-1215-323-T2 (Item 27)

This unit is qualified for 11.79 years although it contains some maintenance items. The alarm relay has a qualified life determined through analysis of 20 years due to a temperature rise of 22.5°C and the transformer is limited by its wiring to a qualified life of 11.8 years. All of the components are qualified to a TID of 3.0×10^5 rads.

Prior to mechanical cycling an RIS representative accidentally broke one of the 1N2070 diodes in the unit. The unit was replaced and is jusfified by the other identical diode still in the program. Additional problems were also encountered during and after mechanical cycling with the relays.

Seven Aromat NC2ED-JP-24V relays were aged at 120°C in addition to the two relays that were aged at 100°C. The two relays aged at 100°C for 2072 hours performed satisfactorily after aging. The seven relays aged at 120°C encountered problems. During mechanical cycling, one of these relays failed early during the test. This is considered a random

10.0 TEST RESULTS (continued)

12. ET-1215-323-T2 (Item 27) (continued)

mode failure. Two of the remaining six relays failed dielectric strength testing prior to radiation. This failure rate (33%) is considered too high to be considered a random mode failure. Since the insulation system for these relays is rated at 105°C, it can be postulated that these failures were a result of thermal overstressing. The qualification of these relays was performed by a combination of testing and analysis. This is permissible according to IEEE Std. 323-1974 in cases where it is not feasible to conduct one or more of the tests. Because of the temperature rise seen at the coils during operation, the required aging time at an aging temperature at or below 105°C was far too great to permit completion of the test program within a reasonable period of time.

In order to address the thermal aging portion of the program, the following analysis was performed using Arrhenius methodology.

Weak Link Material: Polyurethane (Coil Wire Insulation)

Environmental Temperature (T_2): 51.9°C + 22.5°C (Coil Temperature Rise) = 74.4°C = 347.4°K

Activation Energy (Ea): 1.14 (AETC File No. M32-3)

10.0 TEST RESULTS (continued)

12. ET-1215-323-T2 (Item 27) (continued)

Boltzmann's Constant (B): 8.617×10^{-5}

UL Temperature Index (T_1) 130°C = 403°K

Time Temperature Index (t_1) = 60,000 hours

exp [x] = e^x

$$\text{Qualified Life } (t_2) = t_1 \exp^{Ea/B\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$$

$$t_2 = 60{,}000 \exp\left[\frac{-1.14}{8.617 \times 10^{-5}}\left(\frac{1}{403} - \frac{1}{347.4}\right)\right] = 11{,}479{,}612 \text{ hours}$$

This figure is far in excess of the 359,160 hours in 41 years. Therefore, based on this analysis, these relays are qualified for 41 years.

The worst case situation was simulated during the remainder of the test program because two of the surviving relays aged at 120°C were used during the remainder of the test program.

The operation of the relays was intermittent immediately after seismic testing, although these same relays performed satisfactorily during subsequent testing, as well as during the previous seismic testing. Because the failure could not be duplicated later, they were probably caused by an error in testing.

10.0 TEST RESULTS (continued)

13. ET-1214-323-H

This unit is qualified by similitude to Item 27, to the same parameters. The only differences are the following:

a) There are two alarm circuits and relays in Item 27, while only one is used in the ET-1214-323-H.

b) Item 27 contained power isolation component (H1 Option) not found in the ET-1214-323-H.

Every circuit contained in ET-1214-323-H w/s contained in Item 27.

14. ET-1214-323-H1

This unit is also qualified by similitude to Item 27. Both have the same power input circuits and Item 27 differs only in the number of alarm circuits it contains.

15. EI 4420-323

This unit is manufactured in several configurations depending on the type of signal input being monitored and the output desired. The following four configurations were tested, although 16 others were used during seismic testing to balance the chassis.

a) Item 42, 10-50 mA input, 10-50 mA output
b) Item 45, 1-5 mA input, 1-5 mA output

10.0 TEST RESULTS (continued)

15. EI 4420 (continued)

analog isolator that was energized during aging. Apparently this caused enough stress to shorten the life of these capacitors. It should also be noted that there are nine (9) such capacitors on each board which means that 36 were tested. This low failure rate along with the circumstances of the failures that did occur are factors in AETC's conclusion that these failures are not common mode failures.

It should also be noted that the test units had to be recalibrated after radiation aging and humidity testing.

16. EI 4481/EI 4482 Chassis Assembly (Item 39)

This chassis assembly is qualified for 20 years and 3.0 x 10^5 rads TID. Its ability to perform its safety-related function was demonstrated by the fact that the EI 4420 modules performed satisfactorily while mounted in and electrically connected through the chassis assembly.

17. EI 4477 Power Supply (Items 37 and 38)

This power supply has a qualified life of 20 years with the exception of the maintenance items listed in Table VIII.

10.0 TEST RESULTS (continued)

17. EI 4477 Power Supply (continued)

This unit is also qualified to a TID of 3.0×10^5 rads.

During initial functional testing, it was necessary to place a 0.1µf/50 VDC capacitor across terminals 3 and 6 in order to obtain acceptable test results. This capacitor was used for the duration of the test.

It was noted that the output voltage from one output from each unit tested was slightly high before and after humidity testing. The values obtained were, however, considered satisfactory by the customer in view of their unloaded conditions. The PVC leads were overstressed during thermal aging and the insulation on the transformers had to be sprayed with Humiseal to prevent shorting of the wires. This is jusfified since most of the test units contained PVC-insulated wiring that performed well after being thermally aged at 100°C for 2072 hours.

18. EI 4479 (Items 60 and 61)

This power supply has a qualified life of 20 years with the exception of the maintenance items listed in Table VIII. In addition, the unit is qualified to a TID of 3.0×10^5 rads.

10.0 TEST RESULTS (continued)

18. EI 4479 (Items 60 and 61)

In order to attain a qualified life of 16.1 years for the transformers, Item 71A was installed into Item 60 and Item 71 was installed into Item 61 after thermal aging.

It should be noted that Items 60 and 61 needed to be recalibrated after thermal aging.