Technical

Final Report
F-C4408

Report

VOLTAGE TESTS
AND
INSULATION RESISTANCE MEASUREMENTS
ON 1000-V CONTROL CABLE

Prepared for

United Engineers & Constructors, Inc.
Philadelphia, Pennsylvania

Carolina Power and Light Company
Raleigh, North Carolina

April 1976

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY · PHILADELPHIA, PENNSYLVANIA 19103

Attachment 2

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

A series of electrical tests were conducted on eight multiconductor Raychem Flamtrol™ 1000 V control cables submitted by United Engineers & Constructors. The tests consisted of a 5.5 kV alternating-current voltage test, measurement of insulation resistance (IR) at 500 Vdc and a final 16.5 kV direct-current voltage test. The cables were immersed in tap water at room temperature for a minimum of 24 hours prior to the electrical tests. Water was not allowed to enter the ends of the cables where the jackets were stripped back.

The program was conducted at the Franklin Institute Research Laboratories (FIRL) during April 1976.

2. SPECIMEN IDENTIFICATION

The test specimens were delivered in 50-ft lengths from which 15-ft sections were cut to perform the tests described in this report.

Identification of the test specimens is summarized in Table 1.

Table 1. Description of Test Specimens

FIRL Cable No.	No. of Conductors and Wire Size (AWG)	Cable Markings*	Footage Markings on 15-ft Specimen
1	10/C #12	1972 CJ12 050	00090 to 00102
2	3/C #10	1972 CC10 003	00898 to 00910
3	4/C # 9	1972 CD09 016	00172 to 00184
4	4/C #12	1973 CC12 [illegible]9	0116 to 0128
5	7/C #12	1973 CG12 147	00060 to 00072
6	12/C #12	1972 CL12 001	01158 to 01170
7	2/C #12	1976 CB12 434	0800[illegible] to 08016
8	10/C #12	1975 C[illegible]12 383	00070 to 00082

*Cable markings preceeded by "Raychem Flametrol 1000 V Control" and number of conductors and wire size.

3. TEST DESCRIPTIONS

The test program was conducted in accordance with a check list (Appendix A) based upon instructions from representatives of United Engineers & Constructors, Inc. This test conforms with "Completed Cable Test" of IPCEA S-66-524, Part 3.6.2.* Water was not allowed to enter the ends of the cables where the jackets were stripped back. The qualifications of the test personnel are provided in Appendix B. The following paragraphs provide a general description of the test procedures.

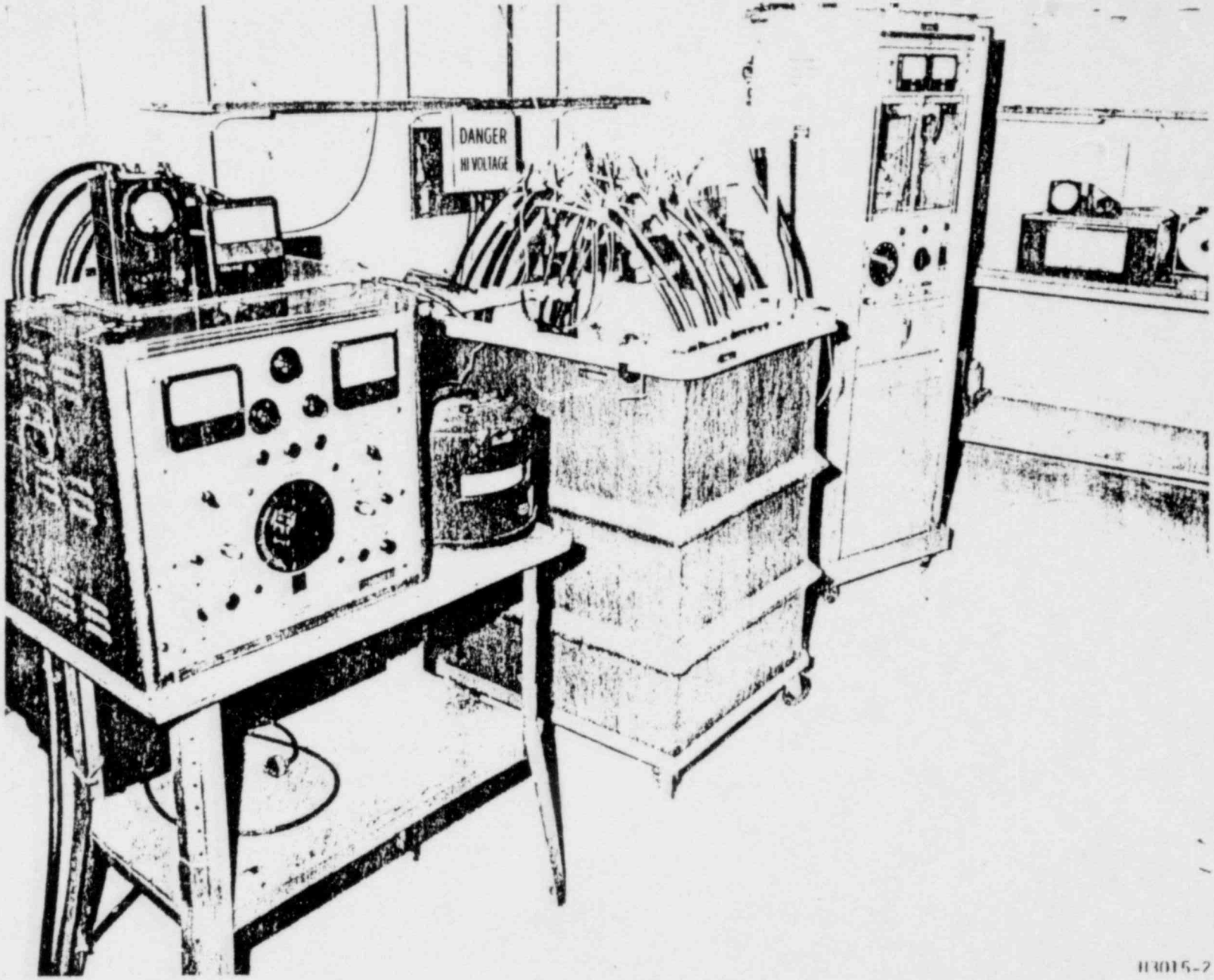
3.1 SPECIMEN PREPARATION

After tagging of the specimens and a visual inspection, the jackets were trimmed back for a distance of approximately 5 in. on both ends of the 15-ft sections of cable. The insulated conductors were fanned out and approximately 1 in. of insulation was removed from each conductor. The cables were coiled in one loose turn (of approximately 20 in. diameter) and the coils were immersed in a polyethylene-lined, fiberglass tank (24 in. x 30 in. x 36 in. deep) filled with tap water at room temperature, with approximately 2 ft of each cable end above the water. The temperature of the water was recorded using a thermocouple with a stripchart recorder and by observation of a thermometer totally immersed in the water. The tank with the immersed cables is illustrated in Figure 1.

3.2 ALTERNATING-CURRENT VOLTAGE TEST

Following immersion of the specimens in tap water for 24 hours, each conductor of every specimen was subjected to an alternating-current voltage test in general accordance with Part 3.6.2.1 of IPCEA S-66-524.* A potential of 5.5 kVac was applied to each conductor (in sequence) at the rate of approximately 300 V/sec. All the other conductors of the cable under test, the conductors of the other cables in the water, and a bare copper pipe in the water

*IPCEA Pub. No. S-66-524 Including Revision No. 3 - September 1974, Cross-linked-thermosetting-polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electric Energy, Insulated Power Cable Engineers Association, Belmont, Massachusetts.



F-C4408

Figure 1. View of Test Equipment and Arrangement

were connected together and to the ground potential-side of the test instrument.* The 5.5 kVac potential was maintained on each conductor for 5 min at which time the charging/leakage current was measured and recorded.

3.3 INSULATION RESISTANCE MEASUREMENTS

The insulation resistance (IR) of each insulated conductor was then measured in accordance with Part 3.6.2.2 of IPCEA S-66-524. The IR was measured with 500 Vdc applied for one minute between each conductor and all other conductors (and the water) at ground potential. The water temperature was measured as in Section 3.1 above.

3.4 DIRECT-CURRENT VOLTAGE TEST

After the IR measurements of Section 3.3, and while still in the tank of water, a direct-current voltage test was conducted in accordance with Part 3.6.2.3 of IPCEA S-66-524. A potential of 16.5 kVdc was applied at the rate of approximately 500 V/sec to each conductor, in sequence, with all other conductors (and the water) at ground potential. The potential of 16.5 kVdc was maintained on each conductor for 5 min at which time the leakage current was measured.

*A description of the instruments used is provided in Appendix C.

4. TEST RESULTS

4.1 ALTERNATING-CURRENT VOLTAGE TESTS

The results of the alternating-current voltage tests are summarized in Table 2. Original data are included in Appendix D. All of the specimens withstood the applied potentials of 5.5 kVac for 5 min.

4.2 INSULATION RESISTANCE MEASUREMENTS

The results of the IR measurements are presented in Table 3. Original data are included in Appendix D.

The resistance constant for the specimens was calculated using the lowest measured IR (6.2×10^{11} Ohms) and the following equation from IPCEA S-66-524:

$$R = K \log_{10} \frac{D}{d}$$

Where

R = Insulation resistance (IR) in megohms-1000 feet

K = Constant for the insulation (to be calculated) in megohms-1000 feet

D = Diameter over the insulation

d = Diameter under the insulation

The calculated value of K (Appendix E) was 31,000 megohms-1000 feet which exceeds the minimum value of 10,000 needed to meet the acceptance criterion of IPCEA S-66-524, Part 3.6.2.2 and the more conservative value of 20,000 used by the Raychem Corporation.

4.3 DIRECT-CURRENT VOLTAGE TESTS

The results of the direct-current voltage tests are summarized in Table 4. Original data are included in Appendix D. All of the specimens withstood the applied potential of 16.5 kVdc for 5 min.

Table 2. Summary of 5.5 kV Alternating-Current Voltage Test[1,2]

FIRL Cable No.	Conductor Color	Leakage/ Charging Current (mA)[3]	Test Results
*1	Black	1.0	
	White	1.0	
	Red	1.0	
	Green	0.9	
	Orange	[illegible]	
	Blue	0.9	
	White/Black	[illegible]	
	Red/Black	[illegible]	
	Green/Black	0.8	
	Orange/Black	0.9	
*2	Black	[illegible]	
	White	[illegible]	
	Red	[illegible]	
3	Black	[illegible]	
	White	[illegible]	
	Red	[illegible]	
	Green	[illegible]	
4	Black	[illegible]	
	White	[illegible]	
	Red	[illegible]	
	Green	[illegible]	
5	Black	[illegible]	
	White	[illegible]	All conductors withstood a potential of 5.5 kVac for 5 min.
	Red	[illegible]	
	Green	[illegible]	
	Orange	[illegible]	
	Blue	[illegible]	
	White/Black	1.0	
*6	Black	[illegible]	
	White	1.0	
	Red	1.0	
	Green	1.0	
	Orange	1.0	
	Blue	1.0	
	Black/White	1.0	
	White/Black	1.0	
	Red/Black	1.0	
	Green/Black	1.0	
	Orange/Black	1.0	
	Blue/Black	1.0	
*7	Black	1.2	
	White	1.2	
8	Black	1.0	
	White	1.0	
	Red	1.0	
	Green	1.0	
	Orange	1.0	
	Blue	1.0	
	White/Black	1.0	
	Red/Black	1.0	
	Green/Black	1.0	
	Orange/Black	1.0	

NOTES:
1. All cables were immersed in tap water at room temperature for a minimum of 24 hr prior to application of the test potential. The temperature of the tap water was 24 ± 1 C.
2. The potential of 5.5 kVac was applied to each conductor with all other conductors and the water at ground potential.
3. Leakage/charging current measured at the end of the 5-min test period. The lowest division on the current meter was 1.0 mA (Item No. 18-253).

Table 3. Summary of Insulation Resistance Measurements(1,2)

FIRL Cable No.	Conductor Color	Insulation Resistance (Ohms)
1	Black	6.0 x 10[illegible]
	White	3.0 x 10^{13}
	Red	4.5 x 10[illegible]
	Green	1.4 x 10^{13}
	Orange	1.2 x 10^{13}
	Blue	[illegible] x 10^{13}
	White/Black	[illegible] x 10^{13}
	Red/Black	2.6 x 10^{12}
	Green/Black	1.4 x 10^{13}
	Orange/Black	8.4 x 10^{12}
2	Black	8.2 x 10^{12}
	White	7.2 x 10[illegible]
	Red	9.4 x 10[illegible]
3	Black	1.8 x 10[illegible]
	White	2.0 x 10[illegible]
	Red	1.5 x 10[illegible]
	Green	1.8 x 10[illegible]
4	Black	1.5 x 10[illegible]
	White	2.0 x 10[illegible]
	Red	2.0 x 10[illegible]
	Green	2.4 x 10[illegible]
5	Black	2.2 x 10[illegible]
	White	2.4 x 10[illegible]
	Red	1.6 x 10[illegible]
	Green	1.4 x 10[illegible]
	Orange	1.8 x 10[illegible]
	Blue	2.8 x 10[illegible]
	White/Black	2.2 x 10[illegible]
6	Black	2.0 x 10[illegible]
	White	3.5 x 10^{13}
	Red	3.2 x 10^{13}
	Green	4.5 x 10^{12}
	Orange	5.0 x 10[illegible]
	Blue	4.0 x 10^{12}
	Black/White	4.5 x 10^{12}
	White/Black	4.0 x 10^{12}
	Red/Black	4.5 x 10^{13}
	Green/Black	3.5 x 10^{12}
	Orange/Black	4.2 x 10[illegible]
	Blue/Black	4.5 x 10^{12}
7	Black	9.0 x 10^{11}
	White	1.3 x 10[illegible]
8	Black	6.2 x 10[illegible](3)
	White	7.0 x 10^{11}
	Red	2.4 x 10^{12}
	Green	2.4 x 10^{12}
	Orange	9.2 x 10^{11}
	Blue	1.0 x 10^{12}
	White/Black	8.0 x 10^{11}
	Red/Black	2.6 x 10^{12}
	Green/Black	1.4 x 10^{12}
	Orange/Black	2.4 x 10^{12}

NOTES: 1. All cables were immersed in tap water at room temperature for a minimum of 24 hr prior to measurement of IR. The temperature of the tap water at the time of IR measurement was 24 ± [illegible] C.
2. IR was measured with 500 Vdc held for one minute.
3. Lowest value of measured IR used in calculation of the resistance constant. See Appendix E.

Table 4. Summary of 16.5 kV Direct-Current Voltage Test[1,2]

FIRL Cable No.	Conductor Color	Leakage Current (μA)[3]	Test Results
1	Black	25.0	All cables withstood a potential of 16.5 kVdc applied for 5 min.
	White	42.0	
	Red	29.5	
	Green	12.5	
	Orange	17.5	
	Blue	22.0	
	White/Black	21.5	
	Red/Black	29.0	
	Green/Black	20.0	
	Orange/Black	16.5	
2	Black	4.0	
	White	3.0	
	Red	2.0	
3	Black	14.0	
	White	8.0	
	Red	14.0	
	Green	13.0	
4	Black	25.0	
	White	38.0	
	Red	16.0	
	Green	20.0	
5	Black	15.0	
	White	20.0	
	Red	20.0	
	Green	15.0	
	Orange	15.0	
	Blue	15.0	
	White/Black	25.0	
6	Black	16.5	
	White	23.5	
	Red	23.5	
	Green	18.5	
	Orange	14.0	
	Blue	13.5	
	Black/White	19.0	
	White/Black	29.5	
	Red/Black	19.0	
	Green/Black	16.5	
	Orange/Black	16.0	
	Blue/Black	18.5	
7	Black	10.0	
	White	13.5	
8	Black	18.0	
	White	27.0	
	Red	26.0	
	Green	70.0	
	Orange	65.0	
	Blue	100.0	
	White/Black	15.0	
	Red/Black	20.0	
	Green/Black	15.0	
	Orange/Black	20.0	

NOTES:
1. All cables were immersed in tap water at room temperature for a minimum of 24 hr prior to application of the test potential. The temperature of the tap water was 24 ± 1 C.
2. The potential of 16.5 kVdc was applied to each conductor with all other conductors and the water at ground potential.
3. Leakage current measured at the end of the 5-min test period.

5. CONCLUSIONS

Eight multiconductor Raychem Flametrol cables successfully withstood an alternating-current voltage test of 5.5 kVac for 5 min and a direct-current voltage test of 16.5 kVdc for 5 min.

All measured values of insulation resistance satisfied the IPCEA acceptance criterion ($K \geq 10{,}000$ megohms-1000 ft) and the more conservative criterion used by the cable manufacturer ($K \geq 20{,}000$ megohms-1000 ft).

6. CERTIFICATION

The undersigned certify that this report constitutes a true account of the test conducted and results obtained.

D. V. Paulson
Project Engineer

APPROVED BY:

Zenons Zudans, Vice President
Engineering

S. P. Carfagno, Manager
Performance Qualification Laboratory

Appendix

A

CHECK LIST FOR TEST PERFORMANCE

DOCUMENT C4408-1 Rev. 0 Date 4/19/76

COMPUTED BY / DATE	THE FRANKLIN INSTITUTE RESEARCH LABORATORIES PHILADELPHIA, PA. 19103	PAGE
D. V. Paulson DVP 4/20/76		1 of 2
CHECKED BY / DATE		PROJECT
T. Carfagno 4/20/76		021-C4408-01

TITLE: AC DIELECTRIC, IR and DC DIELECTRIC TESTS

Reviewed for QA 4-20-76

STEP	DESCRIPTION		PERF by	REVIEWED by
	Cable Specimens: FIRL No. / Type / Reel Tag No. 1 — 10/C #12 · — CJ12-050 2 — 3/C #10 · — CC10-003 3 — 4/C # 9 — CD09-016 4 — 4/C #12 — CD12-079 5 — 7/C #12 — CG12-147 6 — 12/C #12 · — CL12-001 7 — 2/C #12 · — CB12-434 8 — 10/C #12 — CJ12-383 General: This check list is a general procedure to be used on complete cable samples (15 ft lengths) as hereafter described.		GTV SM 4/19/76	LEW
1	From the cables described above cut a 15-ft section. Provide temporary identifying tags for each section. Record footage marks. Prepare ends by cutting back jacket approximately 5 in. and flaring out conductors. Strip off 1 in. of conductor insulation.		GTV SM 4/19/76	LEW
2	Perform a brief visual inspection of each section.		GTV	LEW
3	Immerse the 15-ft sections of cables 1, 2, 6 and 7 in tap-water at room temperature for 24-hours. Keep each cable end approximately 1.5 ft above water. Cables 3, 4, 5 and 8 are to be placed in the tap water approximately 18 hours later.		GG LEW GG LEW	4/19/76 4/20/76 SPC
4	AC Dielectric Test Prepare an AC dielectric test set with calibrated voltmeter and milliammeter. The milliammeter should be readable to 1 mA. a. Apply voltage between each conductor and all other conductors and water at a rate of approximately 300 V/s up to 5.5 kV. b. Hold at 5.5 kV for 5 min. c. Record ammeter reading at end of 5 min. d. If failure occurs, record approximate voltage and time.		GG DVP GG GTV	(4)

COMPUTED BY / DATE	THE FRANKLIN INSTITUTE RESEARCH LABORATORIES	PAGE
D.V. Paulson	PHILADELPHIA, PA. 19103	2 of 2
CHECKED BY / DATE		PROJECT 02I-C4408-01

TITLE: AC DIELECTRIC, IR AND DC DIELECTRIC TESTS

STEP	DESCRIPTION		PERF by	REVIEWED by
5	Insulation Resistance Test a. Perform on conductors that withstood ac voltage test b. Measure water temperature prior to IR test, to nearest °F. c. Apply 500 Vdc from megohmeter, with negative terminal on test conductor and positive terminal (ground) tied to all other conductors and water. d. Hold for 1 min, then record insulation resistance. e. After conclusion of all electrical measurements, Project Engineer is to verify that IR measurements comply with acceptance criterion per IPCEA S-66-524, para. 3.6.2.2.		SP SH E.	④
6	DC Dielectric Test Prepare dc dielectric test set with calibrated ammeter and voltmeter. a. Perform on conductors that withstood ac voltage test. b. Apply voltage between each conductor and all other conductors plus water at a rate of approximately 1000 V/s (but not less than 450 V/s) up to a value of 16.5 kVdc. c. Hold at 16.5 kV for 5 min. d. Record ammeter reading at end of 5 min. e. If failure occurs, record approximate voltage and time.		SP SH E.	④
7	Consult the Project Engineer for disposition of the cables.		E.	④
8	Verify that all data acquisition instruments and their calibration dates have been recorded		WMD	④
9	Review the data sheets for completion and submit them to the Project Engineer.		DWP	DPC

Appendix

B

QUALIFICATIONS OF KEY TEST PERSONNEL

APPENDIX B

QUALIFICATIONS OF KEY TEST PERSONNEL

1. SALVATORE P. CARFAGNO, MANAGER, PERFORMANCE QUALIFICATION LABORATORY

As manager of the personnel and facilities utilized in this program, he is responsible for the proper direction and administration, according to FIRL policy and the requirements of the client.

Dr. Carfagno has a Ph.D. in physics, and has engaged in a broad range of studies during his more than 25 years at FIRL. For the past 7 years, he has been heavily involved in qualification testing and analysis of equipment and components for use in nuclear power generating stations. He is the FIRL representative to Subcommittee 2 of IEEE and an active participant in working groups for IEEE Standards on valve actuators and the general qualification guide IEEE 323.

2. DAVID V. PAULSON, CHIEF, ENVIRONMENTAL TEST SECTION

He is responsible to the Manager, Performance Qualification Laboratory, for the performance of assigned programs, including compliance with QA requirements. Mr. Paulson has a B.S. in physics and is a registered professional engineer in Pennsylvania. He has had a varied, 25-year background, strongly accenting the problems of applied research, development and hardware evaluation. For the past three years, he has been a program manager on a variety of nuclear qualification test projects at FIRL. He is a member of IEEE working group drafting a nuclear radiation test guide, and an alternate member to Subcommittee 2 of IEEE.

3. GERALD D. GUSKE, STEVEN MAZZONE AND GUY J. VACCA (TECHNICIANS)

These personnel are responsible to the Test Bay Supervisor (LeRoy E. Witcher) or to the Program Manager (as they may be assigned) for the implementation of detailed tasks in accordance with written and oral instructions. They perform their duties using their extensive experience,

knowledge and laboratory skills.

Mr. Guske has over 16 years experience in electricity and electronics and was a supervisor of an electronic calibration laboratory for RCA, Inc.

Mr. Mazzone has participated in electrical testing in the FIRL Performance Qualification Laboratory for eighteen months. Prior to joining FIRL, he served the U.S. Navy in a nuclear submarine as a missile technician which required 26 weeks of electronics schooling.

Mr. Vacca has been with FIRL for almost 9 years during which most of his experience has been with qualification testing of equipment for nuclear power generating stations. Mr. Vacca is taking evening courses at Drexel University with the goal of obtaining a B.S. in Engineering.

4. GUNTHER COHN, MANAGER, QUALITY ASSURANCE

As manager of the FIRL Quality Assurance (QA) function he is responsible to the President of FIRL and to the client for the proper direction and implementation of QA policies and practices according to the contracted needs of the program.

Mr. Cohn has a M. S. in mechanical engineering and is a registered professional engineer in Pennsylvania. He has served as project leader on a variety of engineering projects and has published sixteen books and manuals plus over 150 technical reports, articles and papers. He has been with FIRL for 29 years.

Appendix

C

LIST OF DATA ACQUISITION INSTRUMENTS

LIST OF DATA ACQUISITION INSTRUMENTS C4408-01

INSTRUMENT NUMBER	16276
INSTR AND MFR	BECKMAN AC DIELECTRIC STRENGTH TEST SET
TYPE/MODEL NUMBER	P45-502/102
SERIAL NUMBER	359
RANGE/FEATURES	5 KVAC 2KVA 0-2.5-5-10-50 KV
DATE CALIBRATED	12 22 75

INSTRUMENT NUMBER	16253
INSTR AND MFR	MULTI-AMP AC METER
TYPE/MODEL NUMBER	105
SERIAL NUMBER	2104
RANGE/FEATURES	10-10000 MA AC
DATE CALIBRATED	02 16 76

INSTRUMENT NUMBER	A217639
INSTR AND MFR	SENSITIVE RESEARCH-ELECTROSTATIC VOLTMETER
TYPE/MODEL NUMBER	MODEL ESH
SERIAL NUMBER	9[illegible]-21
RANGE/FEATURES	0-5-10-20-30 KV
DATE CALIBRATED	0[illegible] 20 76

INSTRUMENT NUMBER	16172
INSTR AND MFR	ESTERLINE ANGUS-2-PEN RECORDER
TYPE/MODEL NUMBER	SPEED SERVO II L11025
SERIAL NUMBER	4 A[illegible]24
RANGE/FEATURES	0-400 DEGREES F TYPE T T/C 0-10 MVDC 1-900 IN/HR
DATE CALIBRATED	02 04 76

INSTRUMENT NUMBER	16235
INSTR AND MFR	GENERAL RADIO MEGOHMMETER
TYPE/MODEL NUMBER	1-864
SERIAL NUMBER	43[illegible]8-1075
RANGE/FEATURES	50K TO 5T OHMS 10-1000 V DC
DATE CALIBRATED	12 11 75

INSTRUMENT NUMBER	1-294
INSTR AND MFR	RESISTOR MICROAMMETER DC
TYPE/MODEL NUMBER	371
SERIAL NUMBER	
RANGE/FEATURES	0 TO 200 MICROAMPS 5 MICRO A DIV ACCURACY=2PC
DATE CALIBRATED	04 26 76

INSTRUMENT NUMBER	11[illegible]
INSTR AND MFR	SENSITIVE RESEARCH MICROAMMETER DC
TYPE/MODEL NUMBER	SENSITIVITY
SERIAL NUMBER	5[illegible]51[illegible]
RANGE/FEATURES	0 TO 500 MICRO AMPS 1 MICRO A DIV ACCURACY=2PC
DATE CALIBRATED	0[illegible] 20 76

LIST OF DATA ACQUISITION INSTRUMENTS

C4408-01

INSTRUMENT NUMBER	4217663
INSTR AND MFR	NJE CORP HIGH VOLTAGE POWER SUPPLY
TYPE/MODEL NUMBER	H80D245
SERIAL NUMBER	9440
RANGE/FEATURES	0 TO 5 MILLIAMPS DC 0 TO 120 KVDC
DATE CALIBRATED	NOT REQD

Appendix

D

ORIGINAL DATA SHEETS

DATE 4/2/76 (24 Hrs)

OPERATOR EG.

TEST PHASE After 24 Hr. SOAK

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
PHILADELPHIA, PA. 19103

PROJECT C4408

INSTRUMENT & CALIBRATION 18-276 & 18-253

TEMPERATURE (WATER) 24°C

AC - Hi Pot
HIGH-POTENTIAL TEST DATA

SAMPLE NO.	VOLTAGE kVac (1)	CURRENT mA (2)	CONDUCTOR COLOR	REMARKS
3	5.5	1.0	BLK	@ 24 Hrs @ 24°C
"	5.5	1.0	WHT	
"	5.5	1.0	RD	
"	5.5	1.0	GRN	
4	5.5	1.0	BLK	
"	5.5	1.0	WHT	
"	5.5	1.0	RD	
"	5.5	1.0	GRN	
8	5.5	1.1	BLK	
"	5.5	1.0	WHT	
"	5.5	1.0	RD	
"	5.5	1.0	GRN	
"	5.5	1.0	ORG	
"	5.5	1.0	BLU	
"	5.5	1.0	~~BLK/WHT~~ 5	WHT/BLK
"	5.5	1.0	~~WHT/BLK~~ 6	RD/BLK
"	5.5	1.0	GRN/BLK	
"	5.5	1.0	ORG/BLK	
5	5.5	1.0	BLK	
"	5.5	1.0	WHT	
"	5.5	1.0	RD	
"	5.5	1.0	GRN	
"	5.5	1.0	ORG	
"	5.5	1.0	BLU	
"	5.5	1.0	WHT/BLK	@ 12.0 Hrs @ 24°C

NOTES: 1. Potentials applied for 5 minutes.
2. Leakage/charging current measured at the end of 5 minutes.

Data checked by: O.L. Paulson Date: 4/23/76

DATE 4/20/76	THE FRANKLIN INSTITUTE RESEARCH LABORATORIES PHILADELPHIA, PA. 19103	PROJECT C4408
OPERATOR J. Guske/D. Paulson		INSTRUMENT & CALIBRATI SEE REMARKS
TEST PHASE: AFTER 24HR SOAK IN TAP WATER	HIGH-POTENTIAL TEST DATA	TEMPERATURE (WATER) 74°F (c) / 24°C THERMOMETE

SAMPLE NO.	VOLTAGE kVac (1)	CURRENT mA (2)	CONDUCTOR COLOR	REMARKS
		INSTRUMENTS USED:		(1) Beckman Dielectric Test Set Item 18-276 Calibrated 12/22/75
				(2) Multi-Amp Ammeter Item 18-253 Calibrated 2/16/7
2	5.5	1.1	BLACK	Meas'd @ 3:45 PM
	5.5	1.0	WHITE	3:51
	5.5	1.0	RED	3:57
7	5.5	1.2	BLACK	
	5.5	1.2	WHITE	
1	5.5	1.0	BLACK	
	5.5	1.0	WHITE	
	5.5	1.0	RED	
	5.5	0.9	GREEN	
	5.5	0.9	ORANGE	
	5.5	0.9	BLUE	
	5.5	1.0	WHITE/BLK	
	5.5	1.0	RED/BLK	
	5.5	0.8	GREEN/BLK	
	5.5	0.8	ORANGE/BLK	Measured @ 6:09 PM
6	5.5	1.1	BLACK	
	5.5	1.0	WHITE	
	5.5	1.0	RED	
	5.5	1.0	GREEN	
	5.5	1.0	ORANGE	
	5.5	1.0	BLUE	
	5.5	1.0	BLK/WT.	

NOTES: 1. Potentials applied for 5 minutes.
2. Leakage/charging current measured at the end of 5 minutes.

Data checked by: E W Paulson Date: 4/23/76

DATE 4/20/76	THE FRANKLIN INSTITUTE RESEARCH LABORATORIES PHILADELPHIA, PA. 19103	PROJECT C4408
OPERATOR SM / SV		INSTRUMENT & CALIBRATION See Pg. 1
TEST PHASE AFTER 2HR SOAK IN TAP WATER	HIGH-POTENTIAL TEST DATA	TEMPERATURE (WATER) See Pg. 1

SAMPLE NO.	VOLTAGE kVac (1)	CURRENT mA (2)	CONDUCTOR COLOR	REMARKS
6 (CONT.)	5.5	1.0	WHITE/BLK	
	5.5	1.0	RED/BLK	
	5.5	1.0	GREEN/BLK	
	5.5	1.0	ORANGE/BLK	
	5.5	1.0	BLUE/BLK	MEASURED @ 1920 hrs

NOTES: 1. Potentials applied for 5 minutes.
2. Leakage/charging current measured at the end of 5 minutes.

Data checked by: [signature] Date: 4/23/76

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PROJECT C4408

SHEET 1 OF 1

INSULATION RESISTANCE MEASUREMENTS

TEST PHASE OR PURPOSE OF MEASUREMENT
After 24-Hr Soak in Tap Water

CABLE TEMPERATURE AND TEST CONDITIONS
24°C

MEASUREMENT INSTRUMENT AND CALIBRATION DATE
GR Megohmmeter Model 1864 6-21-76

DATE	OPERATOR	CLOCK TIME (2400)	TEMPERATURE °C (°F)	SAMPLE NO.	CONDUCTORS ON TERMINALS I (GROUND) (+)	CONDUCTORS ON TERMINALS II (TEST COND'TOR) COLOR	RESISTANCE (Ω OHMS) SCALE READING	RESISTANCE (Ω OHMS) SCALE MULTIPLIER	REMARKS
4/21/76	G	1300	24	3	ALL OTHERS	BLK	1.8	10 T	
				3		WHT	2.0	10 T	
				3		RD	1.5	10 T	
				3		GRN	1.5	10 T	
		"		4		BLK	4.5	1 T	
				4		WHT	2.8	1 T	
				4		RD	2.0	1 T	
				4		GRN	2.4	1 T	
		X		8		BLK	0.62	1 T	
				8		WHT	0.7	1 T	
				8		RD	2.4	1 T	
				8		GRN	2.4	1 T	
				8		ORG	0.92	1 T	
				8		BLU	1.0	1 T	
				8		WHT/BLK	.8	1 T	
				8		RD/BLK	2.6	1 T	
				8		GRN/BLK	1.4	1 T	
				8		ORN/BLK	2.4	1 T	
		X		5		BLK	3.0	1 T	
				5		WHT	2.4	1 T	
				5		RD	1.6	1 T	
				5		GRN	1.4	1 T	
				5		ORG	1.8	1 T	
				5		BLU	2.6	1 T	
		1355		5		WHT/BLK	2.2	1 T	

NOTES: 1. 500 Vdc applied for 1 min. unless otherwise indicated.
Scale Multiplier "T" = 10^{12} ohms

Data checked by: D.C. Rawson Date: 4/23/76

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PROJECT C4408

SHEET 1 OF 1

INSULATION RESISTANCE MEASUREMENTS

TEST PHASE OR PURPOSE OF MEASUREMENT
AFTER 24 HR SOAK IN TAP WATER

CABLE TEMPERATURE AND TEST CONDITIONS
WATER TEMP 74°F BY TC & 24°C BY THERMOMETER

MEASUREMENT INSTRUMENT AND CALIBRATION DATE
GR MEGOHMMETER MODEL 1864 ITEM 421-7802

DATE	OPERATOR	CLOCK TIME (2400)	TEMPERATURE (F)	SAMPLE NO.	CONDUCTORS ON TERMINALS I (GROUND)	CONDUCTORS ON TERMINALS II (TEST CONDUCTOR) COLOR	RESISTANCE (MEGOHMS) SCALE READING	RESISTANCE (MEGOHMS) SCALE MULTIPLIER	REMARKS
4/20/76	[illegible]	1602	24°C	2	ALL OTHERS	BLACK	0.82	10T	
		1606	24.2°C	2	"	WHITE	0.72	10T	
		1608		2	"	RED	0.94	10T	
	[illegible]	1926	24°C	1	"	[illegible]	0.9	1T	
				1	"	[illegible]	1.3	1T	
		1930	24°C	1	"	BLACK	6.0	10T	
				1	"	WHITE	3.0	10T	
				1	"	RED	4.5	10T	
				1	"	GREEN	1.4	10T	
				1	"	ORANGE	1.2	10T	
				1	"	BLUE	1.4	10T	
				1	"	WHT/BLK	1.1	10T	
				1	"	RED/BLK	0.86	10T	
				1	"	GREEN/BLK	1.4	10T	
				1	"	ORANGE/BLK	0.84	10T	
		1950	24°C	6	"	BLACK	2.0	10T	
				6	"	WHITE	3.5	10T	
				6	"	RED	3.0	10T	
				6	"	GREEN	4.5	1T	
				6	"	~~BLUE~~	FAIL		
				6	"	ORANGE	5.0	1T	
				6	"	BLUE	4.0	1T	
				6	"	~~WHITE~~	4.5	1T	BLACK/WHT
				6	"	WHT/BLK	4.0	1T	
				6	"	RED/BLK	4.5	1T	
				6	"	GREEN/BLK	3.5	1T	
				6	"	ORANGE/BLK	4.0	1T	
		2010	23.8°C	6	"	BLUE/BLK	4.5	1T	

1. 500 Vdc applied for 1 min. unless otherwise indicated.
Scale Multiplier "T" = 10^{12} ohms

Data compiled by: [illegible] Date: 4/23/76

DATE 4/21/76 | OPERATOR G. | PROJECT C4408 | INSTRUMENT & CALIBRATI 421-7639 & ISL-118

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TEST PHASE After 24 Hr SOAK | DC-HIPOT | TEMPERATURE (WATER) 20°C

HIGH-POTENTIAL TEST DATA

SAMPLE NO.	VOLTAGE (1)	CURRENT (2)	CONDUCTOR COLOR	REMARKS
	KV dc (1)	μA (2)		
3	16.5	14.0	BLK	Measured at 2:15 PM 4/21/76
"	16.5	8.0	WHT	
"	16.5	14.0	RD	
"	16.5	13.0	GRN	
4	16.5	25.0	BLK	
"	16.5	38.0	WHT	
"	16.5	16.0	RD	Exceeds 50 μA - installed 200 μA meter*
"	16.5	20.0	GRN	
5	16.5	18.0	BLK	
"	16.5	22.0	WHT	
"	16.5	26.0	RD	
"	16.5	70.0	GRN	Installed 200 μA mtr* to measure > 50 μA
"	16.5	65.0	ORG	(*Weston Model 301, calibrated 4/20/76)
"	16.5	100.0	BLU	Arcing btwn WHT/BLK & BLU conductors
"	16.5	15.0	WHT/BLK	& separated conductors by 2-3".
"	16.5	20.0	RD/BLK	
"	16.5	15.0	GRN/BLK	
"	16.5	20.0	ORG/BLK	
5	16.5	15.0	BLK	
"	16.5	20.0	WHT	
"	16.5	20.0	RD	
"	16.5	15.0	GRN	
"	16.5	15.0	ORG	
"	16.5	15.0	BLU	
"	16.5	25.0	WHT/BLK	STOP @ 1710 Hrs 23°C
				* Arcing @ ~15 KV at cable. Reenergized with no arcing and less leakage than previously.
Dry Bulb	74.2°F	R.H. 54% @ 1620 Hrs 4/21/76		
Wet Bulb	63.0°F			

NOTES: 1. Potentials applied for 5 minutes.
2. Leakage/charging current measured at the end of 5 minutes.
Instruments 421-7639 & ISL-118 calibrated 4/20/76.
Data checked by: [signature] Date: 4/23/76

DATE: 4/20/76

OPERATOR: J. Guske, D Paulson, G. Vaccaro

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PROJECT: C4408

INSTRUMENT & CALIBRATION: See Remarks

TEST PHASE: AFTER 24 HR SOAK IN TAP WATER

HIGH-POTENTIAL TEST DATA

TEMPERATURE (WATER): 24°C Thermometer / 74°F Thermocouple

SAMPLE NO.	VOLTAGE (1)	CURRENT (2)	CONDUCTOR COLOR	REMARKS
				INSTRUMENTS USED: 1 NJE ~~SE~~ HI-POT DC 160 KV (CALIBRATION NOT REQ'D
				JTFW NO. 421-7763
				2 Electrostatic Voltmeter
				Item No. 421-7639 Calibrated 4/20/76
	(1)	(2)		3 Sensitive Research Ammeter 50 μA
	kVdc	Microamps		Item No ISL-115, CALIBRATED 9/20/76
2	16.5	4.0 μA	BLACK	Measured @ 4:32 PM
2	16.5	3.0 μA	WHITE	
2	16.5	2 μA	RED	Measured @ 4:47
7	16.5	10.0 μA	BLACK	24.0°C @ 2034 hrs
7	16.5	13.5 μA	WHITE	
1	16.5	25.0 μA	BLACK	24°C @ 2055 hrs
1	16.5	42.0 μA	WHITE	
2	16.5	9.5 μA	BLACK	CHECKED AS REQUESTED BY SPONSOR LESS THAN 2 MINS HELD REMOVED AC TESTER FROM GROUND LOOP NO CHANGE - PROCEEDING BY DIR. OF SPONSOR SHORTENED GROUND LEADS
1	16.5	29.5 μA	RED	
1	16.5		GREEN	SHUT DOWN AFTER 1 MIN - MISSING A GROUND LEAD
1	16.5	12.5 μA	GREEN	
1	16.5	17.5 μA	ORANGE	
1	16.5	22.0 μA	BLUE	
1	16.5	21.5 μA	WHT/BLK	
1	16.5	29.0 μA	RED/BLK	

NOTES: 1. Potentials applied for 5 minutes.
2. Leakage/charging current measured at the end of 5 minutes.

Data checked by: E V Paulson Date: 4/23/76

DATE 4/20/76

OPERATOR SH / GV

TEST PHASE ~~Soak~~ After 24 HC ~~Soak~~ IN TAP H_2O

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HIGH-POTENTIAL TEST DATA

PROJECT C4408

INSTRUMENT & CALIBRATI

TEMPERATURE (WATER)

SAMPLE NO.	VOLTAGE ~~KVAC~~ (1)	CURRENT ~~mA~~ (2)	CONDUCTOR COLOR	REMARKS
1	16.5	20.0 mA	Green/BLK	
1	16.5	16.5 mA	Orange/BLK	
6	16.5	16.5 mA	BLACK	24 °C @ 2215 hrs.
6	16.5	23.5 mA	WHITE	
6	16.5	23.5 mA	RED	
6	16.5	18.5 mA	GREEN	
6	16.5	14.0 mA	ORANGE	
6	16.5	~~35~~ .135 mA	BLUE	
6	16.5	19.0 mA	BLK/WHT	
6	16.5	29.5 mA	WHT/BLK	
6	16.5	19.0 mA	RED/BLK	
6	16.5	16.5 mA	~~Gree~~ BLK	
6	16.5	16.0 mA	Orange/BLK	
6	16.5	16.5 mA	BLUE/BLK	
				END 2335 hrs.

NOTES: 1. Potentials applied for 5 minutes.
2. Leakage/charging current measured at the end of 5 minutes.

Data checked by: L. Parker Date: 4/23/76

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PAGE 1 of 1

PROJECT 02I-C4408-01

TITLE

VISUAL INSPECTION REPORT

Event immediately preceding inspection

Before immersing in ambient water bath

Item	Comments and Observations	Obs	Date
1	No obvious damage other than minor abrasions of cable jacket. (15 ft. section only)	bjr	4/9/76
2	Same as cable #1 above.		
7	No apparent damage		
6	Minor cuts & abrasions on cable jacket No other apparent damage.		
8	Minor abrasions on cable jacket		
5	No apparent damage other than minor jacket abrasions.		
3	Same as #5 cable.		
4	Same as #5 cable.		

Notes: Reviewed 4/9/76 D. L. Parker

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PROJECT
02F-C4408-01

TITLE

VISUAL INSPECTION REPORT

Event immediately preceding inspection

Item	Comments and Observations	Obs	Date
7	15 ft. section ~~008~~ 08004 — 08016 footage marks. Remaining section 08018 — 08052.	SJC	4/19/
2	15ft section 00898 — 00910 Remaining section footage marks 00852 — 00896		
1	15ft section 00090 — 00102 Remaining section 00104 — 00124		
6	15ft section 01158 — ~~01164~~ 01170 Remaining section 01172 — 01218		
5	15 ft. section 00060 - 00072 Remaining section 00074 - 00108		
4	15ft section 0116 — 0128 Remaining Section 0130 — 0166		

Notes: S. J. Paulson 4/20/76

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PAGE 2 of 2

PROJECT C4408

TITLE

VISUAL INSPECTION REPORT

Event immediately preceding inspection

Item	Comments and Observations	Obs	Date
3.	15 ft. section 00172 - 00184 footage marks.	EP SM	4/20/76
	Remaining section 00186 - 00220		
8	15 ft section 00070 - 00082		
	Remaining section 00084 - 00118		

Notes: D. C Paulson 4/20/76

Appendix

E

CALCULATIONS OF RESISTANCE CONSTANT

APPENDIX E

CALCULATION OF MINIMUM RESISTANCE CONSTANT

1. From Ref. 1, Part 6.15.2

$$R = K \log_{10} \frac{D}{d}$$

$$\text{or } K = \frac{R}{\log_{10} \frac{D}{d}}$$

where R = Insulation resistance (IR) in megohms-1000 feet

K = Constant for the insulation (to be calculated)

D = Diameter over the insulation

d = Diameter under the insulation

2. a. Lowest measured IR was 6.2×10^{11} Ohms for Cable 8, black conductor, which was 15-ft long. Correcting for a 1000-ft length, $R = \frac{15}{1000} \times 6.2 \times 10^{11} = 9.3 \times 10^{9}$ Ohms-1000 ft.

b. For Cable 8, d = 0.0915 in., based on a standard diameter for concentric lay of a 7-stranded #12 AWG (Ref. 2).

c. For Cable 8, D = 0.1815 in., based on d (above) plus twice the thickness of insulation, or 2 x 0.045 in. (Insulation thickness of 0.045 in. was reported by the client.)

3. The measured value of R can be corrected (multiplied) by a temperature correction factor for water temperature above the reference level of 15.6 C. Based on the tap water temperature of 24 ± 1 C, a correction factor between 1.47 and 6.85 could be selected from Ref. 1, Table 6 - 10. For worst-case analysis, a value of 1.0 is used, i.e., no correction is made.

4. $$K = \frac{9.3 \times 10^9}{\log_{10}\left(\frac{0.1815}{0.0915}\right)}$$

$$= \frac{9.3 \times 10^9}{0.2975} = 3.1 \times 10^{10}$$

or 31,000 megohms-1000 ft

References: 1. IPCEA S-66-524, Revision No. 3 - September 1974, Cross-linked-thermosetting-polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electric Energy, Insulated Power Cable Engineers Association, Belmont, Massachusetts.

2. Table 4-14 of Standard Handbook for Electrical Engineers, Fink and Carroll, Tenth Edition, McGraw-Hill Book Company, New York.