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ENGINEERING DATA TRANSMITTAL

Page 1 of 1

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5. Proj./Prog./Dept./Div.:	**6. Design Authority/ Design Agent/Cog. Engr.:**	**7. Purchase Order No.:**
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8. Originator Remarks:		**9. Equip./Component No.:**
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1	1	Design Authority WG Brown	WG Brown	10/24/96	T4-07						
1	1	Cog.Eng. TR Benegas	TR Benegas	12/4/96	S2-24	S2-24					
1	1	Cog. Mgr. CE Hanson	CE Hanson	12/04/96	S7-12						
1	1	CP Shaw	Craig Shaw	10/23/96	S2-24						
1	1	RE Merriman	RE Merriman	10/23/96	E6-27						
1	1	RR True	R. R. True	12-19-96	4-07	3	-3-	Central Files			A3-88

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SL Taylor		Warren Brown 10/21/96	[ ] Approved
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			[ ] Disapproved w/comments

BD-7400-172-2 (05/96) GEF097

Environment Qualification of Power Cable for the Hydrogen Mitigation Pump #3

T. R. Benegas
SESC, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

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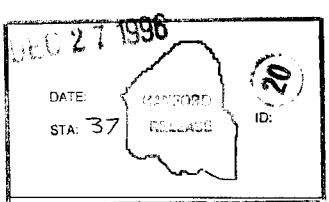
Key Words: Mitigation, Pump #3, Cables, HMR #3, 241-SY-101, Qualification

Abstract: This report presents the severe environment qualification of the power cable in severe radiation and thermal conditions. This qualification program provides Flour Daniel Hanford Company information for the use of the new cable in the mixer pump for hydrogen mitigation and retrieval purposes.



Louis J Bishop 12-27-96
Release Approval Date

Approved for Public Release

Environment Qualification of Power Cable for the Hydrogen Mitigation Pump #3

Thermal and Radiation Environment

June 21, 1996

Prepared for:

WESTINGHOUSE HANFORD COMPANY
P. O. Box 1970
Richland, Washington 99352

Prepared by:

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
3250 Port of Benton Boulevard
Richland, Washington 99352

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1.0 INTRODUCTION

The Hydrogen Mitigation Test Pump (Mixer Pump) was installed in Tank 241-SY-101 of the Hanford underground storage tanks in July 1993. The pump mixes two distinct layers of waste in the tank: a fluid upper layer and a thick slurry lower layer. Mixing of these waste layers is performed to gradually release radiochemically produced hydrogen and prevent the tank's periodic "burps". A modified version of the Hydrogen Mitigation Test Pump (Mixer Pump) can also be used in the retrieval mode where it will be used to remove fluid waste from the tank.

The Mixer Pump service environment in the waste tanks presents severe radiation, chemical and thermal conditions.

A severe environment qualification of the hydrogen mitigation test pump (Hydrogen Mitigation Test Pump #1) was performed and reported in Reference 1. Hydrogen Mitigation Test Pump #1 is presently installed in Waste Tank 241-SY-101. Hydrogen Mitigation Pump #2, presently in storage, is a backup to Hydrogen Mitigation Pump #1.

Hydrogen Mitigation Pump #3 is presently undergoing engineering design and fabrication. Hydrogen Mitigation Pump #3 is identical in design and fabrication to Hydrogen Mitigation Pump #1, except for the capability to change the motor oil in Hydrogen Mitigation Pump #3. Hydrogen Mitigation Pump #3 has the same mitigation capability of the Hydrogen Mitigation Pump #1 and can also perform in a retrieval mode. For this reason the motor/pump of Hydrogen Mitigation Pump #3 is mounted lower in a tank necessitating a longer support column, and power and instrument cables. Hydrogen Mitigation Pump #3 also uses a different power cable for the motor. This new cable must be qualified to operate in the severe thermal and radiation environment.

As with the Hydrogen Mitigation Test Pump #1 severe environment qualification program, the qualification of the power cable for Hydrogen Mitigation Pump #3 has been performed using Nuclear Regulatory Commission (NRC) and Institute of Electronic and Electrical Engineers (IEEE) guidance developed for qualifying equipment for nuclear power plants. The basis for this guidance consists of four documents:

NRC 10CFR 50.49
Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants

NRC Regulatory Guide 1.89 (Revision 1) June 1984
Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants

IEEE Standard 323 - 1974 and 1983
Qualifying Class 1E Equipment for Nuclear Power Generating Stations

IEEE Standard 383 - 1974
Type Test of Class 1E Electric Cables; Field Splicers and Connections for Nuclear Power Generating Stations.

The qualification program uses an "analysis methodology which is defined in IEEE Std 323 as:

> "Logical assessment or valid mathematical model of equipment to be qualified. Qualification consists of quantitative analysis supported by test data, operating experience or physical laws of nature to demonstrate that equipment can perform under severe conditions."

This report presents the severe environment qualification of the power cable in severe radiation and thermal conditions. This qualification program provides Westinghouse Hanford Company information for the use of the new cable in the mixer pump for hydrogen mitigation and retrieval purposes.

2.0 EQUIPMENT

The Mixer Pumps consist of four equipment subsystems: the motor/pump, the mechanical structure, instrumentation packages, and the control system.

A review of the mixer pumps' equipment interaction with the severe radiation, thermal, and chemical environment yielded the following information:

Motor/Pump

In the motor/pump subsystem, the only components sensitive to the severe environment are the power cable, motor, oil and seals. The pump indexing equipment is located in the pump pit outside the severe environment.

Mechanical Structure

The mechanical structure is made of carbon and stainless steel. These materials are not affected by the radiation environment; however, they are susceptibility to chemical/thermal environments.

Instrumentation Packages

The operating instrumentation packages on the SY-101 Mixer Pump are temperature, pressure, moisture, vibration and strain sensors. Parameters monitored include discharge leg pressure, temperature, and flow; pump discharge plenum pressure; motor vibration, oil temperature, and moisture; mixer pump column bending. Some of these instruments are located in the severe environment and are susceptible to its effects; however, the failure of these components will not affect the pump's ability to operate satisfactorily.

Control System

The Control System is located outside the tank and is not affected by the severe environment.

The power cable used in the Hydrogen Mitigation Pump #3 was supplied by Radix Wire Company. The power cable specifications, requested by Westinghouse Hanford Company, were as follows:

> Silicone rubber motor lead with K-fiber braid Type SRML-K, copper wire, Class H stranding (350 kcmil-427 strands), 600 V, 125°C minimum, UL Style 3410, Nuclear Radiation Resistance rated excellent, nominal O.D. 350 kcmil-1.06" maximum.

This cable is described by Radix Wire Company in Appendix A. Radix Wire Company Cable SRML-K is identical to SRK cable. The quality assurance element of this program established the equivalence for the two nomenclatures of the power cable.

3.0 SEVERE ENVIRONMENT CONDITIONS

The power cable operates in thermal and radiation environments associated with the Hanford underground storage tanks as well as the stress associated with the pump's operation. In order to establish the service conditions for the power cable, the severe environments of Waste Tank 241-SY-101 (SY-101) were used as the baseline. The replacement pump will be installed in Tank SY-101 and will operated until removed or failure. The pump will be operated on a schedule consistent with tank safety considerations. The pump is assumed to operate in its "mixer mode" of three times per week, for 25 minutes each time. In addition, the pump will operate in a "retrieval mode" 24 hours per day for 4 weeks. Both the "mixer" and "retrieval" mode are included in this qualification testing. This operating scenario converts to a non-operating state of 97% and a mixer and retrieval operating state of 3%. These percentages are of the time the pump is continuously in-place in the waste tank. This Hydrogen Mitigation Pump #3 mixer pump is assumed to be installed on January 1, 1997.

3.1 Thermal

The SY-101 ambient waste temperature has been established at 118°F (SAIC 1995). This is the thermal environment of the pump under non-operating conditions. Engineering analysis on Hydrogen Mitigation Pump #3, with the specified Radix cable, has established the cable temperature to be 257°F during pump operation (Merriman 1995).

3.2 Radiation

The radiation environment of the waste tank has been established using tank radiological sampling measurements. The details are presented by SAIC (1995). Allowances must be made for shielding of the cable by the exterior mechanical structure of the mixer pump. SAIC (1995) established a shielding factor of 2.9 between the dose rate and dose outside the pump and the exposure of the cable. In Table 1, the dose rate and integrated dose in the waste tank are estimated. This table also estimates the cable's integrated dose, including the shielding provided by the mixer pump's mechanical structure.

Table 1. Dose and Dose Rate Baseline

CY	Year	Dose Rate	Integrated Dose*	Shielded Cable
1997	0	758	0.0E+00	0.0E+00
2002	5	676	3.1E+07	1.1E+07
2007	10	602	5.9E+07	2.0E+07
2012	15	537	8.4E+07	2.9E+07
2017	20	479	1.1E+08	3.7E+07
2022	25	427	1.3E+08	4.4E+07
2027	30	380	1.4E+08	5.0E+07
2032	35	339	1.6E+08	5.5E+07
2037	40	302	1.7E+08	6.0E+07
2042	45	269	1.9E+08	6.4E+07
2047	50	240	2.0E+08	6.8E+07
year	years	rad/hr	rad	rad

* Dose rate and integrated dose are internal to waste tank, but external to pump.

For these estimates of radiation dose, the mixer pump is assumed to be installed in the waste tank on January 1, 1997.

4.0 QUALIFIED LIFE TESTING

4.1 Thermal and Radiation Testing

National Technical Systems, Inc. (NTS), performed the thermal aging and radiation testing of the mixer pump cable. "Environmental Qualification Test Procedure for Cable Sample" (Appendix B) describes the test procedures and "National Technical Systems, Inc., Environmental Qualification Test Report for Cable Samples" (Appendix C) presents the results of this thermal aging and radiation testing.

Six 10-foot sections of cable were provided to NTS for thermal and radiation testing. Five sections were used for testing and one was designated as spare.

For the thermal aging testing, the test procedure simulated non-operating thermal aging at 118°F for 97% of the time and mixer/retrieval operation at 257°F for 3% of the time. The cable sections were aged for equivalent service life of 20 years, 30 years, and 40 years. The thermal aging was followed by radiation exposure equivalent to 20 years, 30 years, and 40 years (i.e., 3.7×10^7 rads, 5.0×10^7 rads and 6.0×10^7 rads) service lives.

One section of cable was only thermally aged for 40 years, and another was only radiation tested for 40 years (6.0×10^7 rads) service life.

4.2 Thermal and Radiation Test Results

The test results are presented in Appendix C. The cable successfully passed the thermal aging tests for the 20, 30, and 40 years of service life. Upon radiation exposure for 20, 30, and 40 years equivalents, the cable with 40 years thermal/radiation aging/exposure failed. The cables with 20 years thermal/radiation aging, and 30 years thermal/radiation aging passed the tests conducted to the guidelines of IEEE 323 and IEEE 383 for type tests of Class IE electric cables.

5.0 SUMMARY

The power cable being used in Hydrogen Mitigation Pump #3 has undergone thermal aging and radiation qualification testing. This cable manufactured by Radix Wire Company is a silicone rubber motor lead cable.

The baseline thermal and radiation environments used for the qualification testing are equivalent to the severe environments of waste Tank 241-SY-101 of the Hanford underground storage tanks. It is assumed the Hydrogen Mixer Pump #3 is installed in the waste tank on January 1, 1997 and is non-operational 97% of the time and operational 3% of the time. The operation includes both mixing and retrieval.

The cable passed thermal aging qualification testing equivalent to 20, 30, and 40 year service life. Upon further exposure to 20, 30, and 40 year equivalent radiation environments, the cable exposed to the combined 20 and 30 year thermal/radiation environments passed the tests and are considered qualified to operate in these environments. The cable exposed to the combined 40 year thermal/radiation environments failed the tests and are not qualified to operate in this environment.

The cables exposed only to the 40 year thermal and 40 year radiation environments also passed the qualification tests.

6.0 REFERENCES

1. Science Applications International Corporation, 1995, *Severe Environments Qualification of SY-101 Hydrogen Mitigation Test Pump*, WHC-SD-WM-IT-727.

2. R. E. Merriman, 1995, *Design Analysis HMT #3-1*, WHC-Mitigation Equipment Engineering, September 21, 1995.

APPENDIX A

Radix Wire Company
Power Cable Specifications

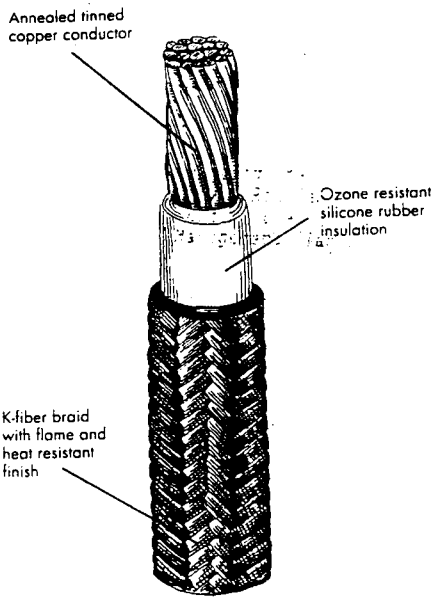
MOTOR LEAD & APPARATUS WIRE
600 VOLT 200°C, SPECIFICATION RW-20002
SIZES 26 AWG THROUGH 500 MCM
UL STYLE 3410

FEATURES
- Superior abrasion and cut-through resistance.
- High temperature resistant to 200°C.
- Flexible.
- Moisture resistant.
- Fire resistant.

APPLICATIONS
- Above grade in raceway, conduit or internal wiring of electrical equipment.
- High temperature locations with some mechanical abuse.
- Lead wire for hazardous location motors.

CONSTRUCTION
- Annealed tinned copper; solid or stranded.
- Ozone resistant silicone rubber insulation.
- K-Fiber outer braid, with a moisture, heat and flame resistant finish.
- Outer Braid may be color coded, black is standard.

COMPLIANCE
- UL listed style 3410.
- Passes UL VW-1, IEEE-383 Vertical Tray Flame Test.
- Silicone rubber insulation meets requirements of ICEA S-19-81.



SRML-K is designed for use in high temperature applications as a single conductor, flexible apparatus and lead wire where resistance to abrasion and mechanical abuse is desired. This wire is widely used in steel and glass plants, as well as hazardous location motor leads.

MOTOR LEAD & APPARATUS WIRE

600 Volt 200°C, Specification RW-20002 UL STYLE 3410

Part Number	Size AWG/ MCM	Strands/ Strand Diameter	Conductor Diameter (In)	Insulation Thickness (In)	Braid Thickness (In)	Nominal Diameter (In)	Approximate Weight (Lbs/Mft)
KGG14T007	14	7/0242	0.072	0.045	0.035	0.236	33.4
KGG12T007	12	7/0305	0.088	0.045	0.035	0.252	43.9
KGG10T007	10	7/0385	0.115	0.045	0.040	0.289	60.7
KGG08T054	8	54/0177	0.142	0.060	0.040	0.348	94.2
KGG06T084	6	84/0177	0.210	0.060	0.040	0.420	137.2
KGG04T133	4	133/0177	0.262	0.060	0.040	0.476	193.2
KGG02T259	2	259/0160	0.330	0.060	0.040	0.544	280.1
KGG01T259	1	259/0180	0.365	0.080	0.040	0.615	359.9
KGGX1T259	1/0	259/0202	0.415	0.080	0.040	0.665	444.6
KGGX2T259	2/0	259/0227	0.465	0.080	0.040	0.715	534.4
KGGX3T259	3/0	259/0255	0.514	0.080	0.040	0.764	656.9
KGGX4T259	4/0	259/0286	0.590	0.080	0.040	0.840	811.4
KGG25T427	250	427/0242	0.655	0.095	0.040	0.939	976.6
KGG35T427	350	427/0286	0.775	0.095	0.040	1.059	1327.1
KGG50T427	500	427/0342	0.923	0.095	0.040	1.213	1847.4

Please Contact Our Factory for Sizes or Information Not Listed.

All Dimensions are Nominal

APPENDIX B

Environmental Qualification Test Procedure for Cable Samples

Test Procedure No. 60776-97N
Revision 0

ENVIRONMENTAL QUALIFICATION TEST PROCEDURE FOR CABLE SAMPLES

FOR

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
3250 PORT OF BENTON BOULEVARD
RICHLAND, WA 99352

Purchase Order Number: 13-970050-90

Prepared by: _____ Date: 28 Feb 96
Charles R. Pilotte, Project Engineer, Nuclear Services
NTS/Northeast

Reviewed and Approved by: _____ Date: 28 Feb 96
Independent Reviewer, Nuclear Services
NTS/Northeast

Reviewed and Approved by: _____ Date: 28 Feb 96
Quality Representative, Nuclear Services
NTS/Northeast

Reviewed and Approved by: _____ Date: 1 March 96
SAIC Representative

CRP/sml/6077697.SAI

NTS

Test Procedure No. 60776-97N
Revision 0

ENVIRONMENTAL QUALIFICATION TEST PROCEDURE FOR CABLE SAMPLES

FOR

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
3250 PORT OF BENTON BOULEVARD
RICHLAND, WA 99352

Purchase Order Number: 13-970050-90

Prepared by: Charles R. Pilotte — **Date:** 28 Feb 96
Charles R. Pilotte, Project Engineer, Nuclear Services
NTS/Northeast

Reviewed and Approved by: Richard L. Lufsey — **Date:** 28 Feb 96
Independent Reviewer, Nuclear Services
NTS/Northeast

Reviewed and Approved by: — **Date:** 28 Feb 96
Quality Representative, Nuclear Services
NTS/Northeast

Reviewed and Approved by: _____ — **Date:** _____
SAIC Representative

CRP/sml/6077697.SAI

NTS

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1.0 SCOPE

The purpose of this qualification test procedure is to present the general requirements and methodology which shall be utilized to qualify the SAIC test items identified within Section 3.0 to the environmental conditions anticipated for its intended installation. The intent of the test program is to qualify the test items to encompass the aging requirements contained within SAIC Purchase order No. 13-970050-90. The test program is intended to meet the guidelines of IEEE 323-1983(R90) and IEEE 383-1974(R92) for type tests of Class 1E electric cables.

Specifically, this test procedure details the type testing techniques that will be utilized to provide SAIC with the environmental qualification data stipulated within SAIC Purchase Order 13-970050-90, dated 13 February 1996.

The qualification testing program outlined within this document shall be conducted in accordance with the NTS/Northeast Quality Manual, Revision 3, dated July 14, 1992. This insures that the applicable provisions of 10CFR, Part 21 and Part 50, Appendix B are fulfilled.

2.0 APPLICABLE REFERENCE DOCUMENTS

2.1 IEEE Std. 323-1983(R90), Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

2.2 IEEE 383-1974(R92), Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

2.3 NTS/Northeast Quote Number 6-016-N5668.

2.4 Science Applications International Corporation, Purchase Order No. 13-970050-90, dated 13 February 1996.

2.5 NTS/Northeast Quality Manual, Revision 3, dated July 14, 1992.

2.6 Code of Federal Regulations, Title 10, Part 21, Reporting of Defects and Noncompliance

2.7 Code of Federal Regulations, Title 10, Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

2.8 NTS/Northeast Audit Report No. NTS/A-93-030, dated May 12, 1993 of Isomedix, located in Whippany, NJ.

2.9 NTS/Northeast Report No. NTS/CGS-93-027 dated May 17, 1993 of Springborn Laboratories, located in Enfield, CT.

3.0 COMPONENT DESCRIPTION

The following cable samples will be supplied by SAIC.

Qty 6 Sample Cables; Manufacturer: Radix Wire Co.; P/N SRML-K Radix; 1/C Silicone Rubber Insulation with K-Fiber jacket; 600 VAC, 200°C; UL Style 3410. Each sample 10 feet in length minimum. Distributor: Anixter

Sample cables 1, 2, & 3 shall undergo thermal/radiation aging.

Sample cable 4 shall undergo thermal aging only.

Sample cable 5 shall undergo radiation aging only.

Sample cable 6 is a spare cable and will have activation energy determination performed on insulation jacket.

4.0 PROGRAM SEQUENCE

The environmental qualification shall be conducted in the following sequence:

1. Incoming Inspection
2. Baseline Functional Test
3. Thermal Aging
4. Post Thermal Aging Baseline Test
5. Irradiation
6. Post Irradiation Baseline Test

NOTE: The program sequence performed is per the request of SAIC.

5.0 INCOMING INSPECTION/BASELINE FUNCTIONAL TESTING

5.1 Incoming Inspection

Upon receipt of the test samples at NTS/Northeast, the test items described in Section 3.0 of this document shall be visually inspected to ensure there has been no damage due to shipping and handling and to confirm that the test item model numbers coincide with those listed in the packing list. Any anomalies shall be recorded and brought to the attention of SAIC. If there is no evidence of damage the items shall be logged in, tagged and proceed to testing.

5.2 Baseline Functional Testing

The cable sample numbers 1 through 5 with identification tags attached for traceability shall be coiled around mandrels of approximately 20 times the cable diameter. Each cable sample shall be coiled around the mandrel so that the affected section of each cable under test will be approximately 10 feet. Each cable sample shall then be subjected to the following tests.

A. Continuity Test - Measure and record the continuity of each cable sample.

B. Insulation Resistance - Submerge the test samples in tap water at room temperature. After a one (1) hour soak, measure and record the insulation resistance between the conductor and ground. A test voltage of 500 VDC will be applied for one (1) minute prior to the insulation resistance measurement.

Acceptance Criteria

Insulation resistance values should be $\geq$ 1.0 megohms for each sample.

5.0 INCOMING INSPECTION/BASELINE FUNCTIONAL TESTING (continued)

5.2 Baseline Functional Testing (continued)

C. Dielectric Withstanding Voltage - While still immersed, a test of 2X rated voltage plus 1000 (2X 600 + 1000 = 2200 VAC) will be applied for five (5) minutes.

Acceptance Criteria

No leakage in excess of 5 mA shall occur.

NTS

6.0 THERMAL AGING

The following data shall be used to determine the accelerated aging times to provide a 20 year qualified service life for sample 1, 30 year qualified life for sample 2 and a 40 year qualified life for samples 3 and 4.

6.1 Activation Energy (ev)

The weak-link age sensitive material of the subject cables is the silicone-rubber insulation.

The activation energy value for this material has not been provided by SAIC or the manufacturer of the material. NTS/Northeast shall utilize sample cable 6 for determination of activation energy. Insulation samples shall be sent to Springborn Laboratories located in Enfield, CT for Thermo Gravimetric Analysis. (TGA).

Springborn Laboratories is an approved commercial grade vendor of NTS/Northeast. NTS/Northeast shall maintain under their QA program all records pertaining to Springborn Laboratories to assure compliance with 10CFR, Part 21 and Part 50, Appendix B.

Historical data shows that for cured silicone rubber typical activation energy values fall within the range of 1.5 to 2.5 ev. NTS/Northeast shall conservatively choose a value of 1.0 ev for this program. Actual values determined by Springborn Laboratories will be included within the final test report.

Aging times based on activation energy value of 1.0 ev will be utilized unless actual results from TGA analysis are lower, in which case, calculations will be adjusted. Actual anticipated values from analysis at this time are expected to exceed 1.5 ev.

6.0 THERMAL AGING (continued)

6.2 Service Conditions

The following service temperature profile for the subject cables shall apply for each of the intended qualified service life periods (20, 30 and 40 years).

Non-operating	118°F	97% of time
Mixer/Retrieval Operation	257°F	3% of time

Adding 10% margin and converting to hours, the calculated service life becomes:

A) 118°F (48°C)

[20 years (365 days/yr) + 5 leap year days] [24 hrs/day (1.1)(.97)] = 187,066 hours

[30 years (365 days/yr) + 7 leap year days] [24 hrs/day (1.1)(.97)] = 280,587 hours

[40 years (365 days/yr) + 10 leap year days] [24 hrs/day (1.1)(.97)] = 374,133 hours

B) 257°F (125°C)

[20 years (365 days/yr) + 5 leap year days] [24 hrs/day (1.1)(.03)] = 5,786 hours

[30 years (365 days/yr) + 7 leap year days] [24 hrs/day (1.1)(.03)] = 8,678 hours

[40 years (365 days/yr) + 10 leap year days] [24 hrs/day (1.1)(.03)] = 11,571 hours

6.3 Aging Duration

Using the Arrhenius Equation, the thermal aging time required to produce the applicable qualified service life for the subject cables plus 10% margin at the service temperature conditions given, can be calculated as follows:

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

6.0 THERMAL AGING (continued)

6.3 Aging Duration (continued)

where:

t_2 = Thermal Aging Time
t_1 = Service Life

	118°F (48°C)	257°F (125°C)
20 years	187,066 hours	5,786 hours
30 years	280,587 hours	8,678 hours
40 years	374,133 hours	11,571 hours

T_1 = Service Temperature (°K) (118°F = 321°K and 257°F = 398°K)
T_2 = Thermal Aging Temperature (°K) 448°K
ϕ = Activation Energy (1.0 eV)
K = Boltzmann's Constant = .8617 x 10^{-4} eV/°K

The following table results in the calculated values for a 20, 30 and 40 year qualified service life using an aging temperature of 175°C (448°K) for T_2.

Service Life	118°F	257°F	Total Hours
20 years	6.62 hours	223.40 hours	230 hours
30 years	9.93 hours	335.05 hours	345 hours
40 years	13.25 hours	446.70 hours	460 hours

Total hours tabulated have been rounded-off to nearest hours. The four (4) cables therefore shall be aged at 175°C as follows:

Sample 1	230 Hrs = 20 Yrs + 10% Margin
Sample 2	345 Hrs = 30 Yrs + 10% Margin
Samples 3 & 4	460 Hrs = 40 Yrs + 10% Margin

During thermal aging the four (4) cables shall be mounted on mandrels. Thermal aging will be conducted within a forced hot-air temperature chamber. The aging oven temperature conditions will be continuously monitored and recorded. The test items will remain de-energized during aging.

6.0 THERMAL AGING (continued)

6.4 Post-Thermal Aging Baseline Test

Baseline functional testing as described in Section 5.2 shall be performed on all test items and results recorded on NTS/Northeast data sheets.

Following completion of post thermal testing the items shall be sent to Isomedix for Irradiation testing.

7.0 IRRADIATION

The samples listed below mounted on mandrels of approximately 20 times the O.D. of the cable shall be carefully packaged and sent to Isomedix Inc., located in Whippany, NJ for irradiation exposure.

Isomedix is an approved vendor of NTS/Northeast and complies to the applicable requirements of 10 CFR, Part 21 and Part 50, Appendix B. An audit was performed on Isomedix which resulted with Isomedix being added to NTS/Northeast Approved Vendor listing under NTS/Northeast Audit Report No. NTS/A-93-030.

Four samples as identified shall undergo irradiation testing. The Total Integrated Dose shall be as follows for each sample.

Sample 1	20 Yrs	3.7×10^7 Rads
Sample 2	30 Yrs	5×10^7 Rads
Sample 3	40 Yrs	6×10^7 Rads
Sample 5		6×10^7 Rads

The samples shall be oriented such that the irradiation source is uniformly dispersed. The samples shall be exposed to a Cobalt -60 gamma field, at a dose rate of between 5×10^5 rads per hour and 1×10^6 rads per hour.

Halfway through the irradiation exposure the test samples shall be rotated 180°(if required) to provide even distribution of gamma doses throughout the test samples.

Dosimetry will be performed using Harwell 4034 Red Perspex dosimeters, utilizing a Bausch and Lomb Model 1001 spectrophotometer as the readout instrument,or equivalent. This system is traceable to the National Institute of Standards and Technology (NIST). This system has a total uncertainty of $\pm$ 8% error.

7.0 IRRADIATION (continued)

Upon completion of testing, Isomedix shall carefully package the test samples and return them to NTS/Northeast. The cables shall remain mounted on the mandrels to minimize any damaging of the cables from handling.

Isomedix shall issue documentation identifying the samples tested, Total Integrated Dose received and equipment utilized with certification to NIST. All documentation shall be certified by an authorized Quality Assurance representative of Isomedix. The documentation issued shall be made an attachment to the final report issued by NTS/Northeast to SAIC.

7.1 Post Irradiation Baseline Test

Following the Irradiation exposure and return to NTS/Northeast the samples shall be visually inspected for any signs of damage or deterioration. The results observed shall be documented on a NTS/Northeast test data sheet.

Following this the baseline functional testing described in Section 5.2 of this procedure shall be repeated, having the same acceptance criteria.

7.1.1

After completion of the baseline testing per Section 5.2, the following additional testing shall be performed.

A) While still immersed a Dielectric Voltage test shall be performed with a test potential of 80 VAC/mil thickness of insulation. The test potential of shall be applied for a duration of five (5) minutes. Actual mil thickness of the insulation jacket shall be measured and recorded by NTS/Northeast.

B) Upon completion of step A, the cables shall be removed from the bath and allowed to dry for 24 hours. Next, the cables shall be removed from the mandrels and straightened. Following this, the cable shall be reversed wraped around the mandrels.

7.0 IRRADIATION (continued)

7.1 Post Irradiation Baseline Test (continued)

7.1.1 (continued)

C) The cables shall be submerged in the water bath and allowed to soak for a period of 1 hour.

D) A test potential of 80 VAC/mil thickness of insulation shall be applied again for a period of five (5) minutes.

Acceptance Criteria

Leakage current shall not exceed 5 maAc.

Note: The acceptance value of 5 maAc is the limits of NTS/Northeast test equipment. If leakage values of 5 maAc are achieved, NTS/Northeast will document the maximum voltage achieved. Results of steps A through D are for informational purposes only.

8.0 TEST EQUIPMENT REQUIREMENTS

All test equipment used for this program shall be checked prior to testing to assure that it is in calibration and that the parameters being measured are appropriate for the range on the measuring instrument.

Calibration is performed and checked on a routine basis using standards traceable to the National Institute of Standards and Technology (NIST). Calibration of equipment is performed in accordance with the NTS quality program.

A list of test equipment used and verification of the suitability of the measuring instrument shall be included in the final report and will document the type of equipment, accuracies, and calibration due date as a minimum.

9.0 FINAL DOCUMENTATION

Upon completion of the environmental qualification testing, NTS/Northeast will submit a single test report to SAIC. This report will include, but not be limited to, the following:

1. A detailed description of the test items with photographs for identification.
2. Results of all functional tests, including methods and equipment used.
3. A detailed description of the test setups used including photographs.
4. Thermal aging temperature recording.
5. A list of all test equipment used, the last date of calibration and frequency of calibration. (Note: All equipment is calibrated with traceability to the National Institute of Standards and Technology (NIST). The detailed records are available for review and audit at NTS/Northeast).

If applicable, anomalous results and failure to meet acceptance criteria will be noted in the test report.

APPENDIX A: TEST DATA SHEETS

NTS

DATA SHEET

Job Number	60776-97N	**Date**	**Page** of
Customer	SAIC	**Specification**	T.P. 60776-97N
Test Sample	Cable	**Model/Serial No.**	SRML-K
Test	Baseline	**Mode of Operation**	Insulation Resistance
Purchase Order No.	13-970050-90		

Remarks Cables submerged in water bath.
Apply 500 VDC for a period of one (1) minute.
Value of IR measured to be $\geq 1x10^6$ ohms.

			values in ohms			
	Initial Baseline		Post Thermal		Post Irradiation	
Sample #						
1						
2						
3						
4					N/A	
5			N/A			

Inspector:

Test Engineer:

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DATA SHEET

Job Number	60776-97N		**Date**	**Page** of
Customer	SAIC		**Specification**	T.P. 60776-97N
Test Sample	Cable		**Model/Serial No.**	SRML-K
Test	Baseline		**Mode of Operation**	Dielectric Voltage
Purchase Order No.	13-970050-90			@ 2200 VAC

Remarks Cables submerged in water bath.
Apply 2200 VAC for a duration of 5.0 minutes
Leakage current to be 5 MaAc or less.

			Leakage maAC			
	Initial Baseline		Post Thermal		Post Irradiation	
Sample #						
1						
2						
3						
4					N/A	
5			N/A			

Inspector:

Test Engineer:

Form 20.2

NTS

DATA SHEET

Job Number	60776-97N	Date	Page of
Customer	SAIC	Specification	T.P. 60776-97N
Test Sample	Cable	Model/Serial No.	SRML-K
Test	Post Thermal, Irradiation	Mode of Operation	Dielectric Voltage
Purchase Order No.	13-970050-90		

Remarks
1) Cables submerged in water bath. Apply 80 VAC/mil of insulation for five (5) minutes.
2) Remove cable and allow to dry for 24 hours.
3) Remove cable, straighten cable and reverse wrap on mandrel.
4) Re-submerge cable in water and apply 80 VAC/mil of insulation for 5 minutes.

			Leakage maAC			
		Normal Mandrel Wrap		Reverse Mandrel Wrap		
Sample #						
1						
2						
3						
4						
5						

Leakage current shall not exceed 5 maAc.

NOTES: Samples 1, 2 and 3 are post thermal, irradiation.
Sample 4 is post thermal only.
Sample 5 is post irradiation only.

Inspector:

Test Engineer:

Form 20.2

APPENDIX C

National Testing Systems, Inc. Environmental Qualification Test Report for Cable Samples

NTS

Test Report No. 60776-97N
Revision 0

ENVIRONMENTAL QUALIFICATION TEST REPORT FOR CABLE SAMPLES

FOR

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
3250 PORT OF BENTON BOULEVARD
RICHLAND, WA 99352

Purchase Order Number: 13-970050-90

Prepared by: Charles R. Pilotte — **Date:** 24 April 96
Charles R. Pilotte, Project Engineer, Nuclear Services
NTS/Northeast

Reviewed and Approved by: Keith L. Ryan — **Date:** 25 April 1996
Independent Reviewer, Nuclear Services
NTS/Northeast

Reviewed and Approved by: — **Date:** 4/25/96
Quality Representative, Nuclear Services
NTS/Northeast

CRP/sml/6077697.SAI

NTS

TABLE OF CONTENTS

1.0 SCOPE

The purpose of this qualification test report is to present the general requirements and methodology which was utilized to qualify the SAIC test items identified within Section 3.0 to the environmental conditions anticipated for its intended installation. The intent of the test program was to qualify the test items to encompass the aging requirements contained within SAIC Purchase order No. 13-970050-90. The test program was conducted to the guidelines of IEEE 323-1983(R90) and IEEE 383-1974(R92) for type tests of Class 1E electric cables.

Specifically, this test report details the type testing techniques that were utilized to provide SAIC with the environmental qualification data stipulated within SAIC Purchase Order 13-970050-90, dated 13 February 1996 and the results of the testing activities.

The qualification testing program outlined within this report was conducted in accordance with the NTS/Northeast Quality Manual, Revision 3, dated July 14, 1992. This insures that the applicable provisions of 10CFR, Part 21 and Part 50, Appendix B are fulfilled.

2.0 APPLICABLE REFERENCE DOCUMENTS

2.1 IEEE Std. 323-1983(R90), Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

2.2 IEEE 383-1974(R92), Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

2.3 NTS/Northeast Quote Number 6-016-N5668.

2.4 Science Applications International Corporation, Purchase Order No. 13-970050-90, dated 13 February 1996.

2.5 NTS/Northeast Quality Manual, Revision 3, dated July 14, 1992.

2.6 Code of Federal Regulations, Title 10, Part 21, Reporting of Defects and Noncompliance

2.7 Code of Federal Regulations, Title 10, Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

2.8 NTS/Northeast Audit Report No. NTS/A-93-030, dated May 12, 1993 of Isomedix, located in Whippany, NJ.

2.9 NTS/Northeast Report No. NTS/CGS-93-027 dated May 17, 1993 of Springborn Laboratories, located in Enfield, CT.

2.10 NTS/Northeast Test Procedure No. 60776-97N, Rev. 0, dated 1 March 1996.

3.0 COMPONENT DESCRIPTION

The following cable samples were supplied by SAIC.

Qty 6 Sample Cables; Manufacturer: Radix Wire Co.; P/N SRML-K Radix; 1/C Silicone Rubber Insulation with K-Fiber jacket; 600 VAC, 200°C; UL Style 3410. Each sample 10 feet in length minimum. Distributor: Anixter

Sample cables 1, 2, & 3 underwent thermal/radiation aging.

Sample cable 4 underwent thermal aging only.

Sample cable 5 underwent radiation aging only.

Sample cable 6 was a spare cable and had activation energy determination performed on the insulation jacket.

4.0 PROGRAM SEQUENCE

The environmental qualification was conducted in the following sequence:

1. Incoming Inspection
2. Baseline Functional Test
3. Thermal Aging
4. Post Thermal Aging Baseline Test
5. Irradiation
6. Post Irradiation Baseline Test

NOTE: The program sequence performed was per the request of SAIC.

5.0 INCOMING INSPECTION/BASELINE FUNCTIONAL TESTING

5.1 Incoming Inspection

Upon receipt of the test samples at NTS/Northeast, the test items described in Section 3.0 of this document were visually inspected to ensure there has been no damage due to shipping and handling and to confirm that the test item model numbers coincide with those listed in the packing list. There was no evidence of damage and the items were logged in, tagged and proceeded to testing.

5.2 Baseline Functional Testing

The cable sample numbers 1 through 5 with identification tags attached for traceability were coiled around mandrels having a diameter of 18 inches. Each cable sample was coiled around the mandrel so that the affected section of each cable under test was approximately 10 feet. Each cable sample was then subjected to the following tests. Appendix A of this report contains actual data sheets and values recorded.

A. Continuity Test - Measure and record the continuity of each cable sample.

B. Insulation Resistance - Submerge the test samples in tap water at room temperature. After a one (1) hour soak, measure and record the insulation resistance between the conductor and ground. A test voltage of 500 VDC will be applied for one (1) minute prior to the insulation resistance measurement.

Results

Insulation resistance values were $\geq$ 1.0 megohms for each sample.

5.0 INCOMING INSPECTION/BASELINE FUNCTIONAL TESTING (continued)

5.2 Baseline Functional Testing (continued)

C. Dielectric Withstanding Voltage - While still immersed, a test of 2X rated voltage plus 1000 (2X 600 + 1000 = 2200 VAC) was applied for five (5) minutes.

Results

No leakage in excess of 5 mAAC occurred. Actual leakage average was 1.9 mAAC for initial baseline, 2.03 mAAC for post thermal and 2.05 mAAC for post irradiation. For a test potential of 2200 VAC, 60 Hz, this results in an impedance of 1.16×10^6 ohms for initial baseline, 1.08×10^6 ohms for post thermal and 1.07×10^6 ohms for post irradiation. Actual values recorded for each cable are contained within Appendix A of this report.

6.0 THERMAL AGING

The following data was used to determine the accelerated aging times to provide a 20 year qualified service life for sample 1, 30 year qualified life for sample 2 and a 40 year qualified life for samples 3 and 4.

6.1 Activation Energy (ev)

The weak-link age sensitive material of the subject cables is the silicone-rubber insulation.

The activation energy value for this material had not been provided by SAIC or the manufacturer of the material. NTS/Northeast utilized sample cable 6 for determination of activation energy. Insulation samples were sent to Springborn Laboratories located in Enfield, CT for Thermo Gravimetric Analysis. (TGA).

Springborn Laboratories is an approved commercial grade vendor of NTS/Northeast. NTS/Northeast maintains under their QA program all records pertaining to Springborn Laboratories to assure compliance with 10CFR, Part 21 and Part 50, Appendix B.

Historical data shows that for cured silicone rubber typical activation energy values fall within the range of 1.5 to 2.5 ev. NTS/Northeast conservatively used a value of 1.0 ev for this program. Actual values determined by Springborn Laboratories were 1.43 to 1.61 eV depending on weight loss. Appendix B of this report contains the analytical report provided by Springborn Laboratories.

Aging times based on activation energy value of 1.0 ev were utilized which provided an adequate margin of conservatism.

6.0 THERMAL AGING (continued)

6.2 Service Conditions

The following service temperature profile for the subject cables applies for each of the intended qualified service life periods (20, 30 and 40 years).

Non-operating	118°F	97% of time
Mixer/Retrieval Operation	257°F	3% of time

Adding 10% margin and converting to hours, the calculated service life becomes:

A) 118°F (48°C)

[20 years (365 days/yr) + 5 leap year days] [24 hrs/day (1.1)(.97)] = 187,066 hours

[30 years (365 days/yr) + 7 leap year days] [24 hrs/day (1.1)(.97)] = 280,587 hours

[40 years (365 days/yr) + 10 leap year days] [24 hrs/day (1.1)(.97)] = 374,133 hours

B) 257°F (125°C)

[20 years (365 days/yr) + 5 leap year days] [24 hrs/day (1.1)(.03)] = 5,786 hours

[30 years (365 days/yr) + 7 leap year days] [24 hrs/day (1.1)(.03)] = 8,678 hours

[40 years (365 days/yr) + 10 leap year days] [24 hrs/day (1.1)(.03)] = 11,571 hours

6.3 Aging Duration

Using the Arrhenius Equation, the thermal aging time required to produce the applicable qualified service life for the subject cables plus 10% margin at the service temperature conditions given, was calculated as follows:

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

6.0 THERMAL AGING (continued)

6.3 Aging Duration (continued)

where:

t_2 = Thermal Aging Time
t_1 = Service Life

	118°F (48°C)	257°F (125°C)
20 years	187,066 hours	5,786 hours
30 years	280,587 hours	8,678 hours
40 years	374,133 hours	11,571 hours

T_1 = Service Temperature (°K) (118°F = 321°K and 257°F = 398°K)
T_2 = Thermal Aging Temperature (°K) 448°K
ϕ = Activation Energy (1.0 eV)
K = Boltzmann's Constant = $.8617 \times 10^{-4}$ eV/°K

The following table results in the calculated values for a 20, 30 and 40 year qualified service life using an aging temperature of 175°C (448°K) for T_2.

Service Life	118°F	257°F	Total Hours
20 years	6.62 hours	223.40 hours	230 hours
30 years	9.93 hours	335.05 hours	345 hours
40 years	13.25 hours	446.70 hours	460 hours

Total hours tabulated were rounded-off to nearest hours. The four (4) cables therefore were aged at 175°C as follows:

Sample 1	230 Hrs = 20 Yrs + 10% Margin
Sample 2	345 Hrs = 30 Yrs + 10% Margin
Samples 3 & 4	460 Hrs = 40 Yrs + 10% Margin

During thermal aging the four (4) cables were mounted on mandrels. Thermal aging was conducted within a forced hot-air temperature chamber. The aging oven temperature conditions were continuously monitored and recorded. The test items remained de-energized during aging. Each cable sample was removed from the chamber when the appropriate aging time had elapsed. Appendix C contains actual chart recordings and Appendix E contains photographs.

6.0 THERMAL AGING (continued)

6.4 Post-Thermal Aging Baseline Test

Baseline functional testing as described in Section 5.2 was performed on all test items and results recorded on NTS/Northeast data sheets contained within Appendix A.

Results

Visual observation showed that all cables had some darkening of the silicone insulation and tarnishing of wire conductor strands.

All cable samples had insulation resistance and dielectric voltage results which met the original acceptance criteria. See data sheets contained in Appendix A.

7.0 IRRADIATION

The samples listed below mounted on mandrels of approximately 18 inch diameter were carefully packaged and sent to Isomedix Inc., located in Whippany, NJ for irradiation exposure.

Isomedix is an approved vendor of NTS/Northeast and complies to the applicable requirements of 10 CFR, Part 21 and Part 50, Appendix B. An audit was performed on Isomedix which resulted with Isomedix being added to NTS/Northeast Approved Vendor listing under NTS/Northeast Audit Report No. NTS/A-93-030.

Four samples as identified underwent irradiation testing. The Total Integrated Dose was as follows for each sample.

Sample 1	20 Yrs	3.7×10^7 Rads
Sample 2	30 Yrs	5×10^7 Rads
Sample 3	40 Yrs	6×10^7 Rads
Sample 5		6×10^7 Rads

The samples were oriented such that the irradiation source was uniformly dispersed. The samples were exposed to a Cobalt -60 gamma field, at a dose rate of between 5×10^5 rads per hour and 1×10^6 rads per hour.

Per Isomedix the samples were rotated in 90° turns during irradiation to insure even exposure. To prevent shielding effects from solid mandrels, NTS/Northeast transferred the cables to mandrels of the same diameter constructed of wire mesh to allow for full penetration. This was done without the coils being uncoiled, as they were slid from one mandrel to another and accomplished prior to sending the cables to Isomedix.

Dosimetry was performed using Harwell 4034 Red Perspex dosimeters, utilizing a Bausch and Lomb Model 1001 spectrophotometer as the readout instrument,or equivalent. This system is traceable to the National Institute of Standards and Technology (NIST). This system has a total uncertainty of ± 8% error.

7.0 IRRADIATION (continued)

Upon completion of testing, Isomedix carefully packaged the test samples and return them to NTS/Northeast. The cables remained mounted on the mandrels to minimize any damaging of the cables from handling and shipping. Upon return of the cables to NTS/Northeast, the cables were inspected for visual signs of damage with none being noted.

Isomedix issued documentation identifying the samples tested, Total Integrated Dose received and equipment utilized with certification to NIST. All documentation was certified by an authorized Quality Assurance representative of Isomedix. The documentation issued is contained within Appendix D of this report.

7.1 Post Irradiation Baseline Test

The baseline function testing described in Section 5.2 of this report was repeated, having the same acceptance criteria.

Results

All cables met the acceptance criteria contained within Section 5.2.

7.1.1

After completion of the baseline testing per Section 5.2, the following additional testing was performed.

A) While still immersed, a Dielectric Voltage Test was performed with a test potential of 5400 VAC to 5600 VAC, depending on the cable being tested. The potential was applied for a duration of five (5) minutes. The applied potential was limited to a measured leakage current of 5 mAAC, which is the limit of the NTS/Northeast tester.

B) Upon completion of step A, the cables were removed from the bath and allowed to dry for 24 hours. Next, the cables were removed from the mandrels and straightened. Following this, the cables were reversed wrapped around the mandrels.

NTS

7.0 IRRADIATION (continued)

7.1 Post-Irradiation Baseline Test (continued)

7.1.1 (continued)

C) The cables were submerged in the water bath and allowed to soak for a period of 1 hour.

D) A test potential of 5400 VAC to 5600 VAC was applied again for a period of five (5) minutes.

Results

1. All cables met the acceptance criteria for insulation resistance and dielectric withstand voltage testing at 2200 VAC and continuity testing.

2. Testing at elevated dielectric withstand voltages was limited to 5 mAAC, the maximum leakage current permissible by NTS/Northeast tester which resulted in test voltages of 5400 to 5600 VAC.

3. The resulting impedance at 5 mAAC leakage current for potentials of 5400 to 5600 VAC results in values of 1.08×10^6 ohms to 1.12×10^6 ohms. This is consistent with those values determined at 2200 VAC, which yielded results of 1.07×10^6 ohms to 1.16×10^6 ohms. Therefore, the integrity of the cables insulation was upheld when tested at higher voltages, except for sample #3 as detailed below.

4. On sample #3 the cable having been exposed to 40 year thermal/radiation failed to pass after having been reversed wrapped on the mandrel. A leakage of 5 mAAC was seen with only a potential of 5 VAC applied. Further discussion is provided in Section 8.0, Conclusions and Observations, of this report.

8.0 CONCLUSIONS AND OBSERVATIONS

The cable samples #1 through 5 were aged as detailed in Sections 3.0, 6.0 and 7.0 of this report. As a result of all testing, sample #3 failed to pass the reverse mandrel high voltage testing, which was the final phase of testing.

Suspect was that irradiation was a major contributor to cable embrittlement. To evaluate this at the completion of all testing sample #3 and sample #4 cables had a section of the K-fiber removed from the center length of each cable. Sample #4 saw 40 years thermal aging, while sample #3 saw 40 years thermal/radiation aging. On sample #3 a large crack around the circumference of the silicone rubber was found. No cracking of sample #4 was noted. The cracks found on sample #3 occurred during reverse mandrel wrapping of the cable because of embrittlement.

From each cable sample #1 through 6 a piece of silicone rubber approximately 1½ inches in length was removed from the cable and examined for signs of embrittlement. Sample #6 was a spare cable and was not aged. Silicone rubber from samples #1 through 5 were compared against sample #6. The following observations were noted.

On sample #4 which was thermally aged only to 40 years, the silicone was found pliable, similar to sample #6, the unaged cable. However, it was found that sample #4 was less resistant to being torn indicating that some elasticity had been lost.

On samples #1, 2, 3 and 5, all samples revealed embrittlement. Sample #5 which received radiation only appeared equal to cracking and breaking of material when flexed when compared to sample #3.

8.0 CONCLUSIONS AND OBSERVATIONS (continued)

Samples #1 and 2 had embrittlement but for each sample the silicone rubber could be flexed to a further degree before causing cracking.

Exposure to irradiation was the principle cause to embrittlement. All samples passed testing with the exception of sample #3 undergoing the reverse mandrel wrap testing. Therefore, qualification to a 20 and 30 year life was achieved with the 40 year qualification attempt being unsuccessful.

9.0 TEST EQUIPMENT LIST

All test equipment used for this program was checked prior to testing to assure that it was in calibration and that the parameters being measured were appropriate for the range on the measuring instrument.

Calibration is performed and checked on a routine basis using standards traceable to the National Institute of Standards and Technology (NIST). Calibration of equipment is performed in accordance with the NTS quality program.

A list of test equipment used and verification of the suitability of the measuring instrument is included on the following page.

LIST GENERATED ON : 04/24/96

NTS Equipment List
FOR MJO # 60776 -97N

INV #	DESCRIPTION	MANUFACTURER	MODEL #	SERIAL #	RANGE	ACCURACY	CAL FREQ (months)	CAL DUE DATE	CAL STATUS
CH396	TEMPERATURE CHAMBER	THERMOTRON	M-30-CH-3	6433	AMBIENT TO 200C	+/-(2C<OC<1.25C	12	10/12/96	CAL
FM303	POWER SYSTEM TIMER	JODICE	FT-2	04333008	0 TO 999 SECCONDS	+/- 1 DIGIT	12	05/22/96	CAL
FM343	STOP WATCH	COLE-PARMER	L-08610-16	NONE	60 MINUTES	+/-.001%	12	12/08/96	CAL
ML379	DIGITAL MULTIMETER	FLUKE	8842A	4727322	0 TO 1000VDC	SEE MFGR'S SPEC	6	05/10/96	CAL
ML396	DIGITAL MULTIMETER	FLUKE	8842A	5456278	0 TO 1000VDC	SEE MFGR'S SPEC	6	06/30/96	CAL
PA517	AC/DC HI POT	HIPOTRONICS	HD125	9870-01	AC TO 10kV,DC TO 25kV	DC METER:+/-2.8	6	07/05/96	CAL
ZB327	MEGOHMETER	GENERAL RADIO	1862C	2477	0.5 MEGOHMS TO 2M MEGOHMS	+/-3% TO+/-12%	6	06/14/96	CAL
ZR541	MEGOHM METER	GENERAL RADIO	1863	1863-9700	100K TO 1 TERA OHM	+/-2 (RDG+1)%	12	08/04/96	CAL

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CALIBRATION ABBREVIATIONS

UWCE - USE WITH CALIBRATED EQUIPMENT
CBU - CALIBRATE BEFORE USE
NOM - NOT USED FOR QUANTITATIVE MEASUREMENTS
CAL - CALIBRATED

NTS

APPENDIX A

NTS TEST DATA SHEETS

NTS

DATA SHEET

Job Number	60776-97N	Date See Below	Page 1 of 1
Customer	SAIC	Specification	T.P. 60776-97N
Test Sample	Cable	Model/Serial No.	SRML-K
Test	Baseline	Mode of Operation	Insulation Resistance
Purchase Order No.	13-970050-90		

Remarks: Cables submerged in water bath.
Apply 500 VDC for a period of one (1) minute.
Value of IR measured to be ≥ $1x10^6$ ohms.

values in ohms

	Initial Baseline		Post Thermal		Post Irradiation	
Date →	3/12/96		4/1/96		4/17-4/18/96	
Sample #						
1	$>1X10^{12}\Omega$		$>2X10^{11}\Omega$		$>5X10^{11}\Omega$	
2	$>1X10^{12}\Omega$		$>1X10^{12}\Omega$		$>1X10^{12}\Omega$	
3	$>1X10^{12}\Omega$		$>1X10^{12}\Omega$		$>1X10^{12}\Omega$	
4	$>1X10^{12}\Omega$		$>5X10^{11}\Omega$		N/A	
5	$>1X10^{12}\Omega$		N/A		$>1X10^{12}\Omega$	

Inspector: Robert A Powers

Test Engineer: Charles R Pickett

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DATA SHEET

Job Number	60776-97N	Date 3/26/96	Page 1 of 1
Customer	SAIC	Specification	T.P. 60776-97N
Test Sample	Cable	Model/Serial No.	SRML-K
Test	Baseline	Mode of Operation	Dielectric Voltage
Purchase Order No.	13-970050-90		@ 2200 VAC

Remarks: Cables submerged in water bath.
Apply 2200 VAC for a duration of 5.0 minutes
Leakage current to be 5 MaAc or less.

			Leakage maAC			
	Initial Baseline		Post Thermal		Post Irradiation	
Date →	3/12/96		4/1/96		4/17 - 4/18	
Sample #						
1	1.9		2.2		2.1	
2	1.9		2.0		2.1	
3	1.9		2.0		2.0	
4	1.9		1.9		N/A	
5	1.9		N/A		2.0	

Inspector: Robert Romero

Test Engineer: Sandra R. Roberts

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DATA SHEET

Job Number	60776-97N	Date 12/12	Page 1 of 1
Customer	SAIC	Specification	T.P. 60776-97N
Test Sample	Cable	Model/Serial No.	SRML-K
Test	Post Thermal, Irradiation	Mode of Operation	Dielectric Voltage
Purchase Order No.	13-970050-90		

Remarks
1) Cables submerged in water bath. Apply 80 VAC/mil of insulation for five (5) minutes.
2) Remove cable and allow to dry for 24 hours.
3) Remove cable, straighten cable and reverse wrap on mandrel.
4) Re-submerge cable in water and apply 80 VAC/mil of insulation for 5 minutes.

			Leakage maAC			
		Normal Mandrel Wrap		Reverse Mandrel Wrap		
Sample #						
1	4/18/96 IT	5mAAC @ 5500VAC		5mAAC @ 5600VAC		4/19/96
2	4/19/96	5mAAC 5400VAC		5mAAC @ 5400VAC		4/20/96
3	4/19/96	5mAAC @ 5500VAC		5mAAc @ 5VAC	*	4/20/96
4	4/2/96 CRP	5mAAC @ 5600VAC		5mAAc @ 5600VAC		4/3/96 CRP
5	4/19/96	5mAAC @ 5400VAC		5mAAC @ 5400VAC		4/20/96

Leakage current shall not exceed 5 maAc.

NOTES: Samples 1, 2 and 3 are post thermal, irradiation.
Sample 4 is post thermal only.
Sample 5 is post irradiation only.

* Failure

Inspector: Robert A Forrest
Test Engineer: Charles R Abbott

Form 20.2

Procedure No. 60776-97N
Revision 0
~~Page No. A-4~~

NTS

APPENDIX B

ANALYTICAL REPORT BY SPRINGBORN LABORATORIES

Report No. 60776-97N
Revision 0
~~Page No. B-1~~

Springborn Laboratories, Inc.
Applied Physical Sciences Division
One Springborn Center, Enfield, Connecticut 06082-4899 • (860) 749-8371 • Telex 4436041 • Facsimile (860) 749-7533 • 749-8234

Project No. 11885.0113
March 20, 1996

ANALYTICAL REPORT

CLIENT: National Technical Systems
533 Main Street
Acton, MA 01720

ATTENTION: Charles Pilotte

AUTHORIZATION: Purchase Order No. 50709N

SAMPLES RECEIVED: (03/06/96) TRACECODE: A96.0081

Two (2) Samples labeled: K-Fiber Braid and Silicone Rubber

ANALYSIS REQUESTED:

Activation Energy

RESULTS AND DISCUSSION:

Thermal analysis was performed on the submitted samples using a DuPont 9000 thermal analyzer equipped with a DuPont 951 TGA. The samples were analyzed from 25°C to 710°C at 5, 10 and 20°C/minutes under nitrogen. The data was collected and stored on an Omnitherm Xtra Data Acquisitioner. The activation energy was determined at 5, 10, 20 and 50% weight loss. The results of this analysis are found on the attached table.

Please contact us if you have any questions regarding these results or if you require additional information.

Judith V. Haber
Project Leader
Analytical Chemistry

Edward F. Kozloski
Laboratory Manager

60776

 2

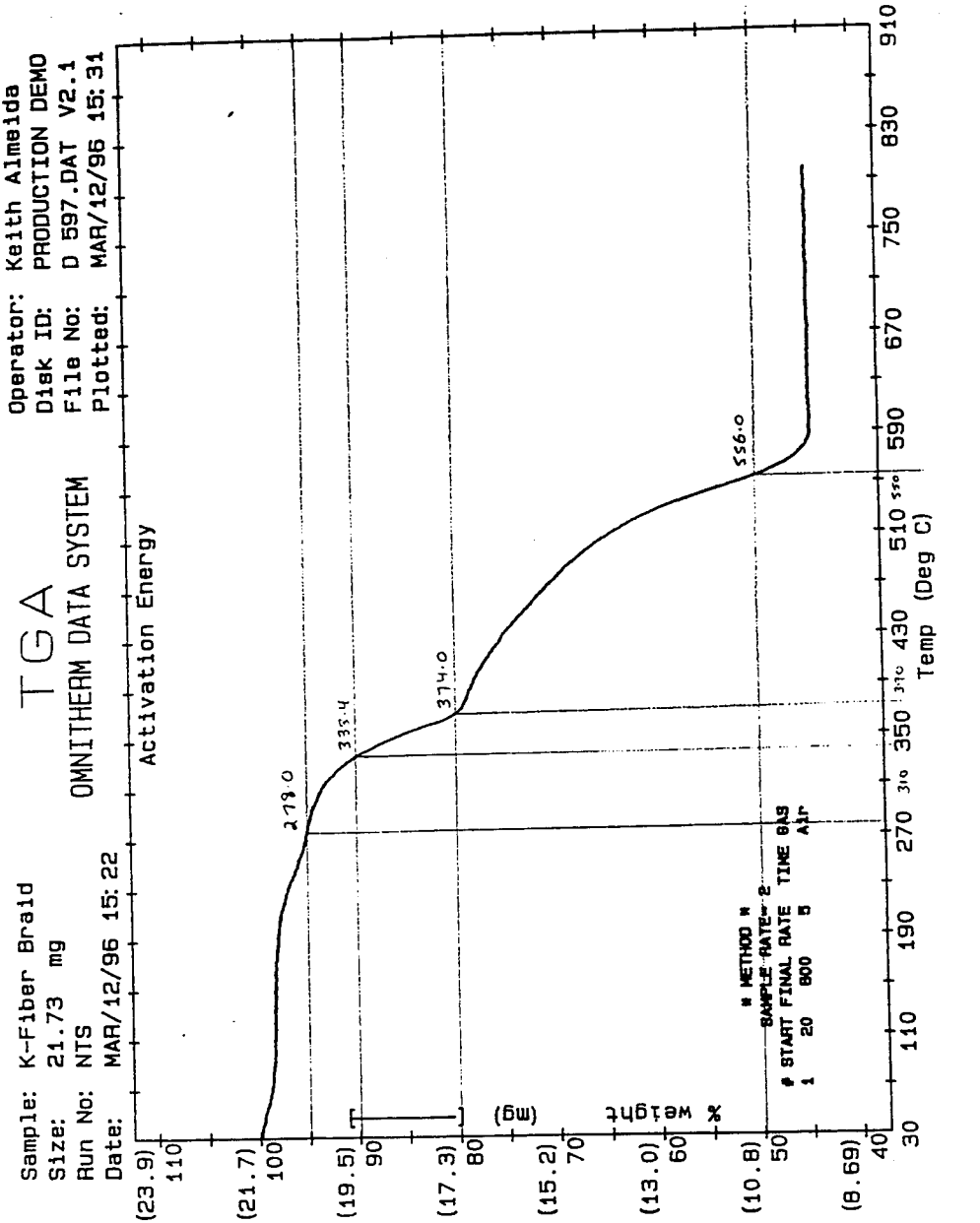
Springborn Laboratories

Project No. 11885.0113
March 20, 1996
NTS
Page Two

RESULTS TABLE				
Sample	Activation Energy (eV)			
	5% Wt Loss	10% Wt Loss	20% Wt Loss	50% Wt Loss
K-Fiber Braid	0.69	1.47	0.44	No 50% loss
Silicone Rubber	1.61	1.76	1.43	No 50% loss

60776

B-50


Sample: K-Fiber Braid
Size: 21.73 mg
Run No: NTS
Date: MAR/12/96 15:22
TGA
OMNITHERM DATA SYSTEM
Activation Energy
Operator: Keith Almeida
Disk ID: PRODUCTION DEMO
File No: D 597.DAT V2.1
Plotted: MAR/12/96 15:31
279.0
333.4
374.0
556.0
% weight
(mg)
Temp (Deg C)
(23.9)
(21.7)
(19.5)
(17.3)
(15.2)
(13.0)
(10.8)
(8.69)
110
100
90
80
70
60
50
40
30
110
190
270
350
430
510
590
670
750
830
910
METHOD
SAMPLE RATE= 2
START FINAL RATE TIME GAS
1 20 800 5 Air

60776

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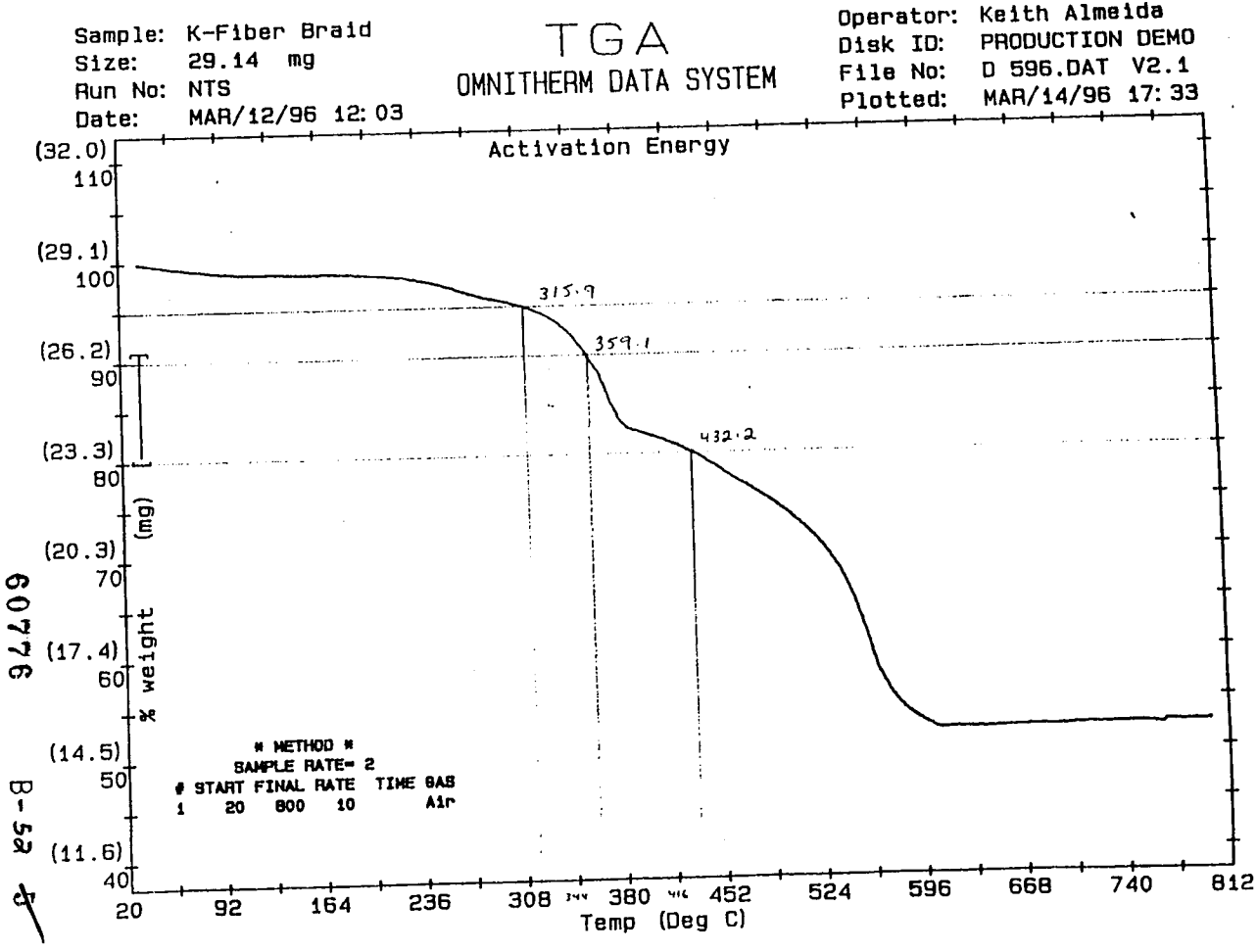

60776

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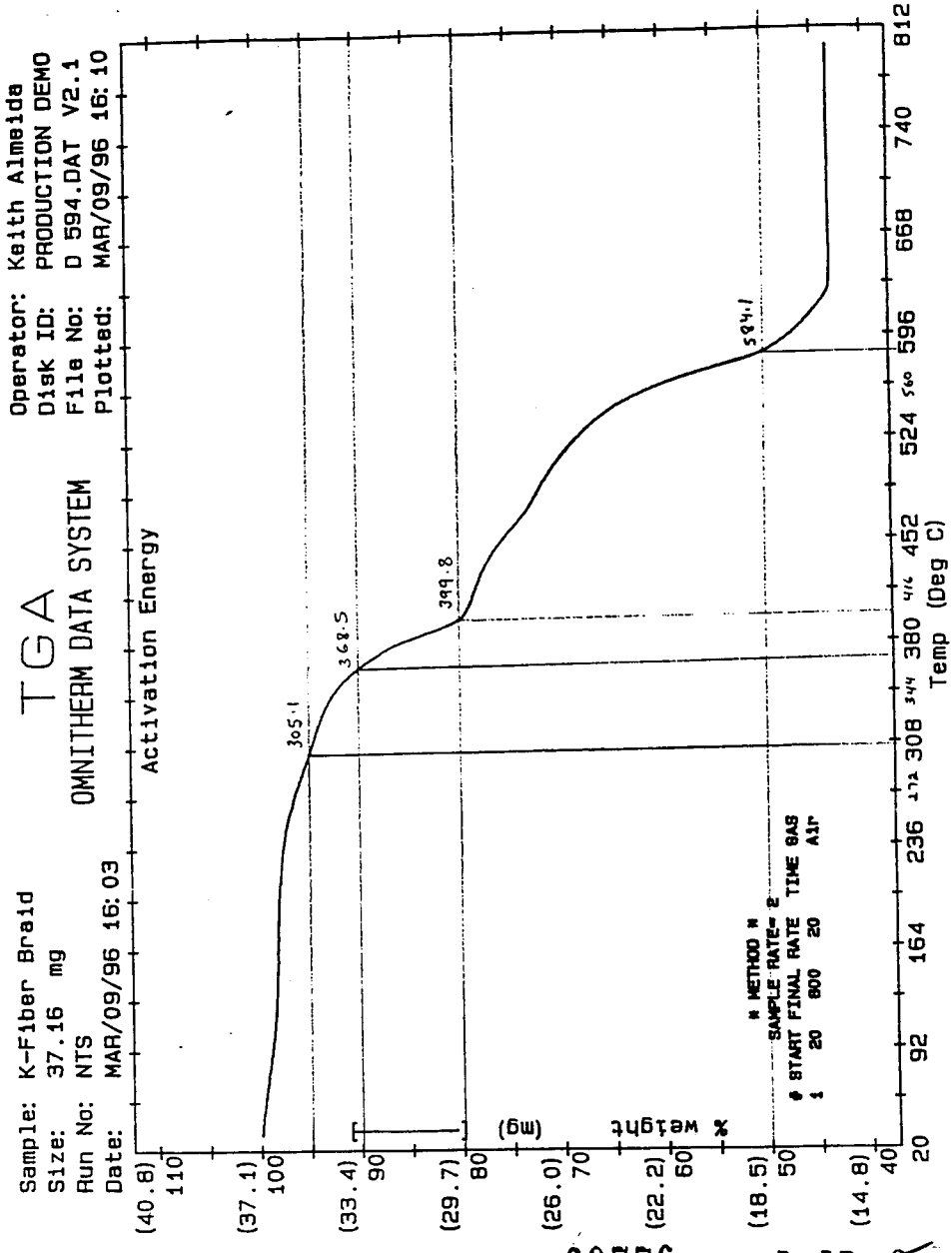
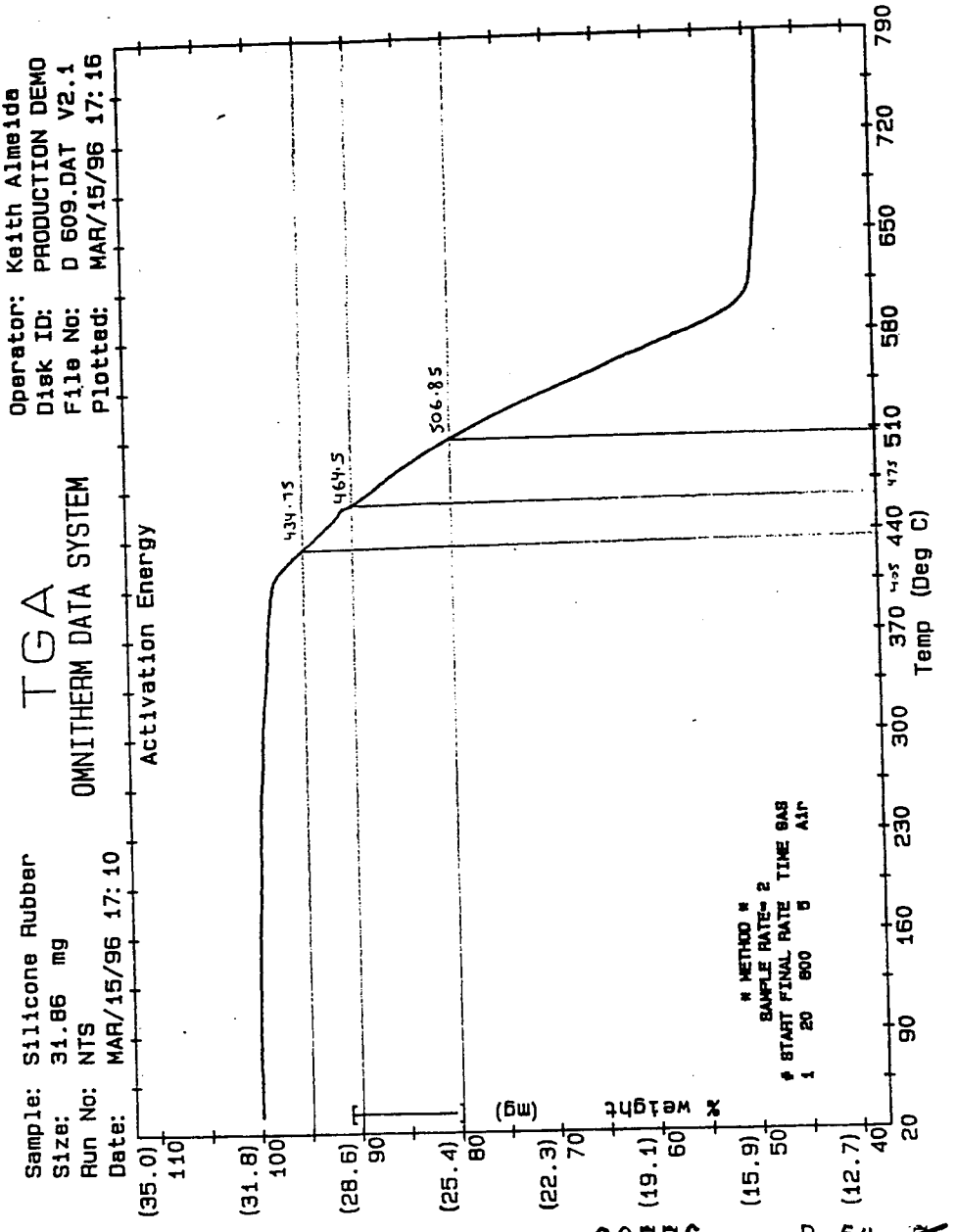
WHC-SD-WM-TI-758, Rev. 0


Sample: K-Fiber Braid
Size: 37.16 mg
Run No: NTS
Date: MAR/09/96 16:03
TGA
OMNITHERM DATA SYSTEM
Activation Energy
Operator: Keith Almeida
Disk ID: PRODUCTION DEMO
File No: D 594.DAT V2.1
Plotted: MAR/09/96 16:10
305.1
368.5
399.8
594.1
% weight
(mg)
Temp (Deg C)
" METHOD "
SAMPLE RATE= 2
START FINAL RATE TIME GAS
1 20 800 20 Air

60776

B-53


Sample: Silicone Rubber
Size: 31.86 mg
Run No: NTS
Date: MAR/15/96 17:10
TGA
OMNITHERM DATA SYSTEM
Activation Energy
Operator: Keith Almeida
Disk ID: PRODUCTION DEMO
File No: D 609.DAT V2.1
Plotted: MAR/15/96 17:16
434.75
464.5
506.85
METHOD
SAMPLE RATE= 2
START FINAL RATE TIME GAS
1 20 800 5 Air
% weight
(mg)
Temp (Deg C)
(35.0) 110
(31.8) 100
(28.6) 90
(25.4) 80
(22.3) 70
(19.1) 60
(15.9) 50
(12.7) 40
20 90 160 230 300 370 440 510 580 650 720 790

60776

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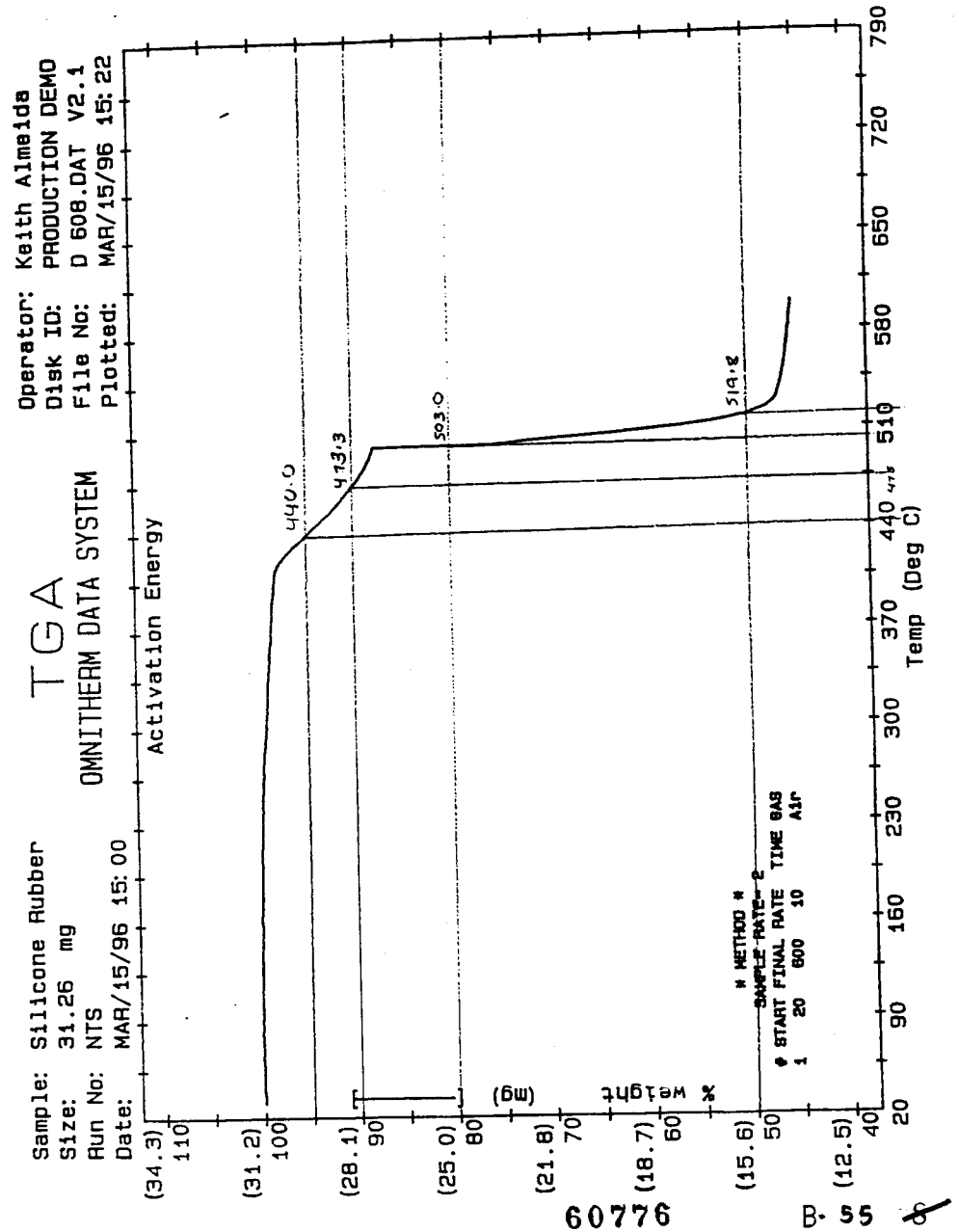
Sample: Silicone Rubber
Size: 31.26 mg
Run No: NTS
Date: MAR/15/96 15:00
TGA
OMNITHERM DATA SYSTEM
Activation Energy
Operator: Keith Almeida
Disk ID: PRODUCTION DEMO
File No: D 608.DAT V2.1
Plotted: MAR/15/96 15:22
440.0
473.3
503.0
519.2
% weight
(mg)
Temp (Deg C)
METHOD
SAMPLE RATE= 2
START FINAL RATE TIME GAS
1 20 600 10 Air

60776

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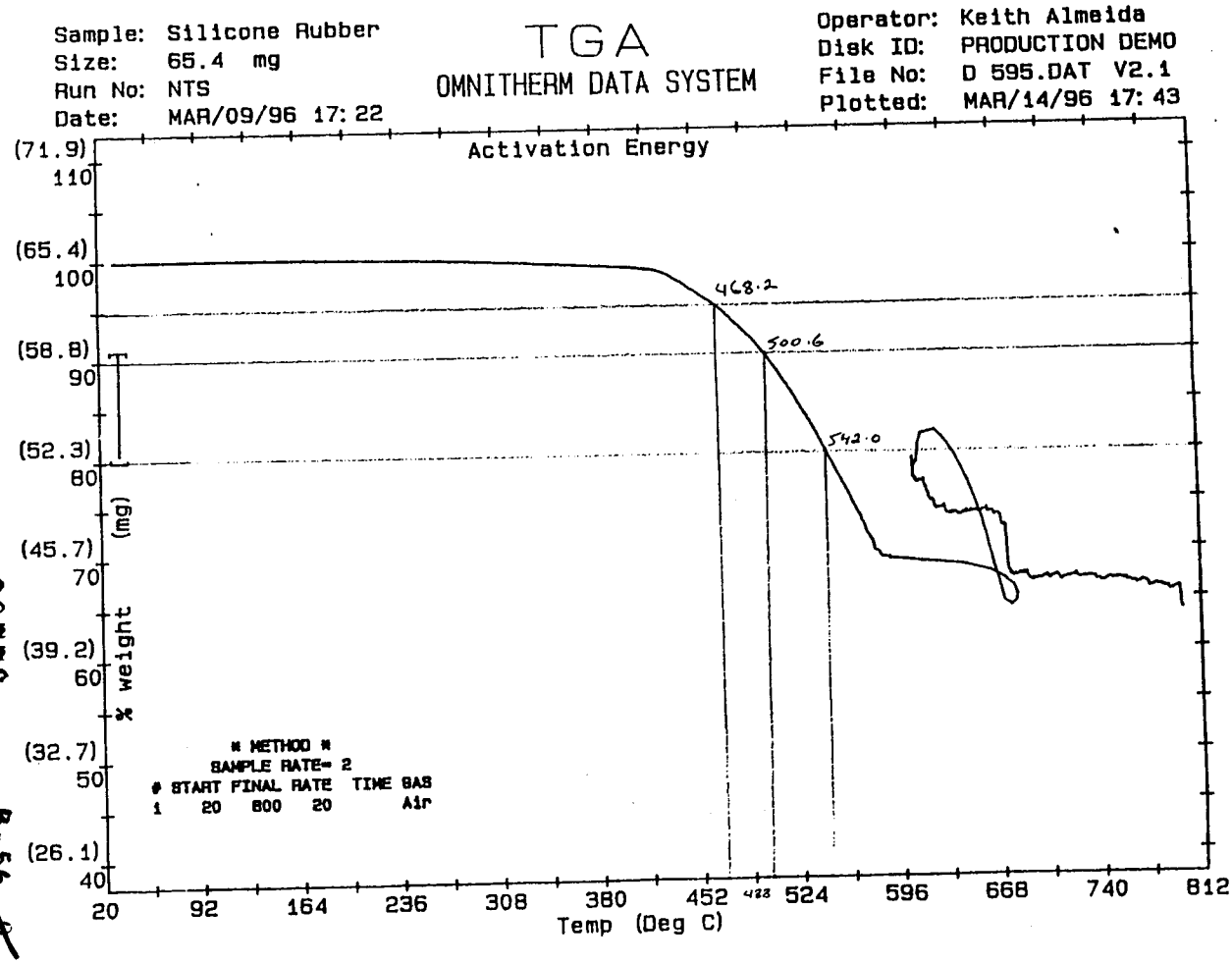

60776

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WHC-SD-WM-TI-758, Rev. 0

APPENDIX C

THERMAL AGING CHARTS

NTS
National
Technical
Systems

Northeast Division
533 Main Street
Acton, MA 01720

DATA SHEET

Job Number 60776-97N

Date 3/13/96 Page 1 of 2

Customer SAIC

Specification T.P. 60776-97N

Test Sample Radix Cable

Model/~~Serial~~ Number SRm2-K

Test Thermal Aging

Mode of Operation Daily Log.

Purchase Order 13-970050-90

Remarks Samples 1 thru 4 were placed in oven @ 8:30 AM 3/13/96 at room temp. Chamber was set @ 175°C Remove cables at the following times: #1 @ 230 hrs, #2 @ 345 hrs, #3, 4 @ 460 hrs

Date	Day	Time	Temp	Comments	
3/13/96	Wed	9:45 AM	175°C	Start Aging	
3/14/96	1/2	8:45 AM	175°C	23 hrs completed	
3/15/96	2/3	8:45 AM	175°C	47 hrs completed	
3/16/96	3/4	8:45 AM ~~7:30 AM~~	175°C	71 hrs "	
3/17/96	4/5	8:45 AM	175°C	95 hrs "	
3/18/96	5/6	8:45 AM	175°C	119 hrs "	
3/19/96	6/7	8:45 AM	175°C	143 hrs "	
3/20/96	7/8	8:45 AM	175°C	167 hrs "	
3/21/96	8/9	8:45 AM	175°C	191 hrs "	
3/22/96	9/10	8:45 AM	175°C	215 hrs @ 11:55 PM Removed #1 @ Total aging @ 230 hrs.	
3/23/96	10/11	8:45 AM	175°C	239 hrs Completed	
3/24/96	11/12	8:45 AM	175°C	263 hrs "	
3/25/96	12/13	8:45 AM	175°C	287 hrs "	
3/26/96	13/14	8:45 AM	175°C	311 hrs "	
3/27/96	14/15	8:45 AM	175°C	335 hrs " 6:45 PM (@ 345 hrs)	removed #2 @
3/28/96	15/16	8:45 AM	175°C	359 hrs	

Inspector Robert McGowan

Test Engineer Charles P. Corbett

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Form 20.2

National
Technical
Systems

Northeast Division
533 Main Street
Acton, MA 01720

DATA SHEET

Job Number 60776-97N

Customer SAIC

Test Sample Radix Cable

Test Thermal Aging

Purchase Order 13-970050-90

Date 3/29/96 Page 2 of 2

Specification T.P. 60776-97N

Model/Serial Number SRMC-1

Mode of Operation Daily Log

Remarks

Date	Day	Time	Temp	Comments	
3/29/96	16/17	8:45	175°C	384 hrs completed	
3/30/96	17/18	9:45	175°C	408 hrs "	
3/31/96	18/19	9:45	175°C	432 hrs "	
4/1/96	19/~~20~~ PM	9:45	175°C	456 hrs "	
4/1/96	19	1:45 PM	175°C	Removed #3, 4 @ 1:45 PM 460 hrs	
				Completed. Thermal Aging	
				is Done.	

Inspector Robert Mowry

Test Engineer Charles R. Elliott

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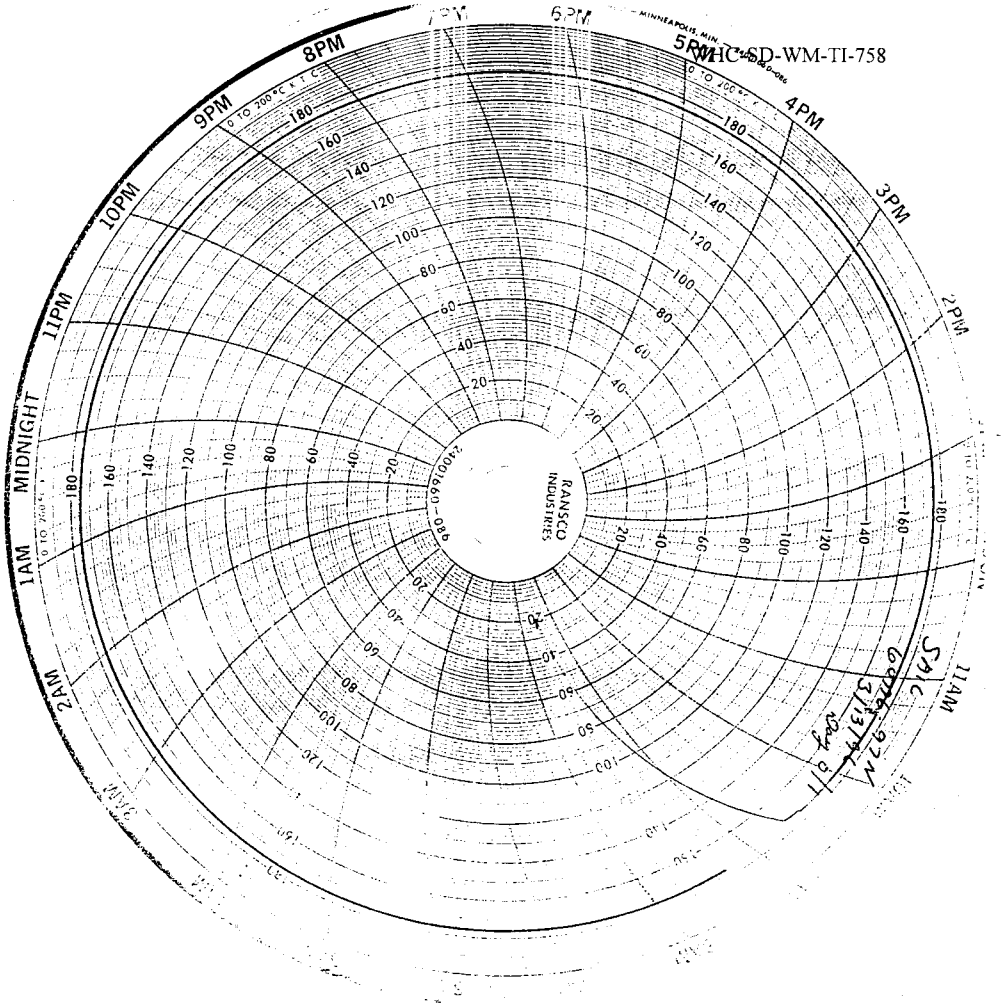
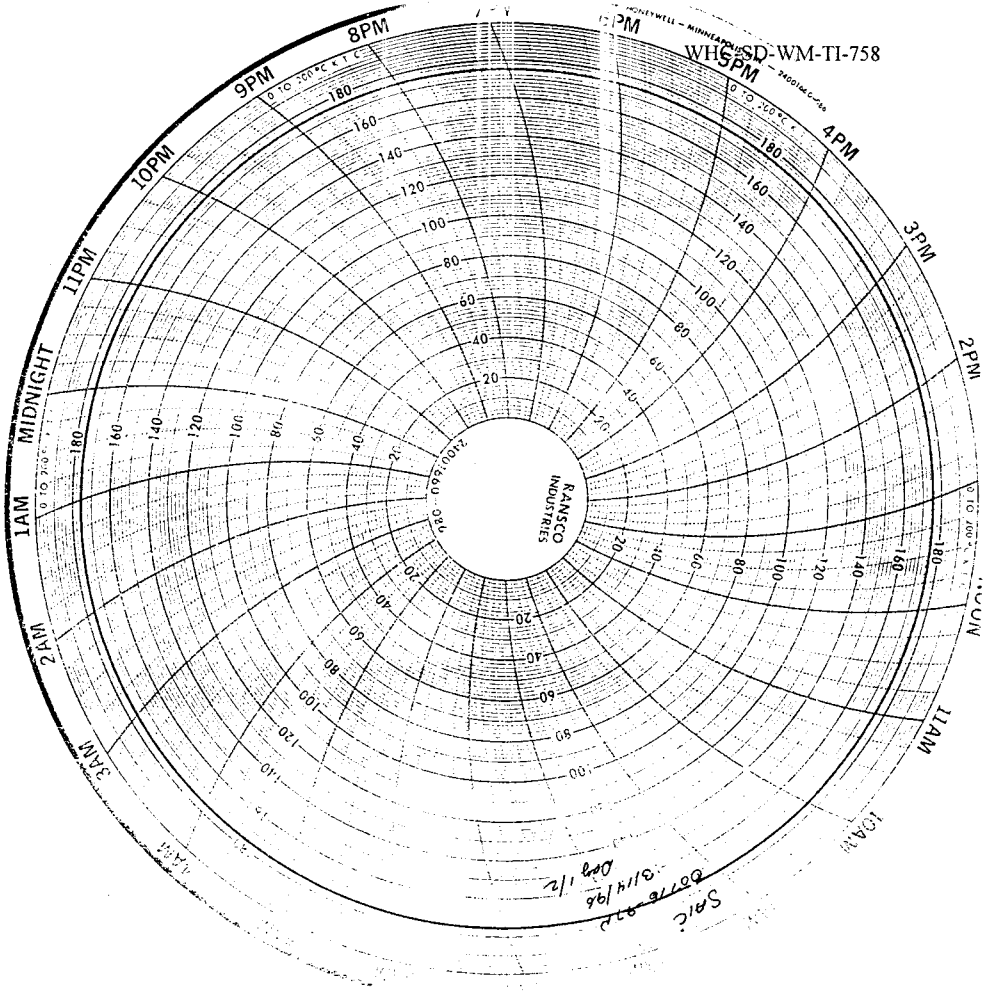
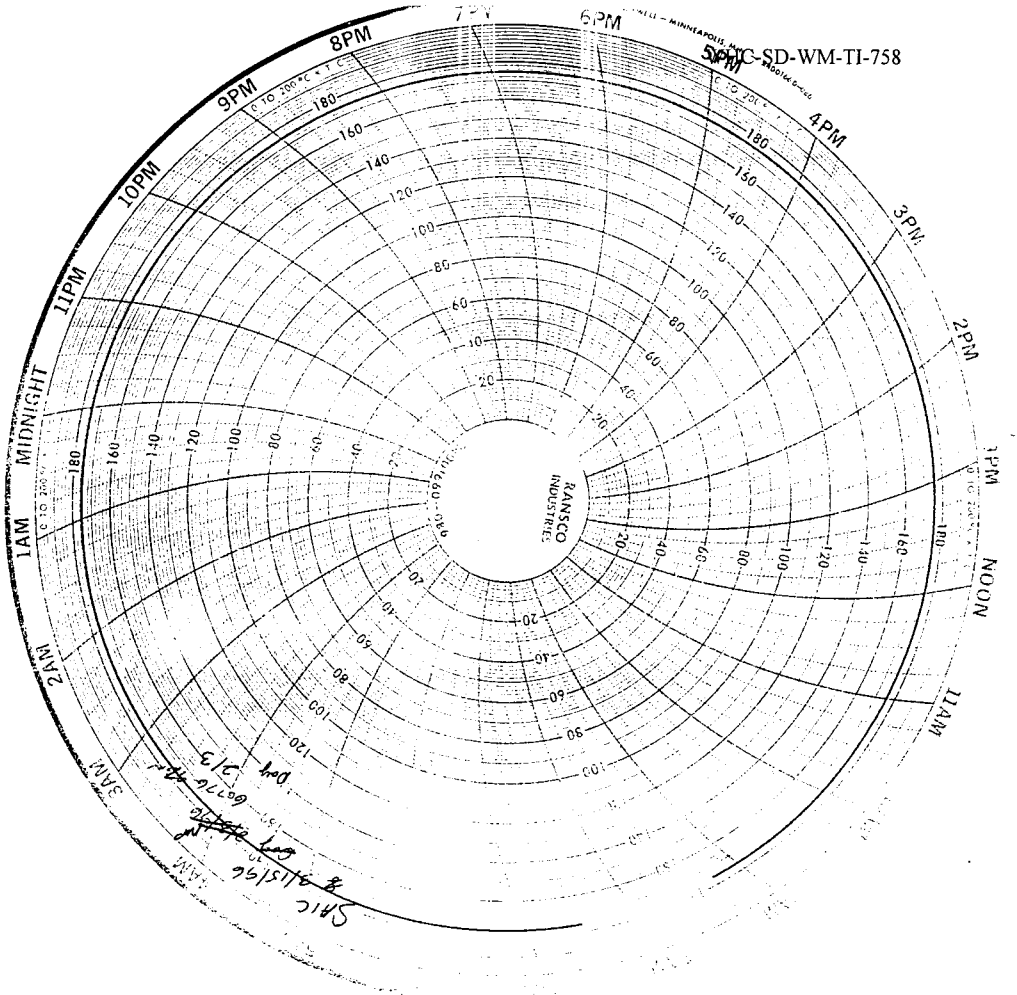
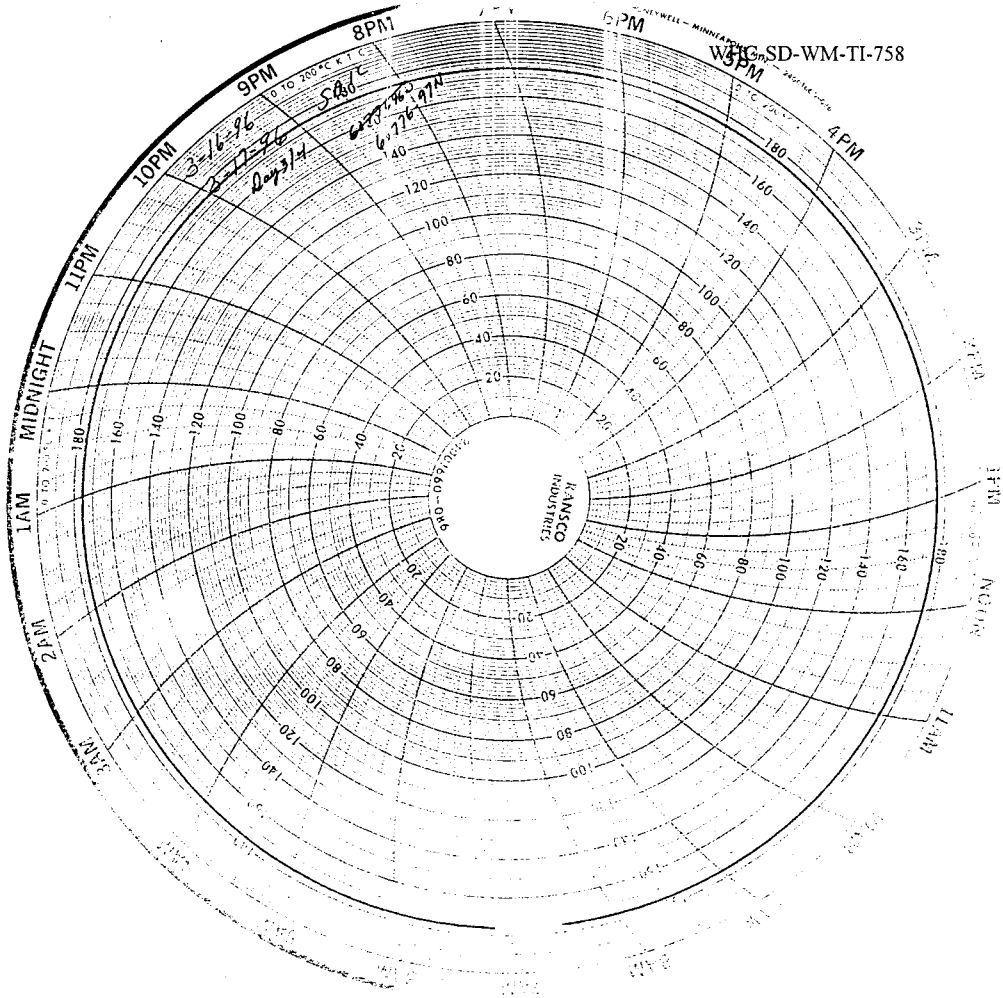
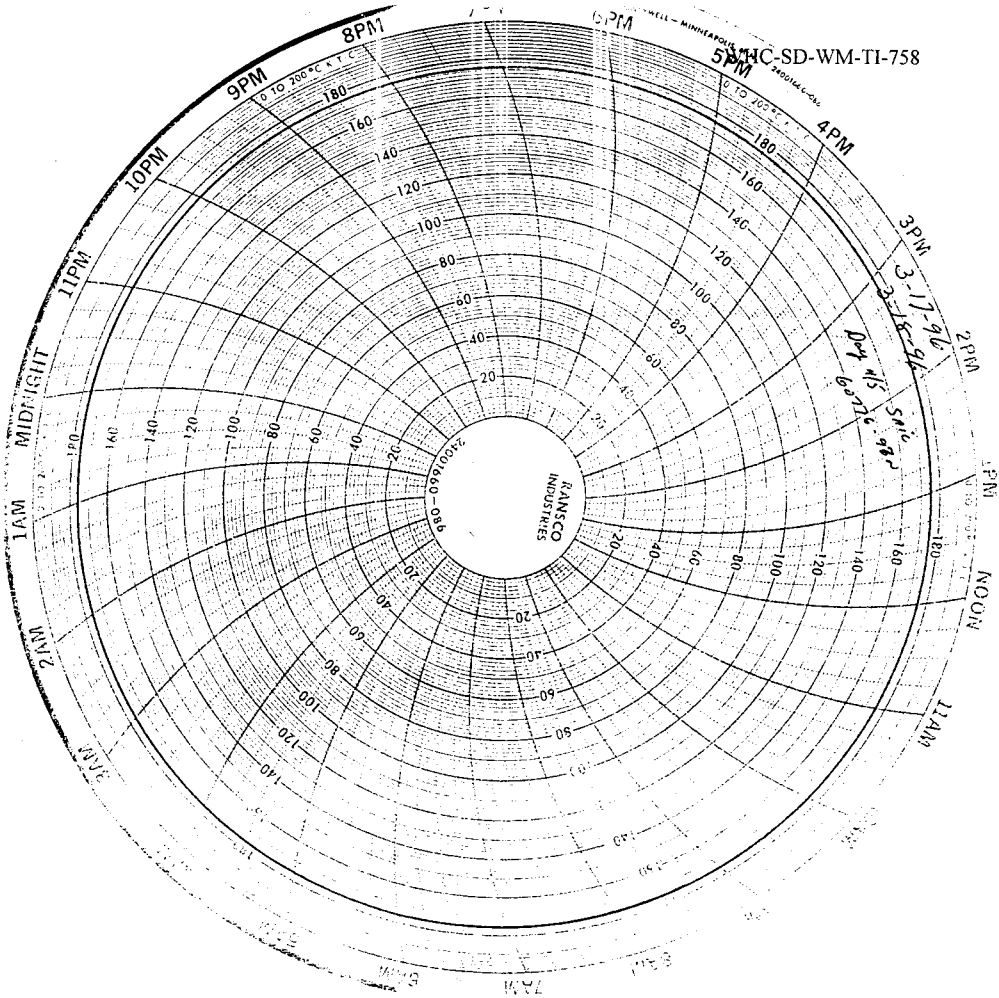
Form 20.2

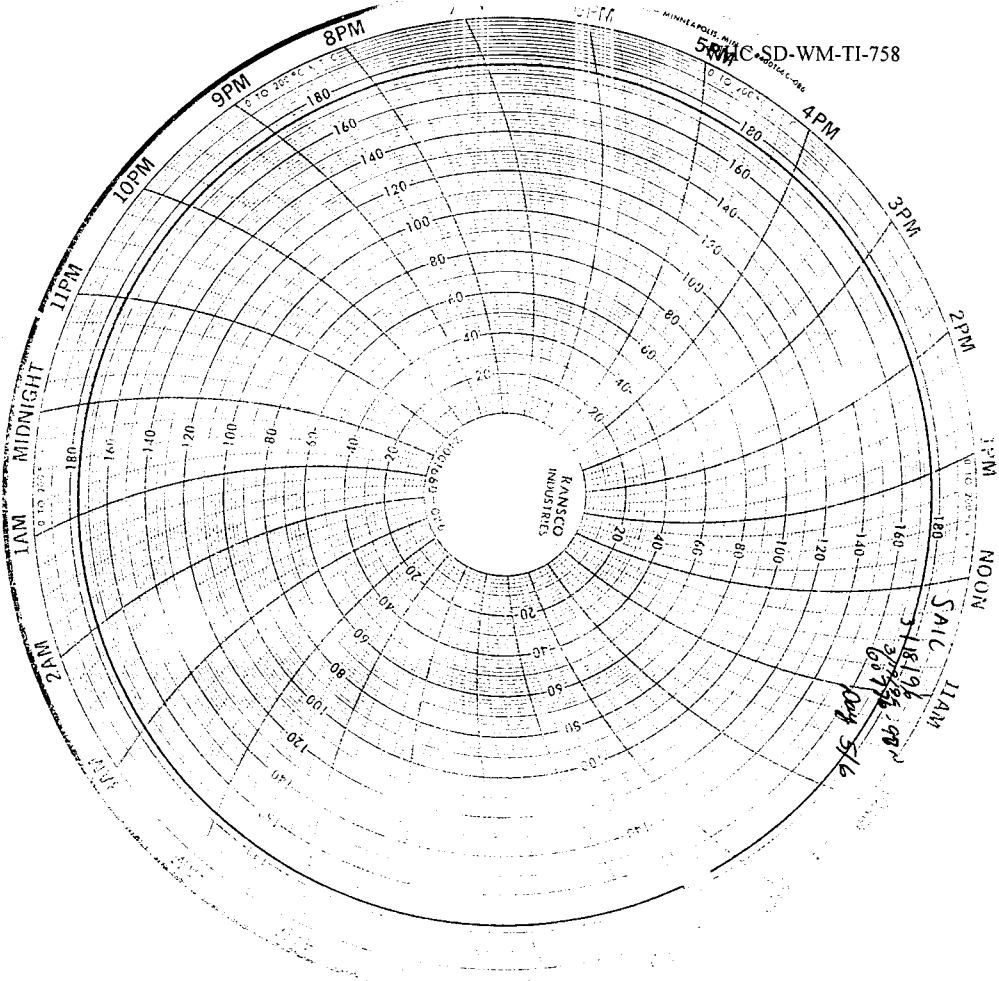


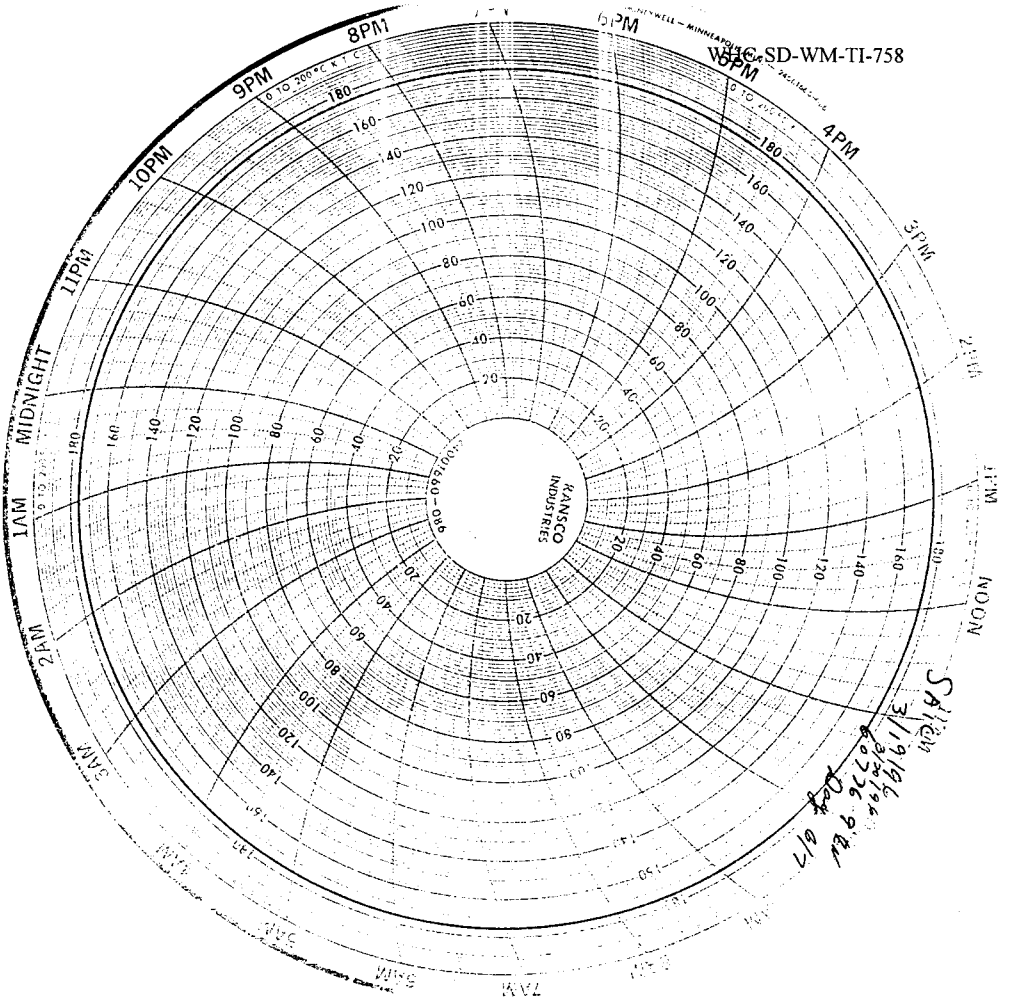


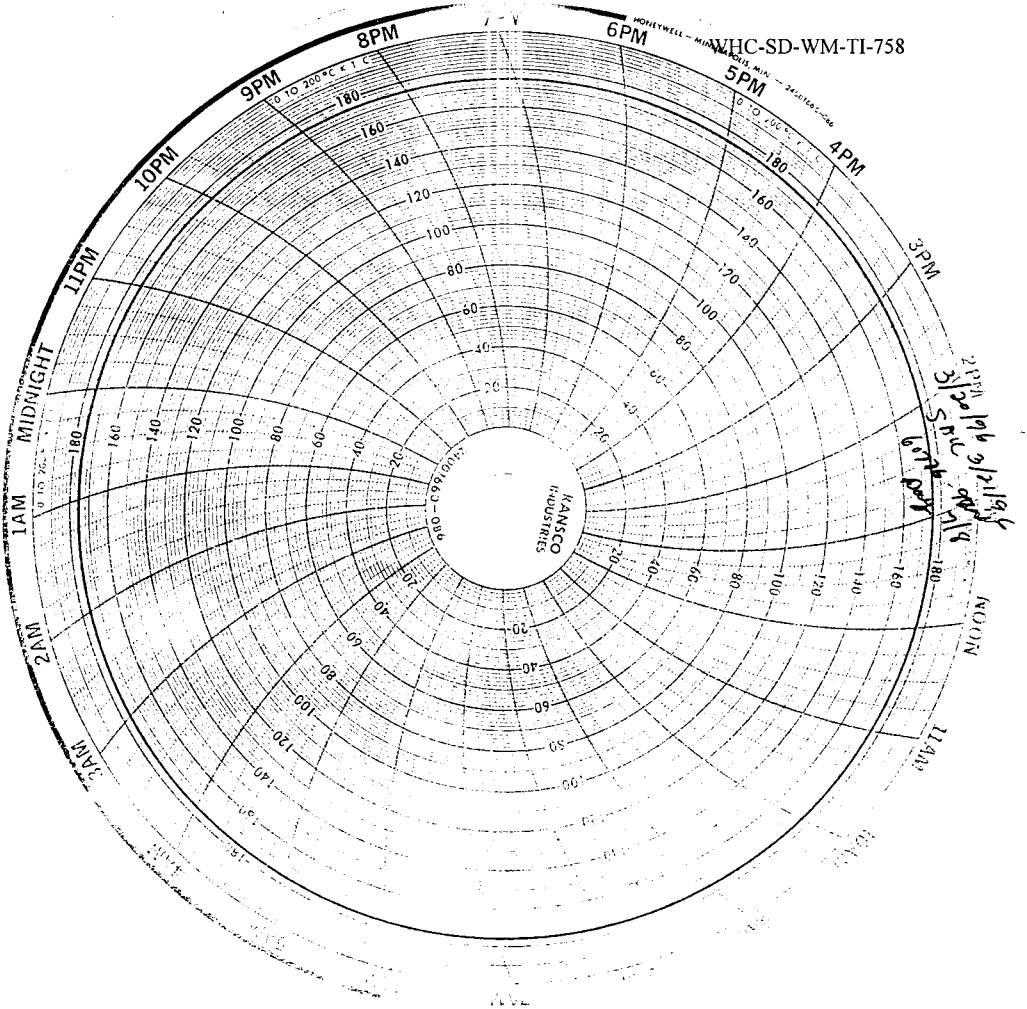


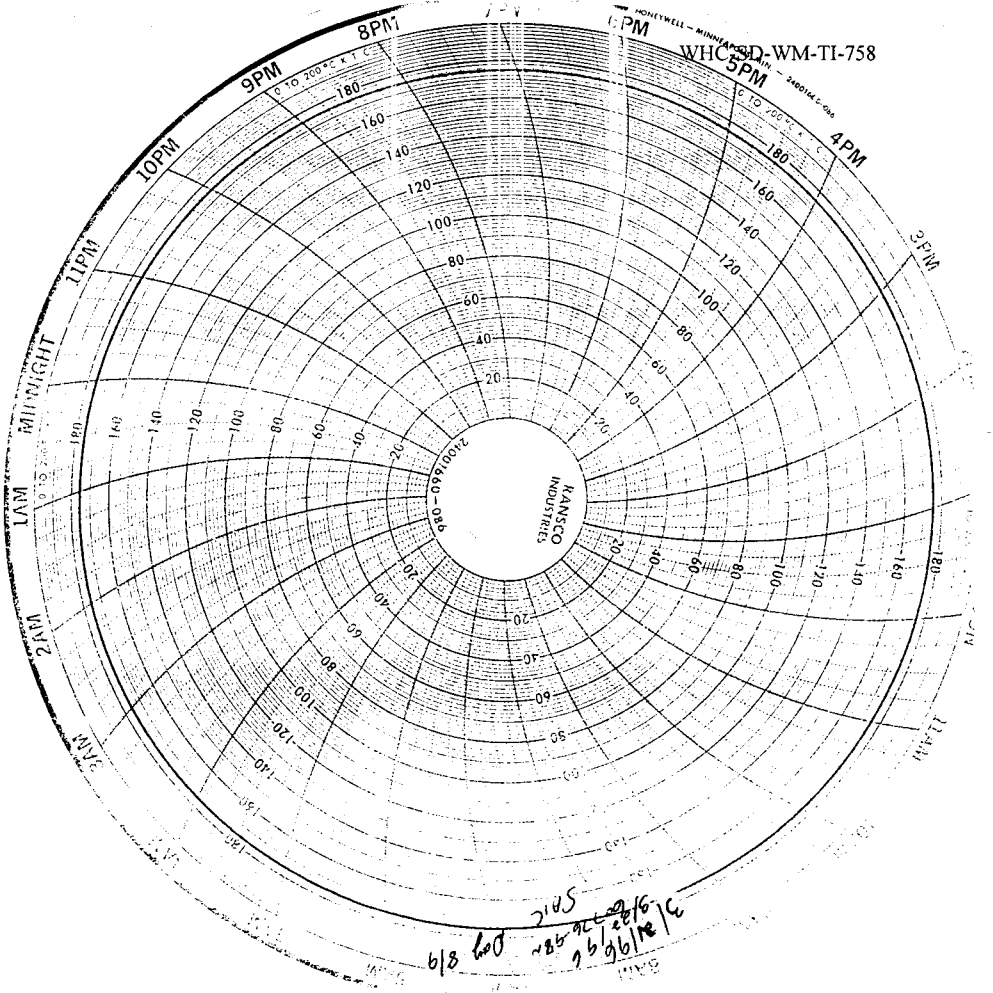




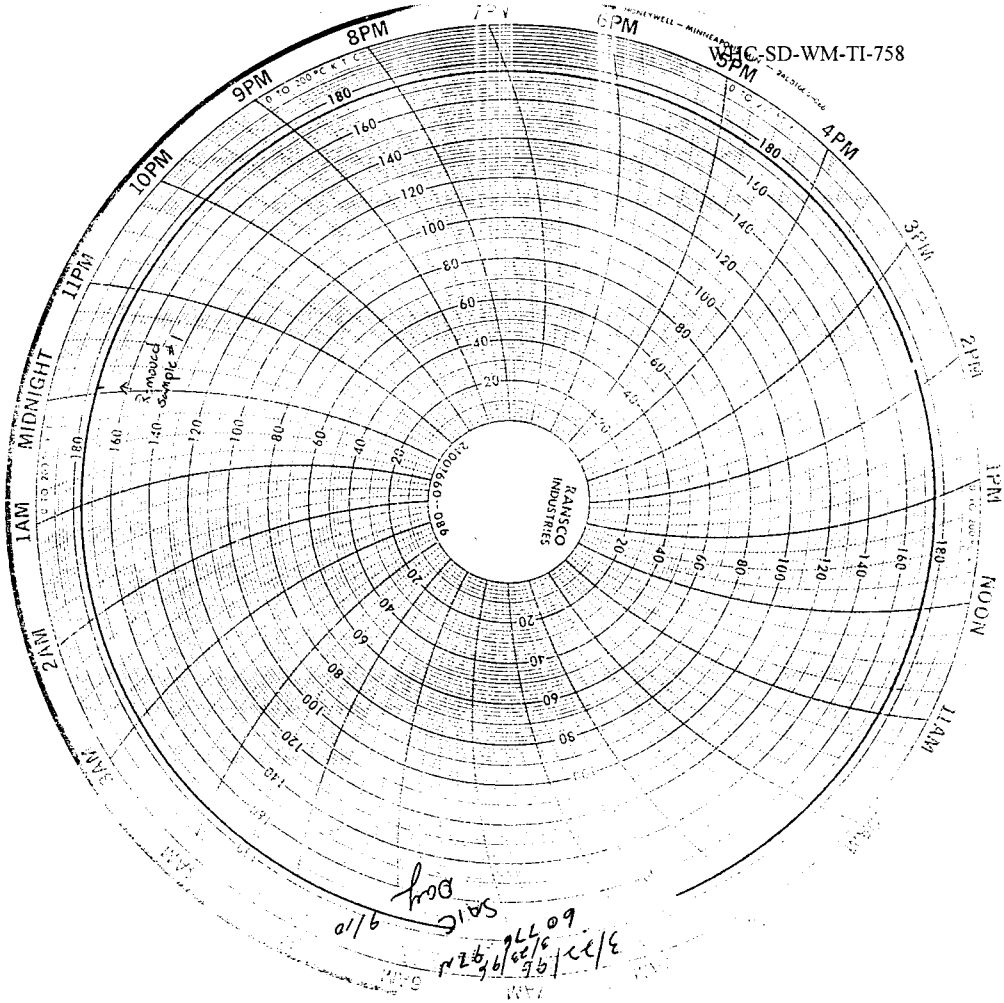

8PM
9PM
10PM
11PM
MIDNIGHT
1AM
2AM
5PM
4PM
3PM
2PM
1PM
NOON
11AM
RANSCO INDUSTRIES

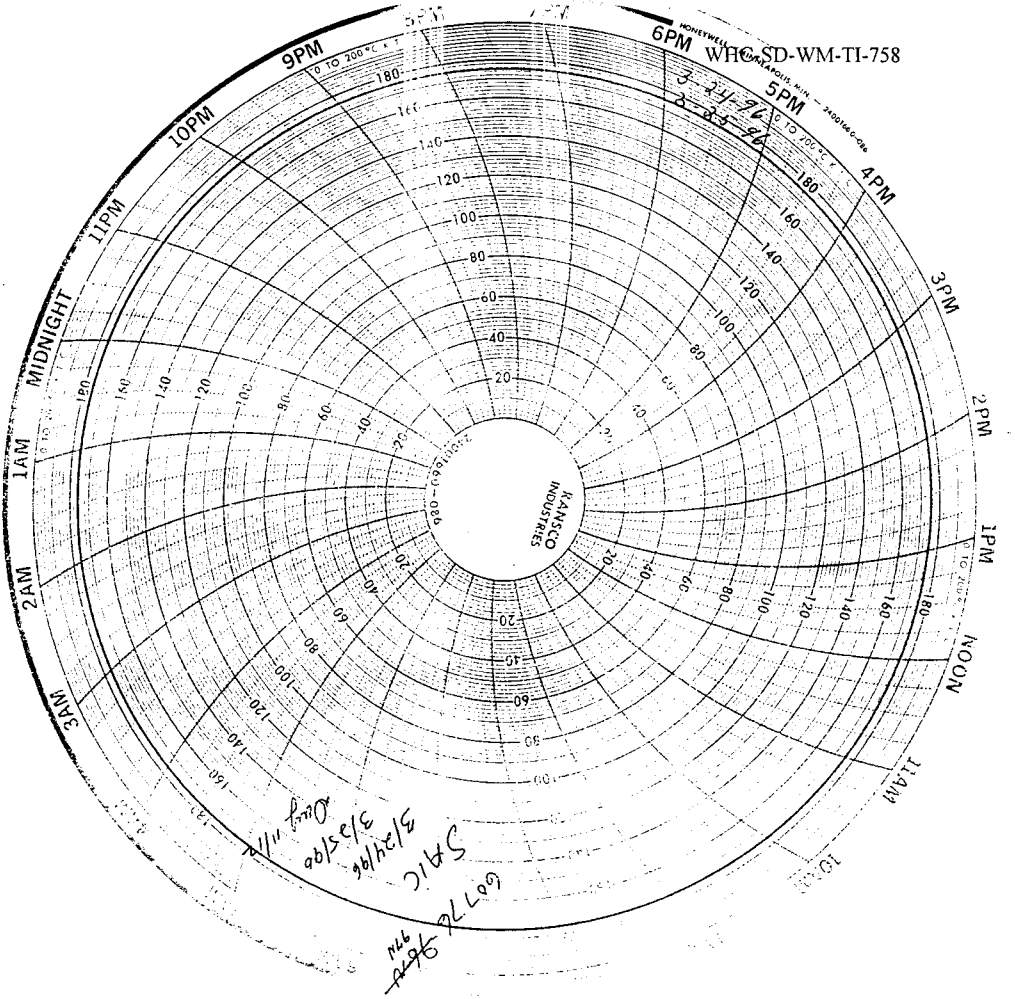




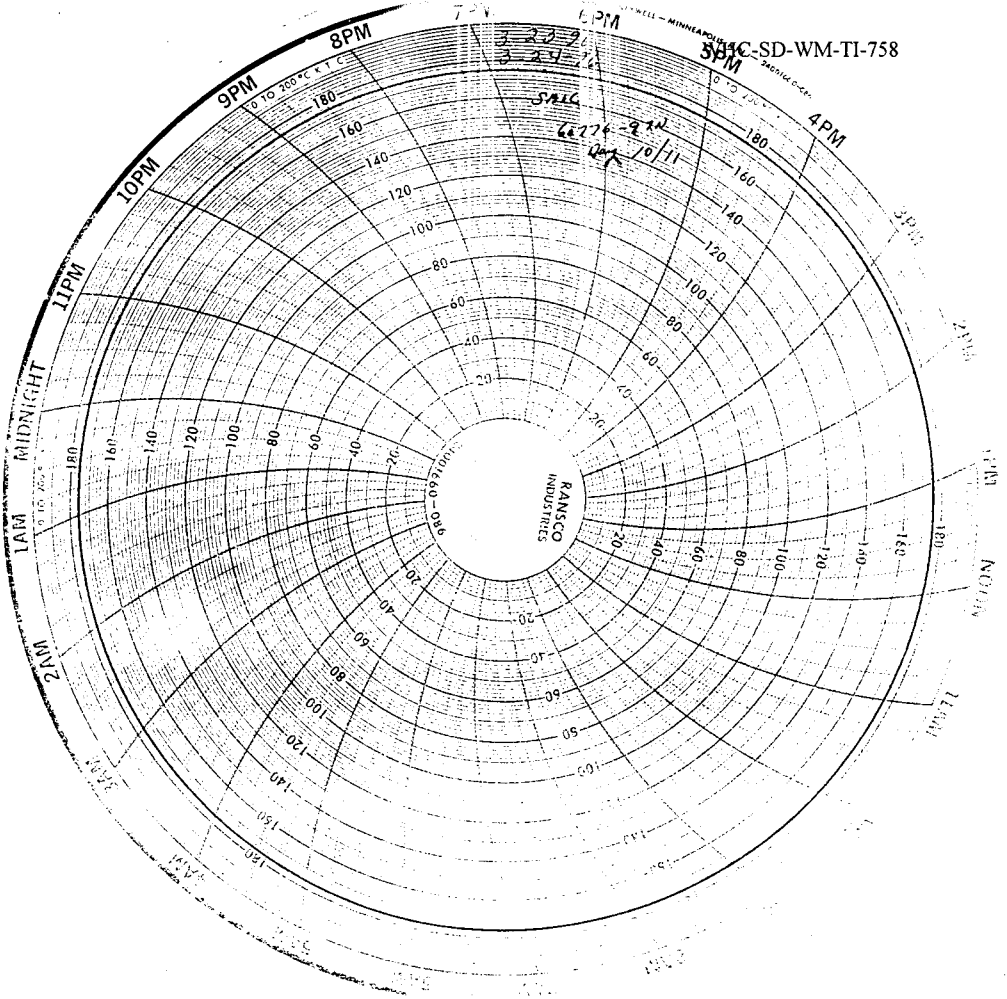


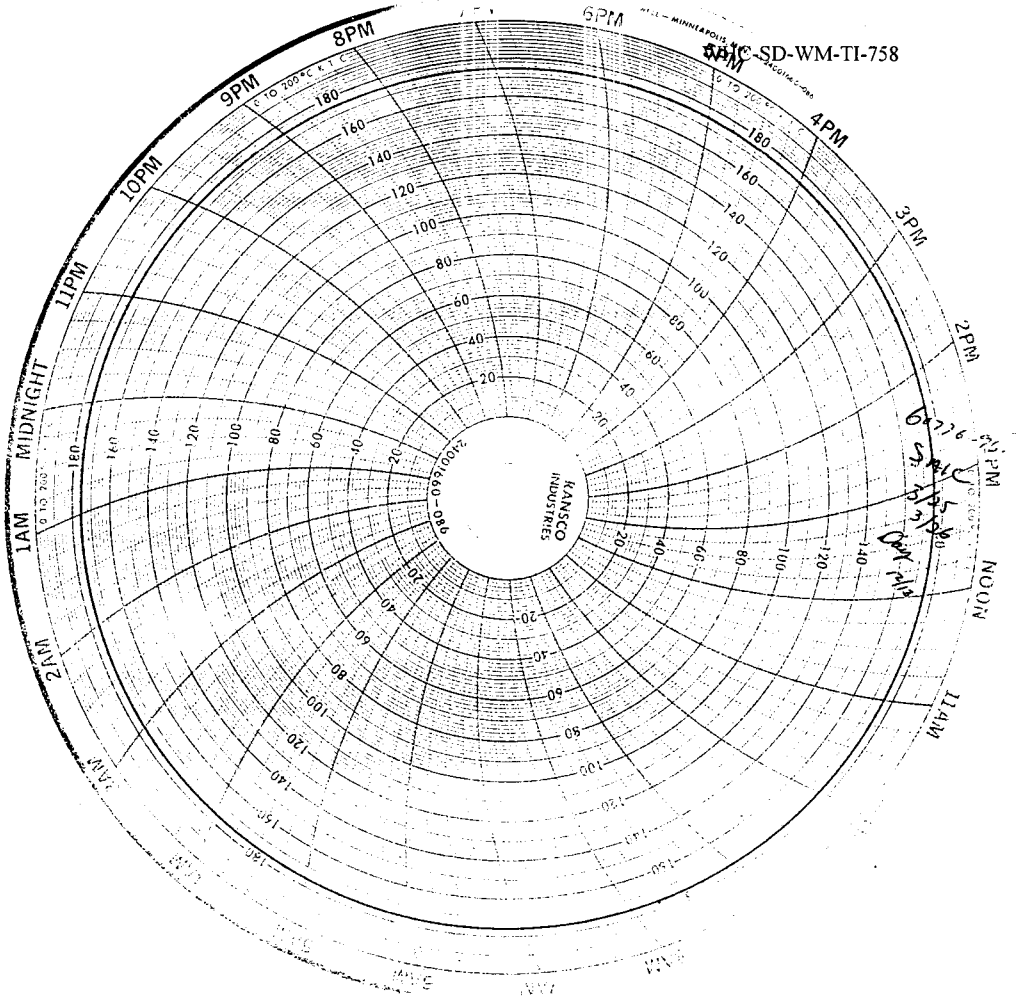
B-68 12

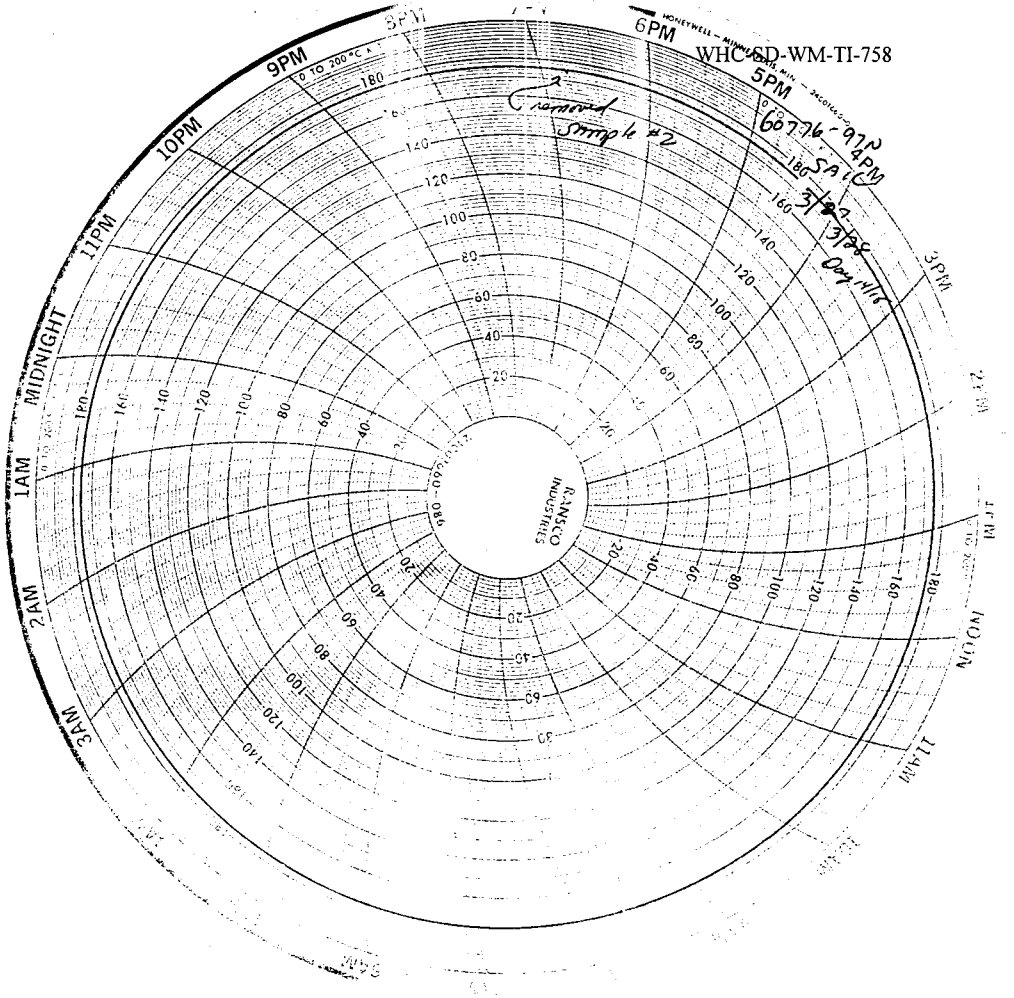


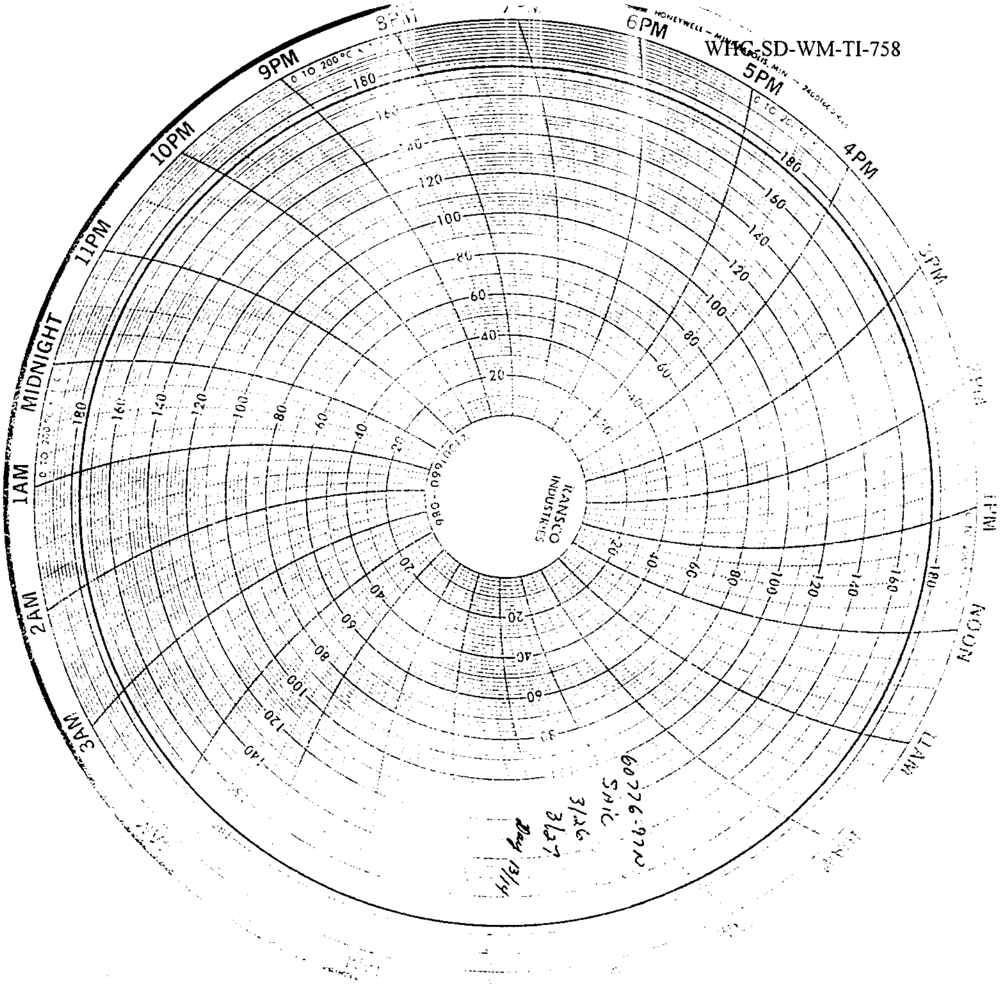


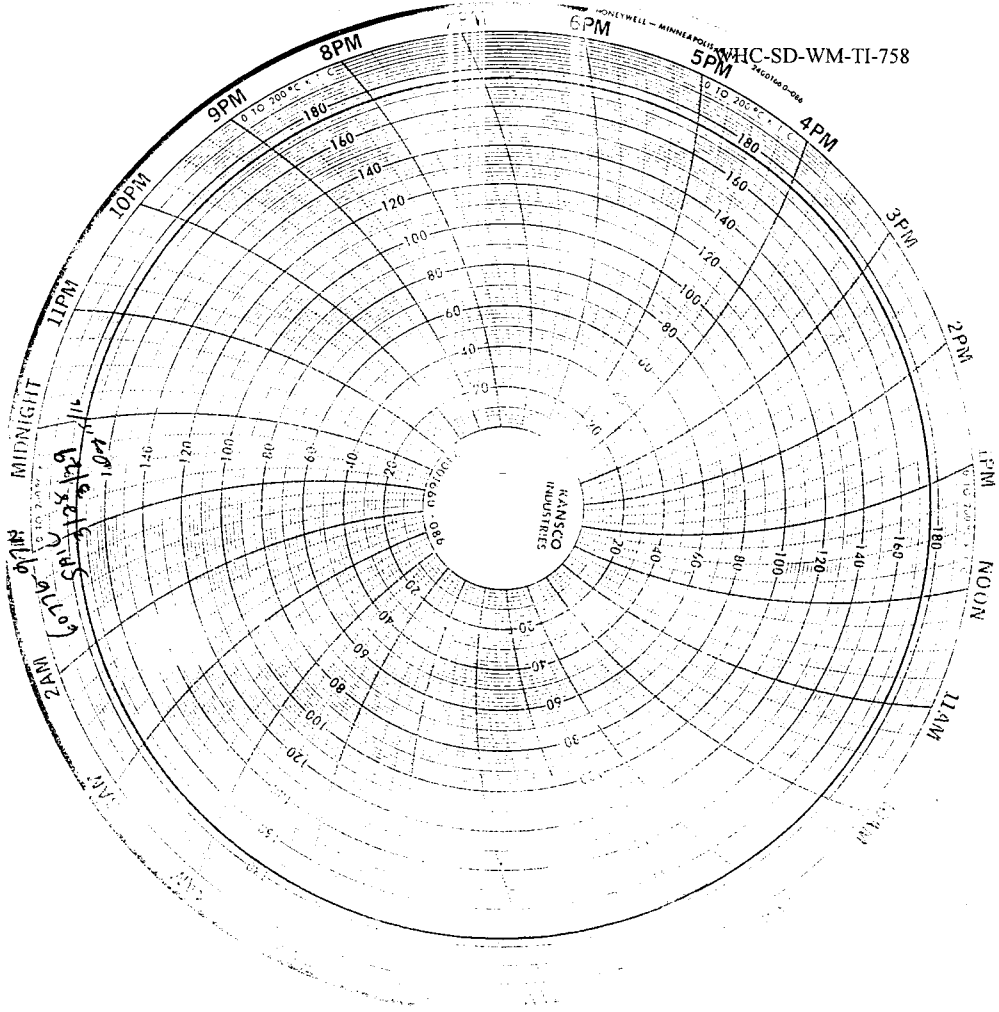
B-70 15

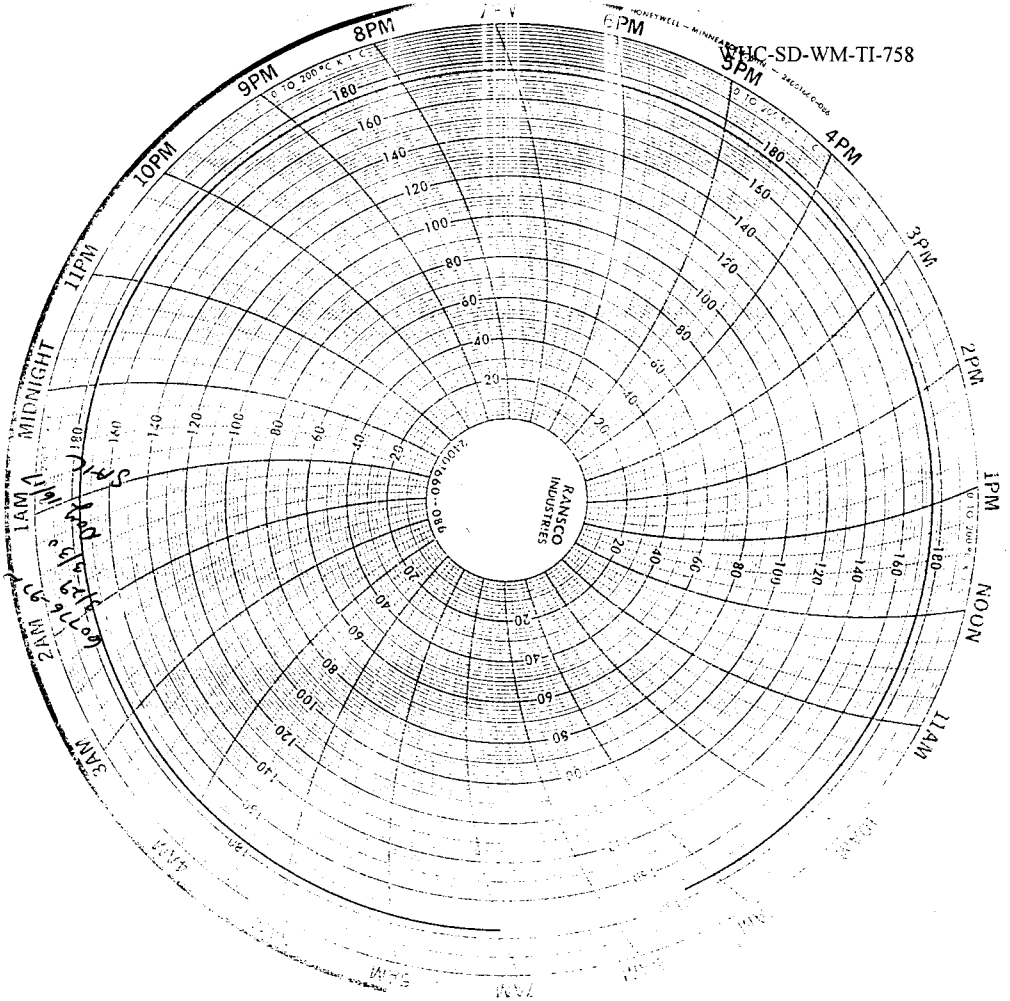


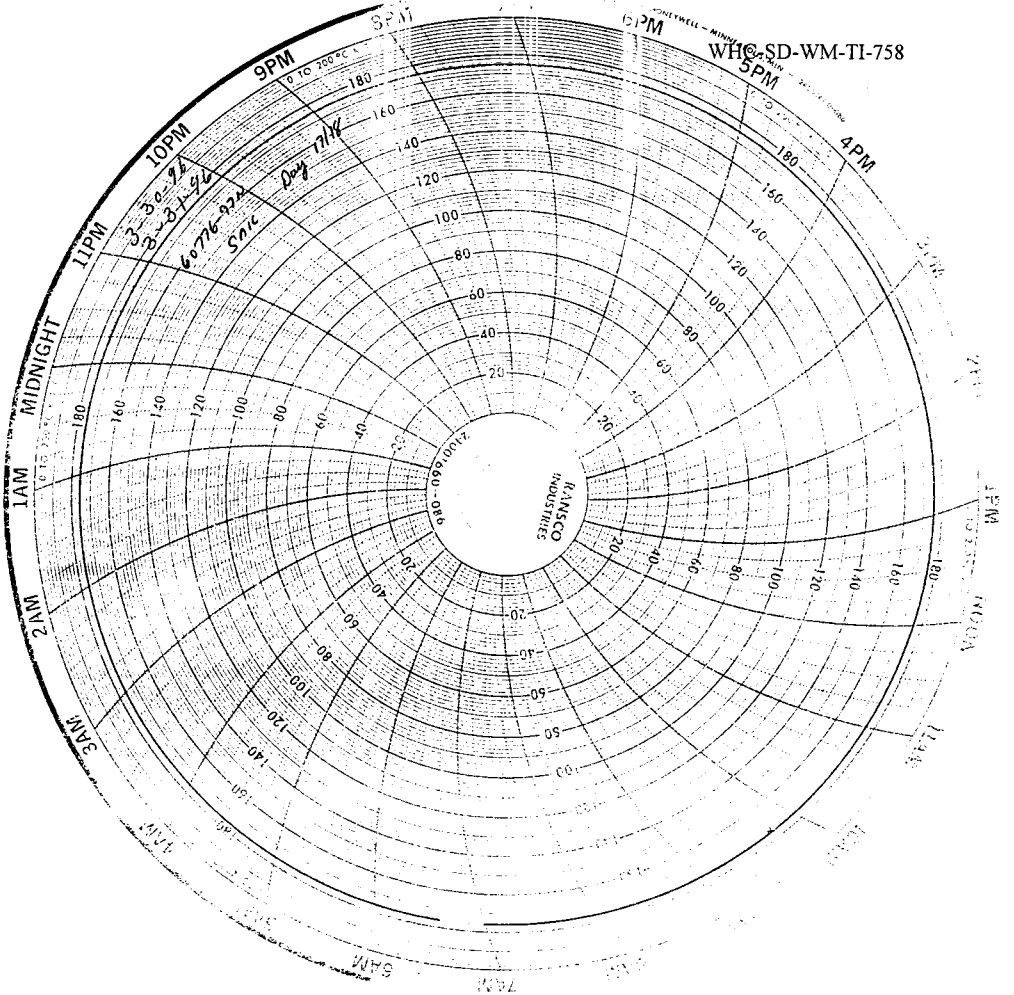


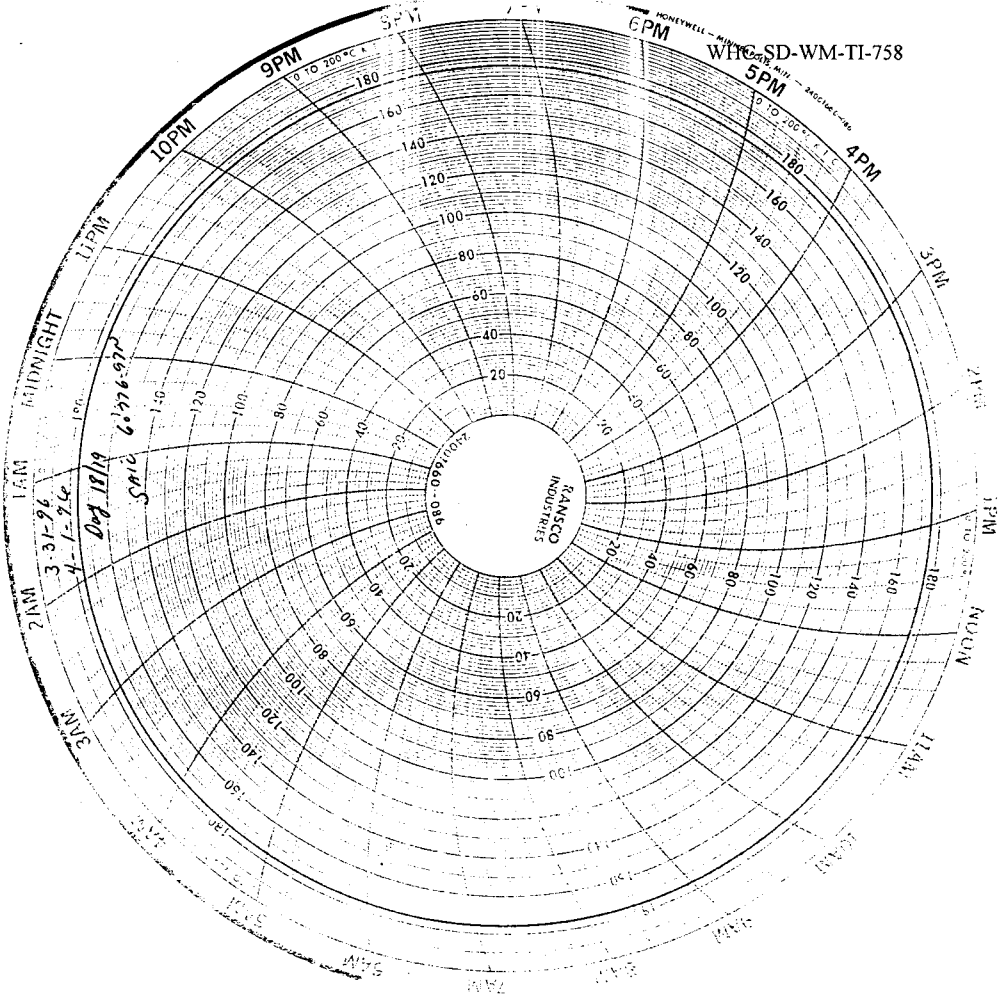


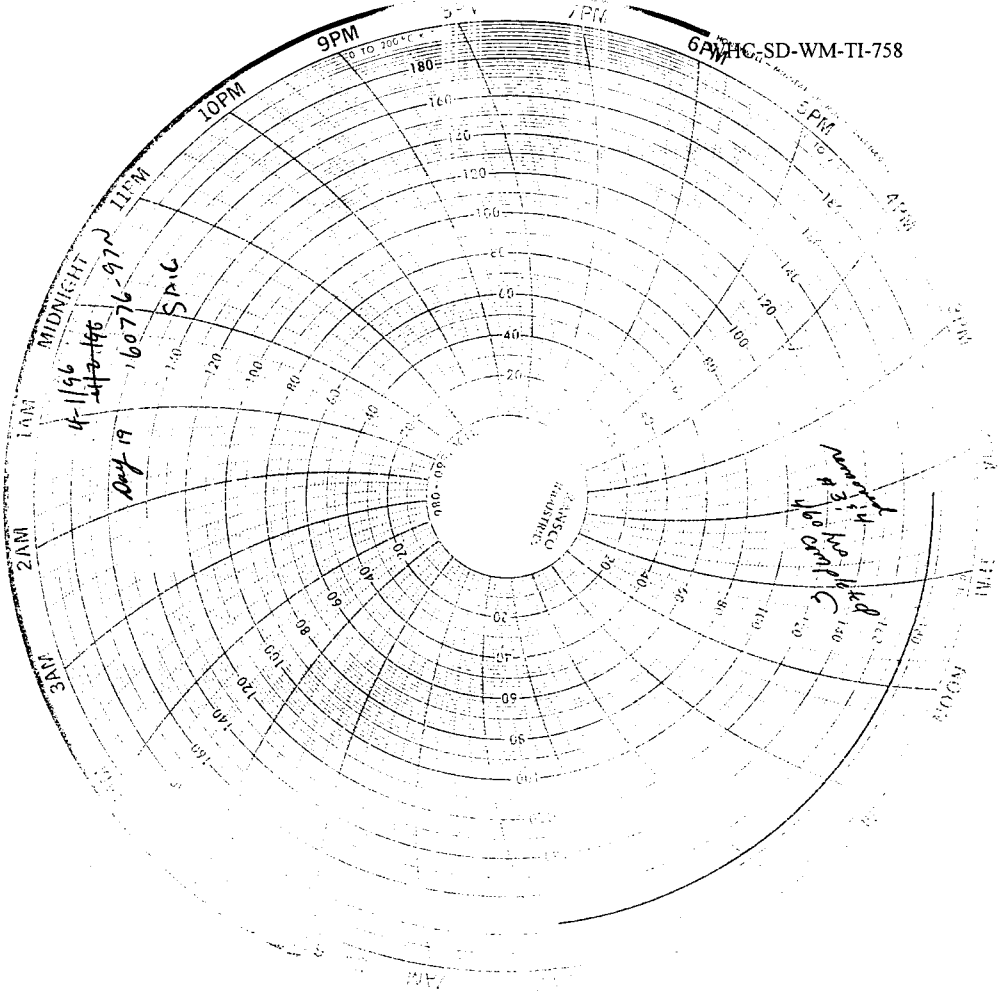












NTS

APPENDIX D

ISOMEDIX REPORT

ISOMEDIX OPERATIONS
9 APOLLO DRIVE
WHIPPANY, NJ 07981

ISOMEDIX (OPERATIONS), INC.
COMPONENT IRRADIATION CERTIFICATION

CUSTOMER	NTS	P.O. #	50749N
AIR EQUIV. REQUIRED DOSE (MRADS)	37.00		
RATE NOT TO EXCEED (MRADS/HR)	1.00		

SPECIMENS:

QTY	PART NO.	SERIAL NO.	DESCRIPTION
1	SRML-KRA-dix	N/A	SAMPLE #1
			SINGLE CONDUCTOR CABLE

DATA:

SOURCE TYPE:	COBALT-60	GAMMA			
TOTAL DELIVERED DOSE (AIR) MRADS:		MIN:	37.96	MAX:	38.63
DOSE RATE (AIR) MRADS/HR:		MIN:	.57	MAX:	.58
TOTAL EXPOSURE HOURS:		66.6			
SPECIMEN ROTATION	2-WAY:		4-WAY:	X	NONE:
DATE IN:	04/08/96	DATE OUT:		04/12/96	

DOSIMETRY:

DOSIMETER TYPE:	HARWELL PERSPEX	BATCH:	DK
TOLERANCE:	±8%	CALIBRATION DATE	10/31/95
READOUT INSTRUMENT:		B&L 1001	
SERIAL NO.:	0715493N	CALIBRATION DATE	01/23/96
COMMENTS:	IRRADIATION CONTROL #46125		

ATTACHMENTS:

WORKSHEETS:	N/A	DRAWINGS:	N/A
NOTICE OF ANOMOLY:		N/A	
AUTHORIZED SIGNATURE:			60776
TITLE:	QA MANAGER	DATE:	04/16/96

Form 1702.3
Original

B-81

ISOMEDIX OPERATIONS
9 APOLLO DRIVE
WHIPPANY, NJ 07981

ISOMEDIX (OPERATIONS), INC.
COMPONENT IRRADIATION CERTIFICATION

CUSTOMER	NTS	P.O. #	50749N
AIR EQUIV. REQUIRED DOSE (MRADS)	50.00		
RATE NOT TO EXCEED (MRADS/HR)	1.00		

SPECIMENS:

QTY	PART NO.	SERIAL NO.	DESCRIPTION
1	SRML-KRA-dix	N/A	SAMPLE #2
			SINGLE CONDUCTOR CABLE

DATA:

SOURCE TYPE:	COBALT-60	GAMMA			
TOTAL DELIVERED DOSE (AIR) MRADS:		MIN:	50.99	MAX:	52.84
DOSE RATE (AIR) MRADS/HR:		MIN:	.55	MAX:	.57
TOTAL EXPOSURE HOURS:		92.7			
SPECIMEN ROTATION	2-WAY:		4-WAY:	X	NONE:
DATE IN:	04/08/96	DATE OUT:		04/14/96	

DOSIMETRY:

DOSIMETER TYPE:	HARWELL PERSPEX	BATCH:	DK
TOLERANCE:	±8%	CALIBRATION DATE	10/31/95
READOUT INSTRUMENT:		B&L 1001	
SERIAL NO.:	0715493N	CALIBRATION DATE	01/23/96
COMMENTS:	IRRADIATION CONTROL #46125		

ATTACHMENTS:

WORKSHEETS:	N/A	DRAWINGS:	N/A
NOTICE OF ANOMOLY:		N/A	
AUTHORIZED SIGNATURE:		Ores Lackanski	60776
TITLE:	QA MANAGER	DATE:	04/16/96

Form 1702.3
Original

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ISOMEDIX OPERATIONS
9 APOLLO DRIVE
WHIPPANY, NJ 07981

ISOMEDIX (OPERATIONS), INC.
COMPONENT IRRADIATION CERTIFICATION

CUSTOMER	NTS	P.O. #	50749N
AIR EQUIV. REQUIRED DOSE (MRADS)	60.00		
RATE NOT TO EXCEED (MRADS/HR)	1.00		

SPECIMENS:

QTY	PART NO.	SERIAL NO.	DESCRIPTION
1	SRML-KRA-dix	N/A	SAMPLE #3
			SINGLE CONDUCTOR CABLE

DATA:

SOURCE TYPE:	COBALT-60	GAMMA			
TOTAL DELIVERED DOSE (AIR) MRADS:		MIN:	61.04	MAX:	62.13
DOSE RATE (AIR) MRADS/HR:		MIN:	.56	MAX:	.57
TOTAL EXPOSURE HOURS:		109.0			
SPECIMEN ROTATION	2-WAY:		4-WAY:	X	NONE:
DATE IN:	04/08/96	DATE OUT:		04/15/96	

DOSIMETRY:

DOSIMETER TYPE:	HARWELL PERSPEX	BATCH:	DK
TOLERANCE:	±8%	CALIBRATION DATE	10/31/95
READOUT INSTRUMENT:		B&L 1001	
SERIAL NO.:	0715493N	CALIBRATION DATE	01/23/96
COMMENTS:	IRRADIATION CONTROL #46125		

ATTACHMENTS:

WORKSHEETS:	N/A	DRAWINGS:	N/A
NOTICE OF ANOMOLY:		N/A	
AUTHORIZED SIGNATURE:			60776
TITLE:	QA MANAGER	DATE:	04/16/96

Form 1702.3
Original

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ISOMEDIX OPERATIONS
9 APOLLO DRIVE
WHIPPANY, NJ 07981

ISOMEDIX (OPERATIONS), INC.
COMPONENT IRRADIATION CERTIFICATION

CUSTOMER	NTS	P.O. #	50749N
AIR EQUIV. REQUIRED DOSE (MRADS)	60.00		
RATE NOT TO EXCEED (MRADS/HR)	1.00		

SPECIMENS:

QTY	PART NO.	SERIAL NO.	DESCRIPTION
1	SRML-KRA-dix	N/A	SAMPLE #5
			SINGLE CONDUCTOR CABLE

DATA:

SOURCE TYPE:	COBALT-60		GAMMA			
TOTAL DELIVERED DOSE (AIR) MRADS:			MIN:	61.05	MAX:	67.16
DOSE RATE (AIR) MRADS/HR:			MIN:	.50	MAX:	.55
TOTAL EXPOSURE HOURS:			122.1			
SPECIMEN ROTATION	2-WAY:		4-WAY:	X	NONE:	
DATE IN:	04/08/96		DATE OUT:		04/16/96	

DOSIMETRY:

DOSIMETER TYPE:	HARWELL PERSPEX	BATCH:	DK
TOLERANCE:	±8%	CALIBRATION DATE	10/31/95
READOUT INSTRUMENT:		B&L 1001	
SERIAL NO.:	0715493N	CALIBRATION DATE	01/23/96
COMMENTS:	IRRADIATION CONTROL #46125		

ATTACHMENTS:

WORKSHEETS:	N/A	DRAWINGS:	N/A
NOTICE OF ANOMOLY:		N/A	
AUTHORIZED SIGNATURE:		Theodore Lauscher	60776
TITLE:	QA MANAGER	DATE:	04/16/96

Form 1702.3
Original

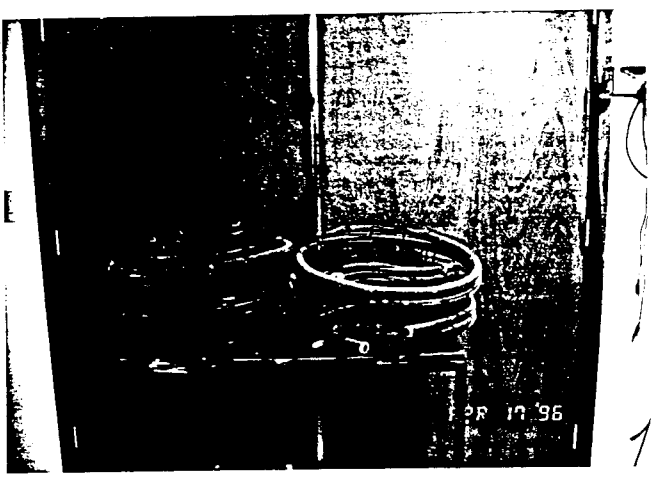
B-84

NTS

APPENDIX E

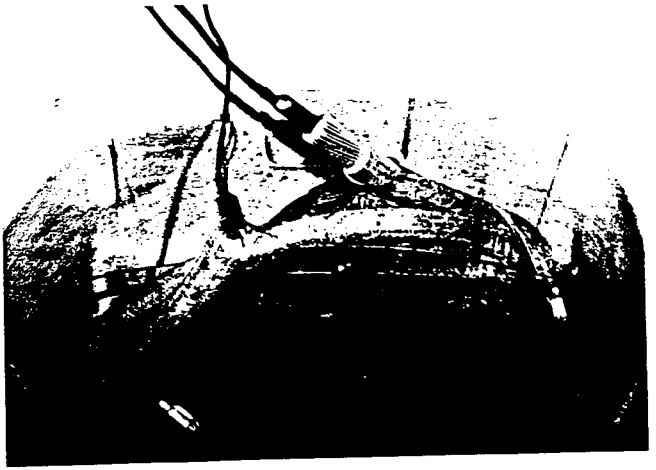
PHOTOGRAPHS

THERMAL AGING, CABLES ON SOLID MANDRELS, SAMPLES 1, 2, 3 & 4

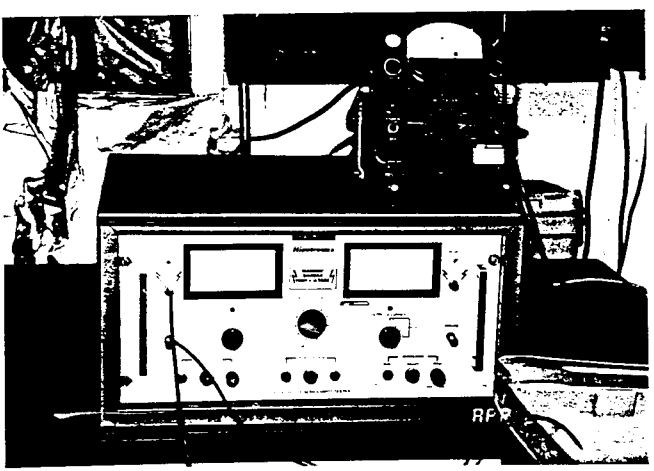


WIRE MESH MANDRELS FOR IRRADIATION, SAMPLES 1, 2, 3 AND 5

NTS



TYPICAL CABLE SUBMERGED IN WATER BATH



HIGH VOLTAGE TESTER AND IR TESTER