CONAX CORPORATION
2300 WALDEN AVENUE
BUFFALO, NEW YORK 14225

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Nuclear Products Division

THERMAL CAPABILITY CURVES (I^2t)
FOR
CONAX
ELECTRIC PENETRATION ASSEMBLIES
AND
ELECTRIC CONDUCTOR SEAL ASSEMBLIES

JUL 13 1982

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REVISION RECORD

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1.0 INTRODUCTION

1.1 This report documents the testing and analysis performed to establish time vs. current thermal capability curves for Conax Electric Penetration Assemblies and Electric Conductor Seal Assemblies.

1.2 All testing was performed either at Conax's Nuclear Products Test Facility in Buffalo, NY or at G.E. High Power Laboratory in Philadelphia, PA.

1.3 All test specimens and components were identical in design concepts and materials to those utilized in Conax Electric Penetration Assemblies and Electric Conductor Seal Assemblies.

1.4 All pertinent test equipment and descriptions used by Conax are given in Table 1 with a complete description of Conax test facilities given in Reference 2.5.

Table 1

Equipment Description Summary

Item No.	Description	Remarks
1	Thermocouple	Type T - 30 AWG Fiberglass Insulated. P/N-972337330010 1% Acc'y
2	Data Logger	Fluke, Inc. Model No. 2240B 0.01% Acc'y
3	Oven	Blue M Model No. OV-490A-2
4	Helium Leak Tester	Veeco, Inc. Model No. MS-170 Acc'y - 6×10^{-11} scc/sec

1.5 Some testing utilized as supporting documentation (Ref. 2.4) for this task was initiated over 3 years ago with a major effort over the past year on a number of different sub-tasks resulting in sufficient data to complete this study.

1.6 This report will not attempt to document, analyze, or compare all tests and test results beyond what is necessary for this particular application. For example, after three weeks of solid testing at G.E's High Power Laboratory it became apparent that an exploratory approach in defining the time/current capability limits of the Conax design would be impractical and extremely costly. However, data from those tests not only gave insight into the final developement of the curves but it also produced data that demonstrated the conservatisms embodied in the classical Onderdonk* Equation (Ref. 2.13).

* $I^2t = A^2 (0.0297) \text{ Log } [(T_f+234)/(T_i+234)]$

Where: I = current in amperes
t = time in seconds
A = conductor cross sectional area in circular mils
T_f = final conductor temperature in ^oC
T_i = initial conductor temperature in ^oC

2.0 REFERENCES

References 2.4 through 2.12 are maintained on permanent file at Conax and are available for auditing purposes. It should be noted that, in order to maintain an auditable link, all portions of these references are applicable.

2.1 IEEE Std. 242-1975, "Recommended Practice of Protection and Coordination of Industrial and Commercial Power Systems."

2.2 IEEE Std. 317-1976, "IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations."

2.3 U.S. Nuclear Regulatory Commission Regulatory Guide, 1.63, Rev. 2, July 1978.

2.4 Conax Report, IPS-325, "Design Qualification Material Test Report for Materials Used in Conax Electric Penetration Assemblies and Electric Conductor Seal Assemblies."

2.5 Conax Report, IPS-557, "Description of Conax Nuclear Products Test Laboratory Facility."

2.6 Conax Report, IPS-585.3, "Test Report - Qualification of a Conax Low Voltage Power and Control Service Classification Electric Penetration Assembly for Class 1E Service IN BWR and PWR Containment Structures."

2.7 Conax Report, IPS-568, "Engineering Investigation Test Report on the Thermal Mapping of Heat Flow Characteristics of an Environmental Test Chamber during MSLB and LOCA DBE Conditions."

2.8 Conax Report, IPS-694, "Heat Transfer Analysis for EPA in a Containment Wall during DBE Conditions."

2.9 Conax Report, IPS-615, "Test Report - Short Circuit Current Tests - G.E. Report 80ESP54, BF-LVP."

2.10 Conax Report, IPS-611, "Test Report - Short Circuit Current Tests - G.E. Report 80ESP76, PV-12."

2.11 Conax Report, IPS-598, Test Report - Short Circuit Current Tests - G.E. Report - 80ESP55, BF-11."

2.12 Conax Report, IPS-354, "Test Report - Short Circuit Test of MVP Electrical Penetration."

2.13 ICEA P-32-382, "Short Circuit Characteristics of Insulated Cable."

3.0 DEVELOPMENT

3.1 As stated in Reference 2.1, the temperature of a conductor rises as the square of its current load. In addition, under steady state conditions, the ratio of temperature rise above a base ambient temperature to the temperature rise above any other ambient temperature is proportional to the ratio of load currents squared and can be expressed as follows:

$$\left(I_1/I_o\right)^2 = \Delta T_1/\Delta T_o \qquad (1)$$

This relationship can be modified to include the rise time as follows:

$$\Delta T_1 = \left(I_1/I_o\right)^2 \Delta T_o \left(1 - e^{-t/t_o}\right) \qquad (2)$$

The parameter, t_o, is the time constant which is a function of the conductor diameter and conductor insulation materials. By letting I_o equal the steady state current necessary to raise a conductor's temperature 1^oC, for any given initial temperature, Equation 2 can be normalized as follows:

$$\Delta T = \left(I/I_o\right)^2 \left(1 - e^{-t/t_o}\right) \qquad (3)$$

where:
- t = time in minutes
- T = temperature rise in ^oC
- I = current in amps required to produce ΔT
- I_o = steady state current in amps to produce a 1^oC temperature rise
- t_o = time constant

Thus, once I_0 and t_0 are known for a given conductor, a continuous time/temperature/current relationship, as given by Equation 3, exists for that conductor.

The question remains whether Equation 3 can be utilized to predict the performance of Conax Electric Penetrations or Electric Conductor Seal Assemblies under current overload conditions in severe environments. The answer can be found by examining the results of thermal studies Conax has conducted on it's basic feedthrough module design which consists of a stainless steel sheath, Polysulfone sealants, and Kapton insulated copper conductors (See Figure 1a). The primary purpose of the study, which is documented in Reference 2.4 (IPS-325), was to determine the usable service life characteristics of the Conax design versus temperature. Briefly summarized, two failure modes exist for the Conax design that could compromise the safety related function of an Electric Penetration Assembly or an Electric Conductor Seal Assembly. One mode is loss of seal or containment integrity and the other is loss of electrical integrity. During the tests as described in Ref. 2.4 loss of seal integrity (failure was defined as leakage in excess of 1×10^{-6} scc/sec. He @ 75 psig) was the first and only mode of failure to manifest itself under elevated temperatures. Using the failure data an "end-of-life" curve was established for the Conax design which fits the Arrhenius model and requirements of IEEE Standards 1, 98, 99, 101, and 317. This "end-of-life curve" is known to be conservative (Ref. 2.4), is valid for a complete feedthrough module regardless of conductor size, and is expressed as follows: (See Figure 1).

$$\text{Log}\, t = 19718\ 1/K - 43.208 \qquad (4)$$

where: t = time in hours of usable life at temperature, K, in degrees Kelvin.

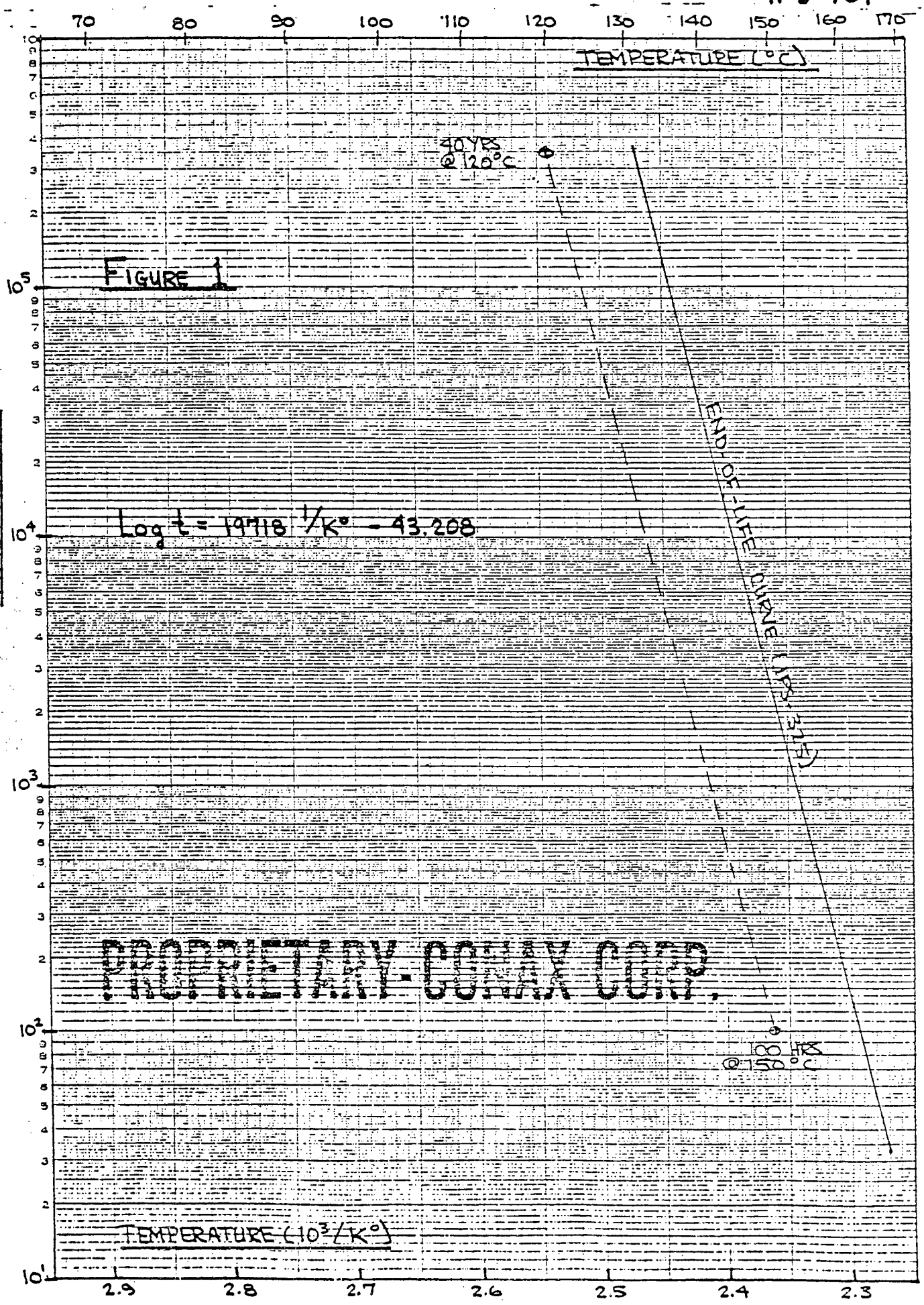
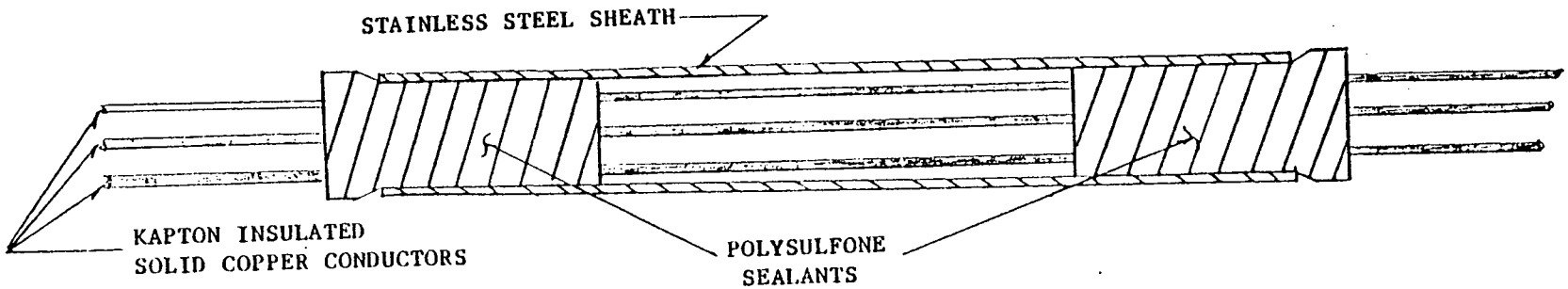


FIGURE 1

EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 340R-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH

FIGURE 1a

Cross Sectional View of Conax's Standard Feedthrough Design



Examining equations 3 and 4 reveals the final solution in deriving a time/current thermal capability curve for the conductor sizes in Conax's design. Consider the following example.

Suppose it was necessary to determine the current capability of a given conductor size for a 1000 second duration in a complete penetration with all conductors fully loaded at rated current. The first step would be to calculate the temperature extreme for a usable 1000 second service life using Equation 4. It is important to note that this temperature extreme is for the full duration on the entire feedthrough module including not only conductors but also sealants and stainless steel sheath and does not consider any heat transfer away from the feedthrough module. Using this temperature and given an initial ambient temperature, a ΔT is computed. Assuming I_o and t_o are known, Equation 3 is employed and a load current for the given conductor size and duration is computed. This process is repeated for all times until a complete curve is generated. Thus, the problem can be completely defined and solved using Equations 3 & 4.

Based on the above derivations a program was developed to:

1) Determine, by test, the parameters I_o and t_o from Equation 3.

2) Generate time/current thermal capability curves using Equations 3 & 4.

3) Select points along the time/current curve and test under the assumed conditions to verify the viability of the whole developement.

4.0 PROGRAM IMPLEMENTATION AND RESULTS

4.1 The first phase of the program was to determine the parameters I_o and t_o. Single conductor test samples consisting of Kapton insulated conductors ranging from #16 AWG to 350 MCM and Kerite insulated 1000 MCM and 1500 MCM conductors were selected for testing.

4.1.1 For the test set-up small portions of insulation were removed from each sample so that two thermocouples (Item 1 - Table 1) could be attached to the bare copper. Instrumentation output (thermocouple readings and current loads) was configured to permanently record on a data logger (Item 2 - Table 1) at intervals from 3 to 30 seconds. (See Appendix D for photographs of test set-up.)

4.1.2 Current loads in accordance with Table 2 were applied to each test sample at room ambient conditions until steady state temperatures were realized. After all data was gathered, temperature rise versus time was computed and plotted as shown in Appendix A.

Table 2

Current Loads - Phase 1

Cond. Size	Current (Amps)
#16 AWG	10, 8
#14 AWG	15, 11, 7
#12 AWG	24, 18, 13
#10 AWG	32, 26, 18
# 8 AWG	44, 35, 24
# 6 AWG	57, 42
# 4 AWG	103, 80, 62
# 2 AWG	166, 133, 103
#2/0 AWG	200, 150, 100
250 MCM	250, 180, 110
350 MCM	302, 222, 145
1000 MCM	300, 450
1500 MCM	450, 600

4.1.3 Once the results were gathered and plotted, the data was analyzed against Equation 3 using linear regression techiques to determine the parameters I_0 and t_0. This analysis revealed a strong correlation between I_0, t_0, and the conductor's diameter and it was evident that the ratio of time constants (t_0) between conductors was directly proportional to the ratio of conductor diameters and that the ratio of steady state currents (I_0) between conductors was directly proportional to the ratio of conductor diameters raised to the 1.5 power (2.5 power for Kerite insulated conductors). This relationship is shown in Table 3 as well as the parameters I_0 and t_0 which have been extrapolated to include all conductor sizes based on the conductor diameter correlations given above. These results are also used to plot Equation 3 against the data obtained during testing and is shown in Appendix A. The plotted equation and data show significant fit.

Table 3

Conductor Parameters

Cond. Size	Cond. Diam. (in)	I_o	t_o	$\frac{I_o(i)}{I_o(i+1)}$	$\frac{t_o(i)}{t_o(i+1)}$	$\frac{d(i)}{d(i+1)}$	$\left(\frac{d(i)}{d(i+1)}\right)^{1.5}$
500 MCM	0.7070	121.84	14.0243	-	-	-	-
350 MCM	0.5916	93.26	11.7352	1.31	1.20	1.20	1.31
250 MCM	0.5000	72.46	9.9182	1.29	1.18	1.18	1.29
2/0 AWG	0.3648	45.16	7.2363	1.60	1.37	1.37	1.60
2 AWG	0.2576	26.80	5.0960	1.69	1.42	1.42	1.69
4 AWG	0.2043	18.95	4.0444	1.41	1.26	1.26	1.42
6 AWG	0.1620	13.40	3.2099	1.41	1.26	1.26	1.42
8 AWG	0.1285	9.48	2.5475	1.41	1.26	1.26	1.42
10 AWG	0.1019	6.70	2.0218	1.41	1.26	1.26	1.42
12 AWG	0.0808	4.74	1.6046	1.41	1.26	1.26	1.42
14 AWG	0.0641	3.35	1.2735	1.41	1.26	1.26	1.42
16 AWG	0.0508	2.37	1.0107	1.41	1.26	1.26	1.42
18 AWG	0.0403	1.67	.8018	1.42	1.26	1.26	1.42
Kerite Bus Bars							
1500 MCM	1.2250	216.66	43.0671	-	-	-	-
1000 MCM	1.0000	130.45	35.1568	1.66	1.23	1.23	1.66*
750 MCM	0.8660	91.04	30.4458	1.43	1.15	1.15	1.43*

WHERE: $\Delta T = \left(I/I_o\right)^2 \left(1 - e^{-t/t_o}\right)$ $\quad * \left[\frac{d(i)}{d(i+1)}\right]^{2.5}$

4.2 The next phase was to actually generate the time/current thermal capablity curves.

4.2.1 The first set of curves generated was for the Kapton insulated conductors used in Conax's basic feedthru module design. The following assumptions were made:

1. The initial temperature of the conductor is assumed to be at 115°C which is 25°C higher than the conductor's normal continuous current temperature rating for all environments.

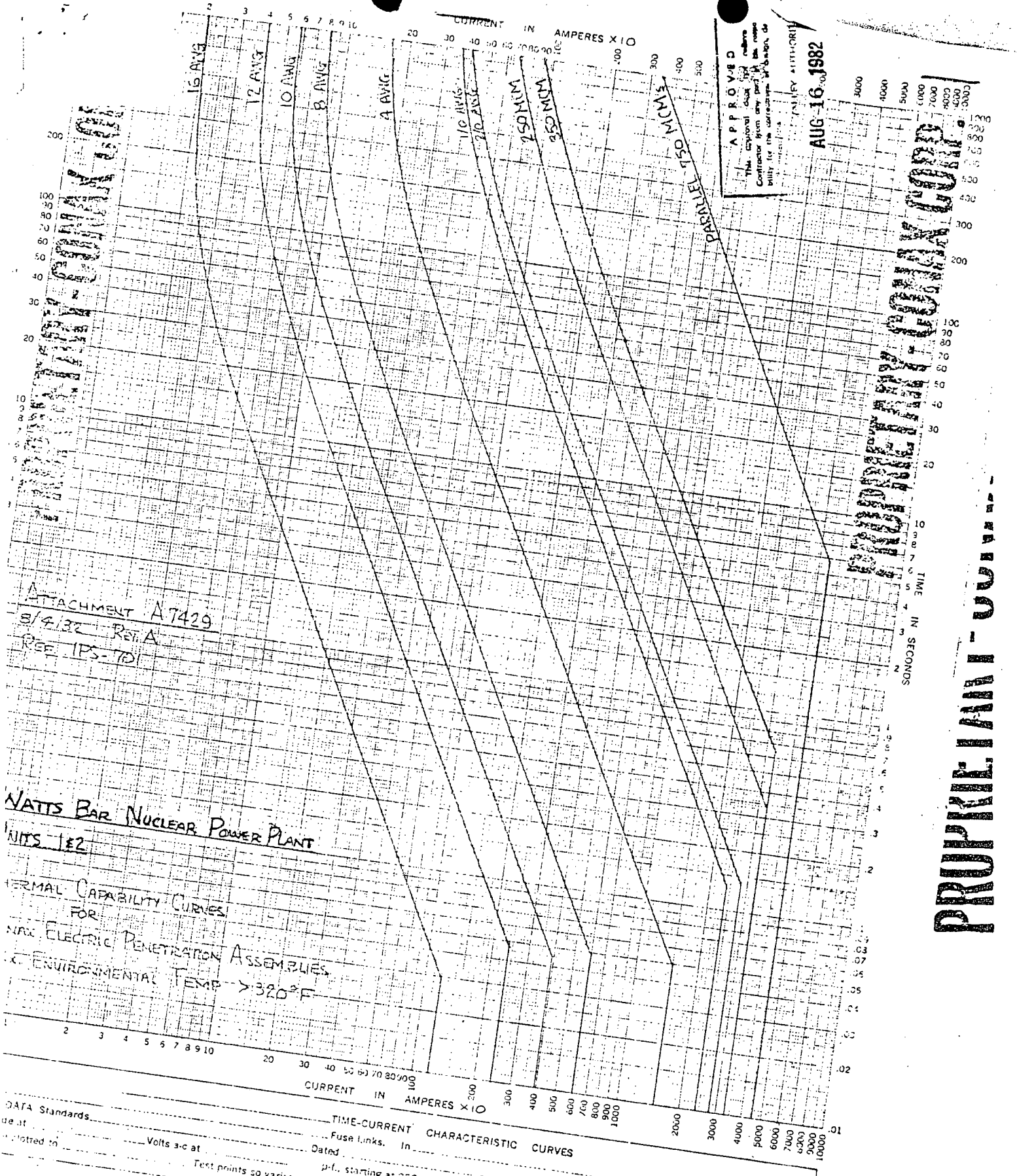
2. It is assumed that only the outboard seal on the feedthrough module is critical and that the inboard or inside containment seal is already compromised.

3. The environment at the outboard seal is assumed to be 150°F.

4.2.2 With the above assumptions the following is noted. The selection of 115°C initial conductor temperature is a conservative prediction since the lower the initial temperature the larger is the ΔT that can be supported and, hence, the larger is the current load. The final judgement on the validity of the assumptions rests with the results of tests when points on the predicted curve are actually tested. If failures resulting in leakage occur, it will be because the load currents are too high implying that the assumptions on initial temperature were too low and permitted an excessive ΔT to be used in the prediction (Eq. 3).

4.2.3 The same procedure was followed for the Kerite insulated bus conductors even though the failure mechanism is different in the respect that the bus bar conductors, which Conax employs only on it's Medium Voltage Power Penetration design, form a containment seal via copper ferrules and ceramic insulator bushings. The ceramic insulator bushing has a bellows assembly that permits the Kerite bus conductor to expand under heat up to 1/4 inch in length before the expanding conductor can stress the ferrule seal. This only occurs when stabilized temperatures are in excess of 250°C. The maximum service life given by Equation 4 at 250°C is only 0.0109 seconds. Thus using Eq. 4 for the Kerite case is conservative since the actual seal life at 250°C is for extended periods beyond 1000 seconds.

4.2.4 Using Equations 3 & 4, the assumed initial conditions, and the technique described in Paragraph 3.0, time/current thermal capability curves were generated as shown in Figure 2. These curves are continuous and completely defined and inter-related by the conductor's physical parameters. Verification by test of the validity of these curves is described in the following sections. (Note: The Figure 2 curves are for thermal consideration only and must be adjusted for electro-mechanical force limitations.)


CURRENT IN AMPERES X 10
16 AWG
12 AWG
10 AWG
8 AWG
4 AWG
1/0 AWG
2/0 AWG
250 MCM
350 MCM
PARALLEL 750 MCM's
TIME IN SECONDS
ATTACHMENT A7429
8/4/82 REV. A
REF. IPS-701
WATTS BAR NUCLEAR POWER PLANT
UNITS 1&2
THERMAL CAPABILITY CURVES
FOR
NAC ELECTRIC PENETRATION ASSEMBLIES
ENVIRONMENTAL TEMP >320°F
CURRENT IN AMPERES X 10
TIME-CURRENT CHARACTERISTIC CURVES
DATA Standards
Fuse Links. In
Volts a-c at
Dated
p.f., starting at 25C with no initial load.
Test points so variations should be
No.
Date
48 5253
APPROVED
AUG 16 1982
PROPRIETARY - COMAX CORP.

4.3 The final phase was to test points along the time/current thermal capability curves under actual conditions.

4.3.1 For this phase four samples of each of the Conax feedthru module types given in Table 4 were, using Conax's standard manufacturing and test process, fabricated and production tested for leak rate, insulation resistance, conductor continuity, and dielectric strength and all samples met or exceeded the requirements given in Table 5. (See appendix B for Data Sheets).

Table 4

Test Samples

Feedthru Module Conductor Density/Wire Size	Conax Part No.	Quantity
36C/#16AWG	2SK-2183-01	4
30C/#14AWG	2SK-2184-01	4
24C/#12AWG	2SK-2185-01	4
19C/#10AWG	2SK-2186-01	4
12C/# 8AWG	2SK-2187-01	4

Table 5

Production Test Requirements

Gas Leak Rate: He @ 75 psig	1×10^{-8} scc/sec
Conductor Continuity:	Verify
Insulation Resistance: @ 500 VDC	1×10^{8} ohms (minimum)
Dielectric Strength: 1 minute	2.2 KVAC

4.3.2 The test set-up is diagramed in Figure 3. Four "Blue M" ovens (Item 3 - Table 1) were placed together as shown. The two intermediate ovens represented a containment nozzle length and the extreme ovens were to simulate inside and outside containment environments. Each test sample feedthru module was configured with two thermocouples (Item 1 - Table 1) on the conductors selected to undergo tests with one at the inboard sealant end and the other at the outboard sealant end. Instrumentation output (thermocouple readings and current loads) was again configured to permanently record on a data logger (Item 2 - Table 1).

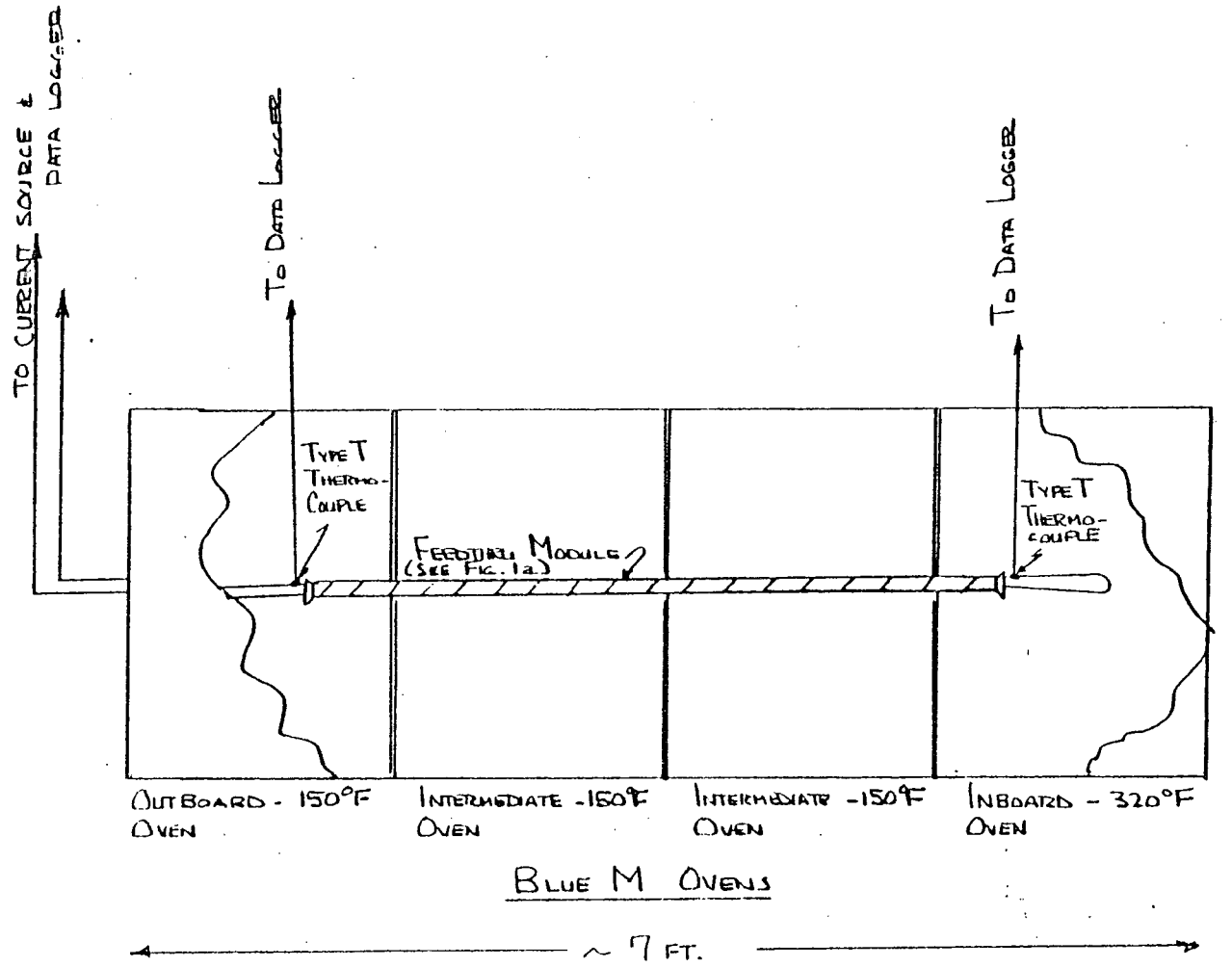


FIGURE 3

TEST SET-UP

4.3.3 The procedure was as follows:

A. The outside containment and two intermediate ovens were set to 150°F with the inside containment oven set at 320°F.

1. The 150°F outside containment oven setting is consistant with the actual maximum outside containment environmental temperature to be expected in an installed state during all accident conditions.

2. The 150°F intermediate oven temperature is designed to represent the heat generated in a nozzle by an electric penetration assembly with a full complement of feedthru modules under full rated continuous current loads. Conax has shown (Ref. 2.6) that up to 50 watts/foot can be generated under full load conditions to produce this 150°F environment. It should be noted that regardless of plant specific conditions the Conax design is always limited to this 150°F temperature extreme.

3 The 320°F inboard oven setting is consistant with the maximum inside containment environment expected at the penetration's location in the containment wall. Conax has shown both by test (Ref. 2.7) and analysis (Ref. 2.8) that even under the worst temperature extremes such as MSLB conditions the temperature at the containment wall and penetration (with or without a termination enclosure box) never exceeds the saturated steam temperature for the given environmental pressure - a phenomena given by the low energy that superheated steam possesses. This 320°F is equivalent to a saturated steam pressure of 90 psia which is larger than the maximum environmental pressure to be expected inside containment.

8. For a given conductor size four time/current points along the time/current capability curve generated during Phase 2 (Section 4.2) were selected. Only one test specimen of each conductor size was used for each of the four time/current points selected to preclude overtesting a sample by subjecting it to more than one test. Single phase current loads were utilized [Remaining conductors were not energized since temperatures of intermediate ovens were set to simulate a complete penetration at full rated current - See 4.3.3 A(2)].. Prior to application of the overload a continuous current load was applied to the tested conductors until temperatures stabilized. Table 6 lists all the overload currents and durations as well as continuous current loads. The following items should be noted:

1. The primary leakage path is localized to the conductors undergoing the tests.

2. The continuous current loads were higher than the continuous current loads predicted by Eq. 3 and the rated current Conax would recommend for an outboard ambient temperature of 150°F and a final conductor temperature of 90°C. This comparison is shown in Table 6.

3. The tested current loads were in most cases higher than those predicted by the curve of Figure 2. This comparison is also shown in Table 6.

Table 6

Test Condition/Comparisons

A	B	C	D	E	F	G	H
Conductor Type-Control Ltr	Test Duration (sec)	Test Current (amps)	Current From Fig. 2	Ratio C/D	Pre-Overload Current	Eq. 3 Pre-Overload Current	Ratio F/G
36C/#16AWG-C	1000	25	20.41	1.22	14.5	11.72	1.24
-B	200	27	21.85	1.24			
-A	100	30	24.35	1.23			
-D	10	72	59.83	1.20			
30C/#14AWG-C	1000	35	28.85	1.21	20.0	16.56	1.21
-B	200	38	31.48	1.21			
-D	100	43	36.21	1.19			
-A	10	110	94.15	1.17			
24C/#12AWG-D	1000	48	40.82	1.18	27.0	23.44	1.15
-C	200	54	45.85	1.18			
-B	100	64	54.45	1.18			
-A	10	173	148.46	1.17			
19C/#10AWG-C	1000	62	57.70	1.07	35.0	33.13	1.06
-D	200	72	67.45	1.07			
-B	100	88	82.56	1.07			
-A	10	247	234.46	1.05			
12C/# 8AWG-D	1000	82	81.69	1.00	47.0	46.87	1.00
-C	200	101	100.40	1.00			
-B	100	127	126.32	1.00			
-A	10	371	370.82	1.00			

C. Finally, after all tests were completed each test sample was leak tested with dry He @ 75 psig at both the inboard and outboard ends. Table 7 summarizes these results (See data sheets in Appendix C) and shows that not one seal sustained any degradation and that the total leak rate never exceeded 2.72×10^{-9} scc/sec. It is noted that Conax's present design permits a maximum of 30 feedthru modules per penetration assembly such that 30 times this highest total observed leak rate would yield a total penetration leak rate of 8.16×10^{-8} scc/sec which more than meets the requirements of IEEE 317 (Ref. 2.2) which permits a total leak rate of up to 1×10^{-2} scc/sec. of dry nitrogen.

4.3.4 Examination of the temperatures recorded during all tests and given in the data sheets of Appendix C show that with the exception of the 10 second duration tests all recorded conductor temperature rises were lower than predicted by Equation 3. This is due to the fact that in the development of Eq. 3 parameters, I_o and t_o, the heat sink effects of a feedthru module were not a factor and conservative results were achieved.

Table 7

Leak Rate Summary
(Helium @ 75 psig)

Cond. Type	Control Letter	Inboard (scc/sec)	Outboard (scc/sec)	Total (scc/sec)
36C/#16AWG	A	$8.0(10^{-11})$	$5.2(10^{-10})$	$6.0(10^{-10})$
	B	$1.0(10^{-10})$	$1.0(10^{-10})$	$2.0(10^{-10})$
	C	$1.2(10^{-10})$	$1.0(10^{-10})$	$2.2(10^{-10})$
	D	$2.5(10^{-10})$	$1.6(10^{-9})$	$1.85(10^{-9})$
30C/#14AWG	A	$2.0(10^{-11})$	$6.0(10^{-11})$	$8.0(10^{-11})$
	B	$2.8(10^{-10})$	$1.0(10^{-10})$	$3.8(10^{-10})$
	C	$1.0(10^{-10})$	$1.0(10^{-10})$	$2.0(10^{-10})$
	D	$1.0(10^{-10})$	$2.0(10^{-11})$	$1.2(10^{-10})$
24C/#12AWG	A	$2.0(10^{-10})$	$1.8(10^{-10})$	$2.8(10^{-10})$
	B	$7.2(10^{-10})$	$2.0(10^{-9})$	$2.72(10^{-9})$
	C	$6.0(10^{-11})$	$1.0(10^{-10})$	$1.6(10^{-10})$
	D	$1.0(10^{-10})$	$1.0(10^{-10})$	$2.0(10^{-10})$
19C/#10AWG	A	$5.8(10^{-10})$	$1.0(10^{-10})$	$6.8(10^{-10})$
	B	$7.6(10^{-10})$	$4.8(10^{-10})$	$1.24(10^{-9})$
	C	$1.0(10^{-10})$	$8.0(10^{-11})$	$1.8(10^{-10})$
	D	$2.0(10^{-11})$	$1.0(10^{-10})$	$1.2(10^{-10})$
12C/# 8AWG	A	$2.0(10^{-11})$	$1.2(10^{-10})$	$1.4(10^{-10})$
	B	$1.0(10^{-10})$	$1.0(10^{-10})$	$2.0(10^{-10})$
	C	$1.0(10^{-10})$	$1.0(10^{-10})$	$2.0(10^{-10})$
	D	$1.0(10^{-10})$	$1.0(10^{-10})$	$2.0(10^{-10})$

4.3.5 The results of these tests have more than verified the validity and conservatism of the time/current thermal capability curves of Figure 2 and no further testing is required. Also, past tests, as documented in References 2.9, 2.10, 2.11, & 2.12, were conducted at G.E.'s High Power Laboratory in Philadelphia at ambient temperatures in excess of 350°F. These tests are summarized and compared in Table 8 to the corresponding points on the time/current capability curves of Figure 2 and show results within the range and capabilities of the Conax Design.

4.3.5.1 It should be noted that test described in Reference 2.9 were performed on a complete penetration assembly configured with feedthrough modules containing conductors ranging from 500 MCM thru #14 AWG. This penetration test specimen had been preconditioned (Ref. 2.6) by subjecting the unit to a total integrated radiation dose of at least 128 megarads and age conditioning the unit for 100 hours at 150°C which, based on the temperature/time relationship of Equation 4 as shown in Figure 1, is equivalent to 40 years service at 120°C. This preconditioning produced no degradation on the unit or its performance during subsequent short circuit current testing as evidenced by complete evaluation testing within the acceptance criteia specified in IEEE Std. 317-1976, such that age conditioning and its effect are not a factor on performance for the Conax design.

5.0 SUMMARY

5.1 Conax has developed a set of time/current thermal capability curves for all conductor sizes in it's basic Electric Penetration Assembly and Electric Conductor Seal Assembly design. These curves have been verified by test and their development has been demonstrated as conservative.

For documentation purposes a full scale set of curves for the particular plant specific requirements and conductor sizes is a separate attachment to this report.

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Table 8

Additional Test Data

Cond. Size	Test Duration (sec)	Test Current (amps)	Current From Fig. 2	Ratio	Ref. No.
500 MCM	1.580	34700	29051	1.19	2.9
350 MCM	0.780	35000	29461	1.19	2.9
250 MCM	0.325	33700	33302	1.01	2.9
2/0 AWG	0.163	28300	25450	1.11	2.9
2 AWG	0.054	21800	22597	0.96	2.9
4 AWG	0.045	15000	15659	0.96	2.9
6 AWG	0.053	9500	9056	1.05	2.9
8 AWG	0.062	5960	5258	1.13	2.9
10 AWG	0.037	3900	4337	0.90	2.9
12 AWG	0.037	2410	2733	0.88	2.9
14 AWG	0.037	1500	1721	0.87	2.9
1500 MCM	15.75	37116	27194	1.36	2.10
1000 MCM	2.67	55000	44032	1.25	2.11
750 MCM	1.28	44000	47696	0.92	2.12

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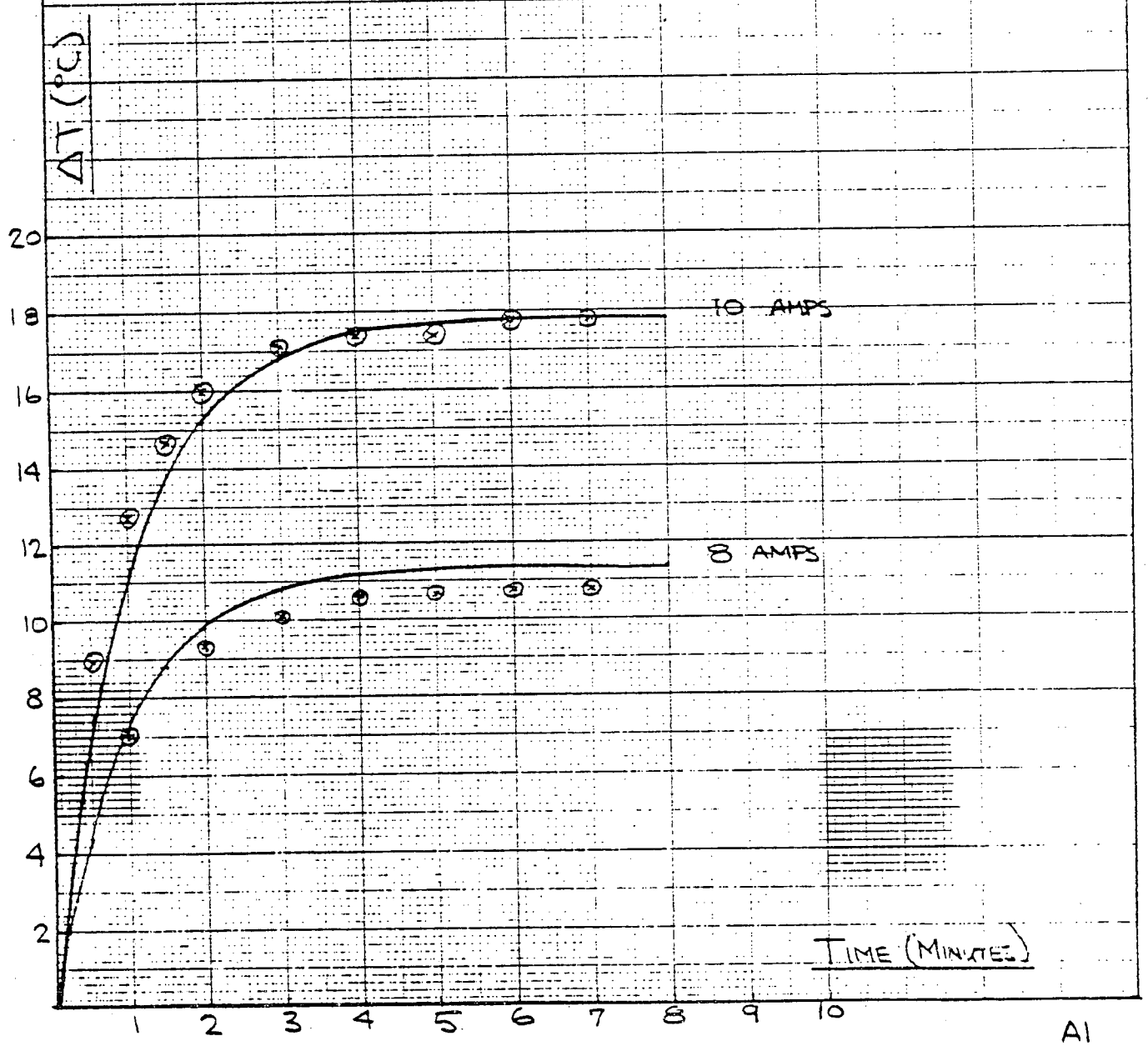
Appendix A

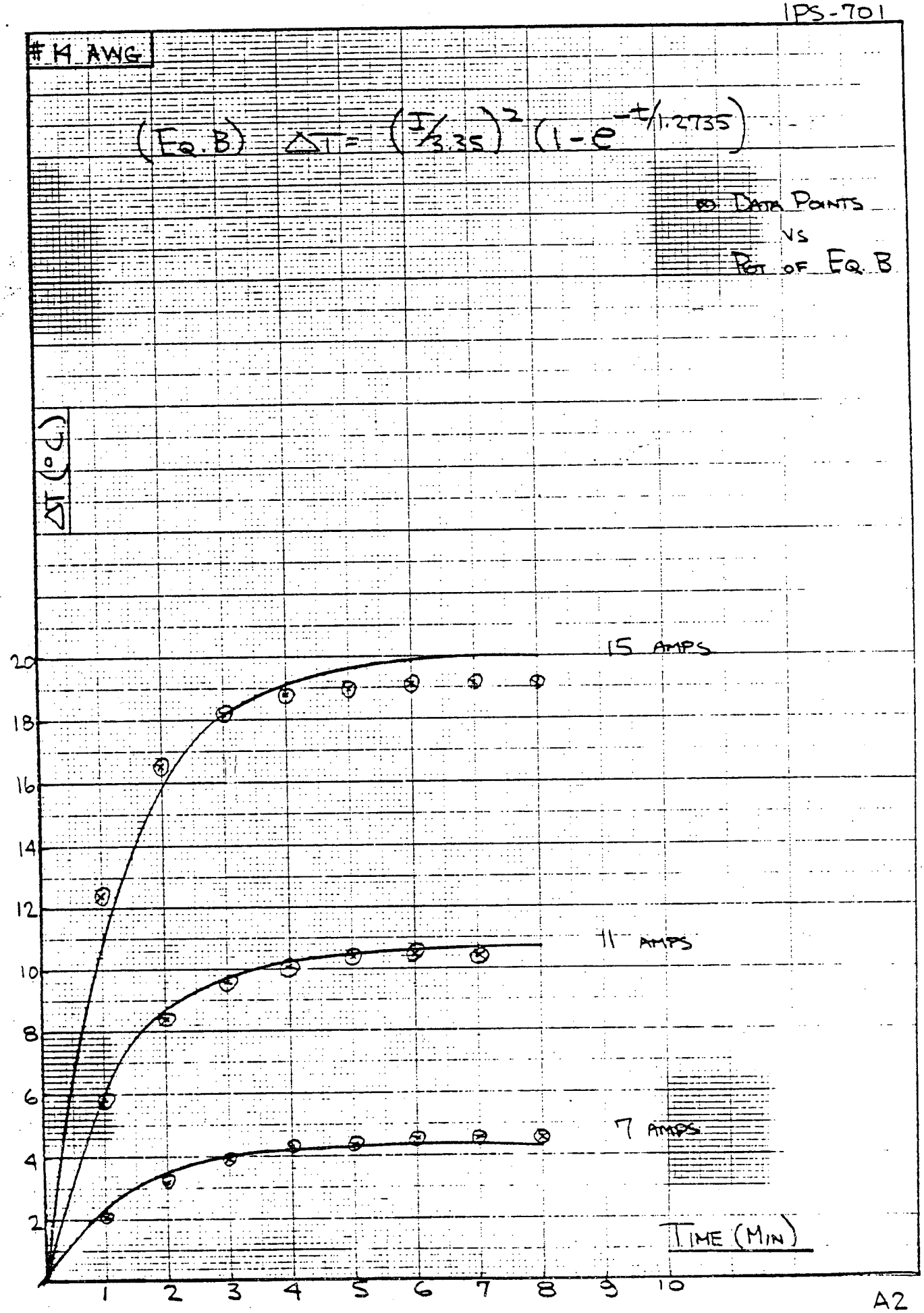
Test Data - Phase 1

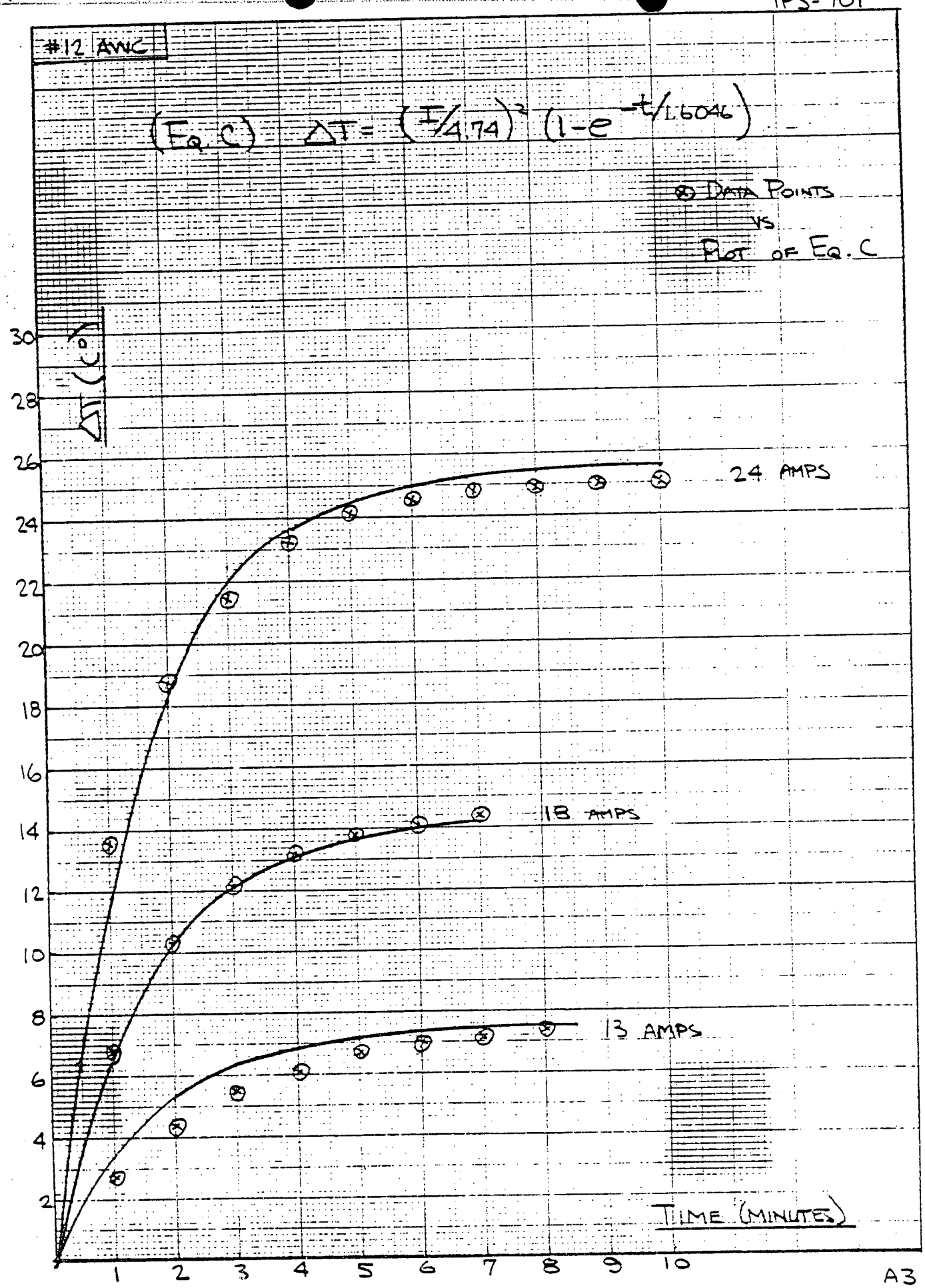
#16 AWG

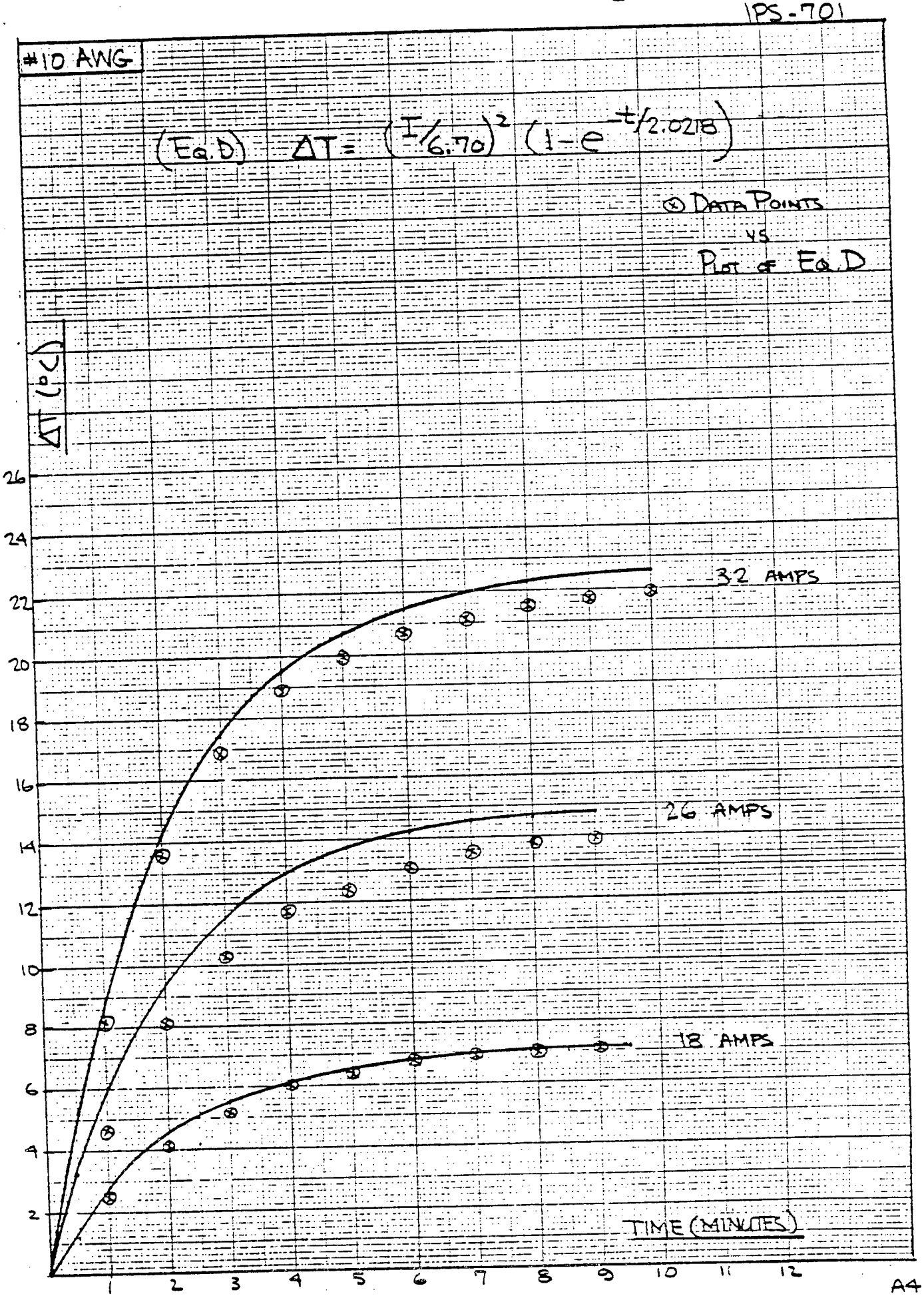
$$(\text{Eq. A}) \quad \Delta T = \left(I/2.37\right)^2 \left(1 - e^{-t/1.0107}\right)$$

⊗ Data Points vs Plot of Eq. A

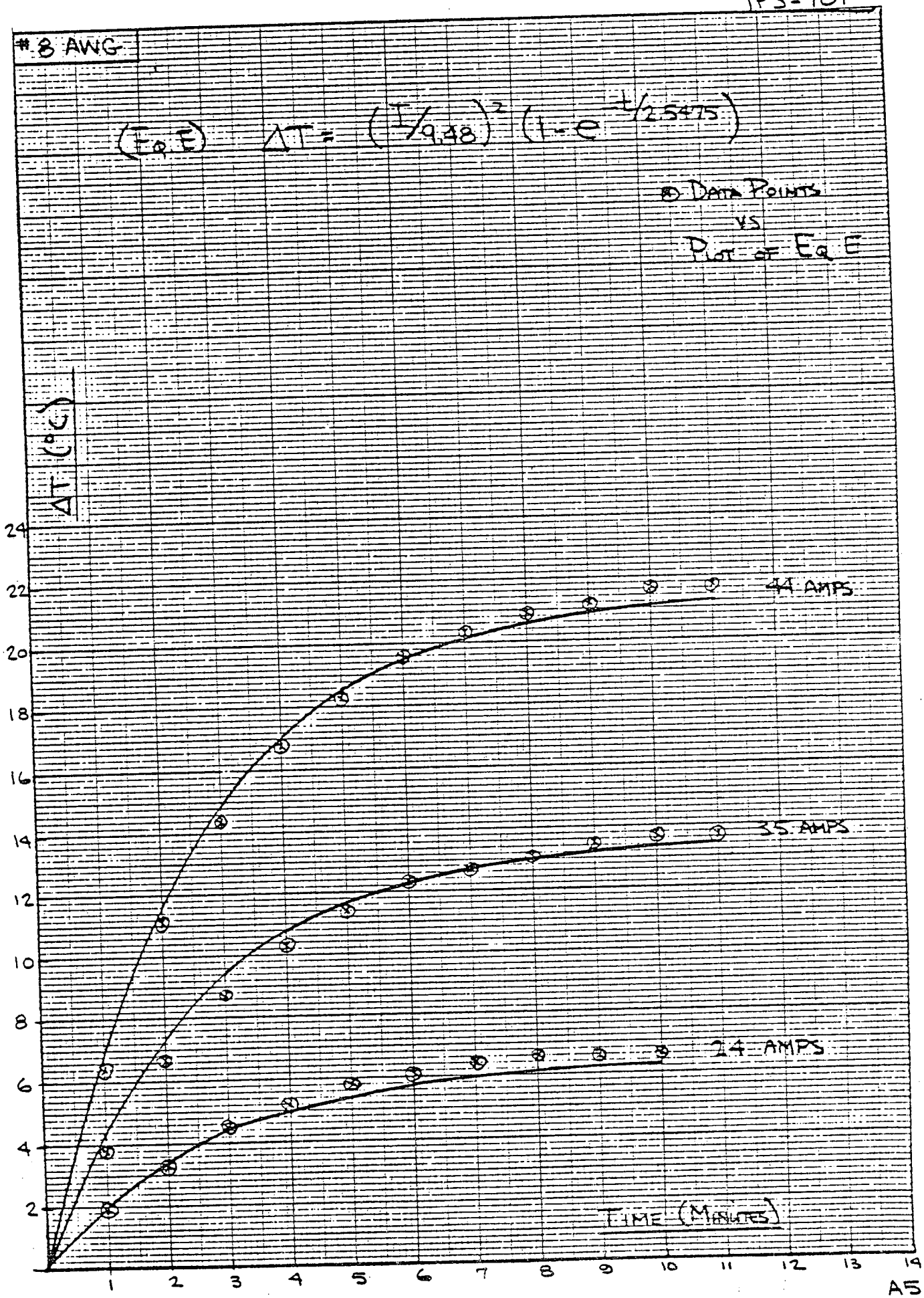



14 AWG
(Eq. B) $\Delta T = \left(I/3.35\right)^2 \left(1 - e^{-t/1.2735}\right)$
⊗ Data Points vs Plot of Eq. B
ΔT (°C)
15 AMPS
11 AMPS
7 AMPS
Time (Min)
20
18
16
14
12
10
8
6
4
2
1
2
3
4
5
6
7
8
9
10

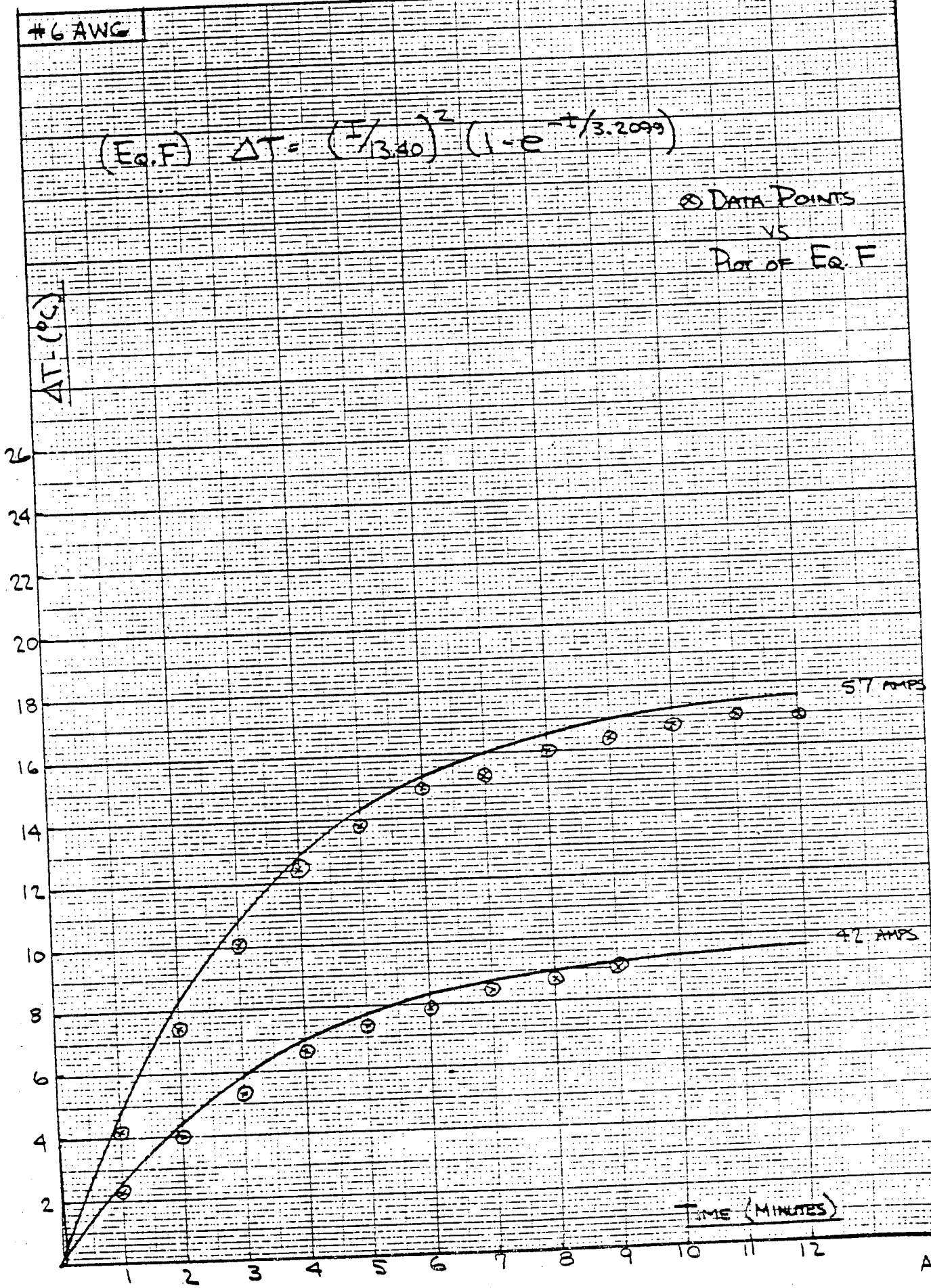

#12 AWG
(Eq. C) $\Delta T = \left(I/4.74\right)^2 \left(1 - e^{-t/1.6046}\right)$
⊗ Data Points
vs
Plot of Eq. C
ΔT (C°)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
24 AMPS
18 AMPS
13 AMPS
Time (minutes)
1
2
3
4
5
6
7
8
9
10


#10 AWG
(Eq.D) $\Delta T = \left(I/6.70\right)^2 \left(1 - e^{-t/2.0218}\right)$
⊗ Data Points
vs
Plot of Eq.D
ΔT (°C)
26
24
22
20
18
16
14
12
10
8
6
4
2
32 AMPS
26 AMPS
18 AMPS
TIME (MINUTES)
1
2
3
4
5
6
7
8
9
10
11
12

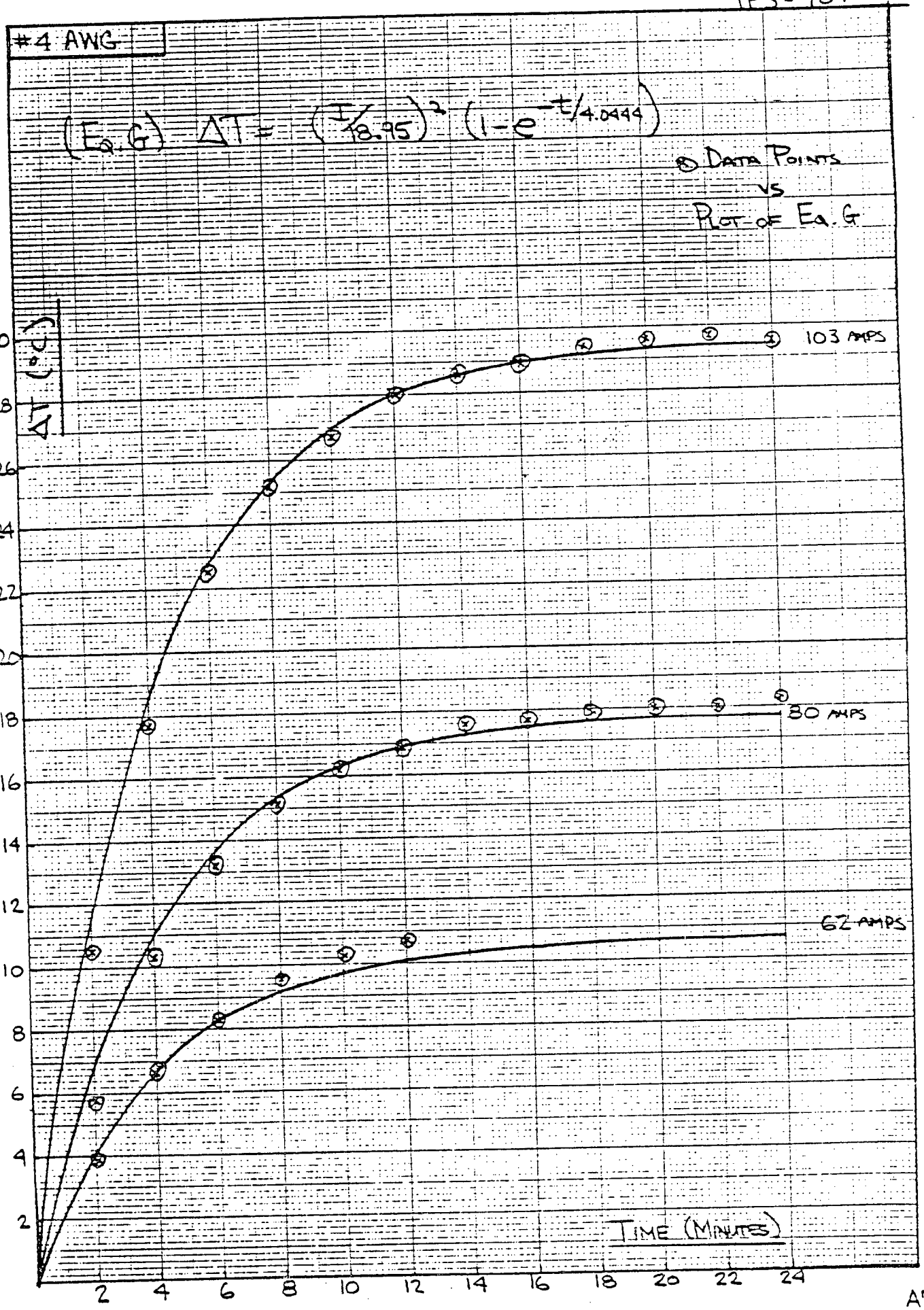
PS-701

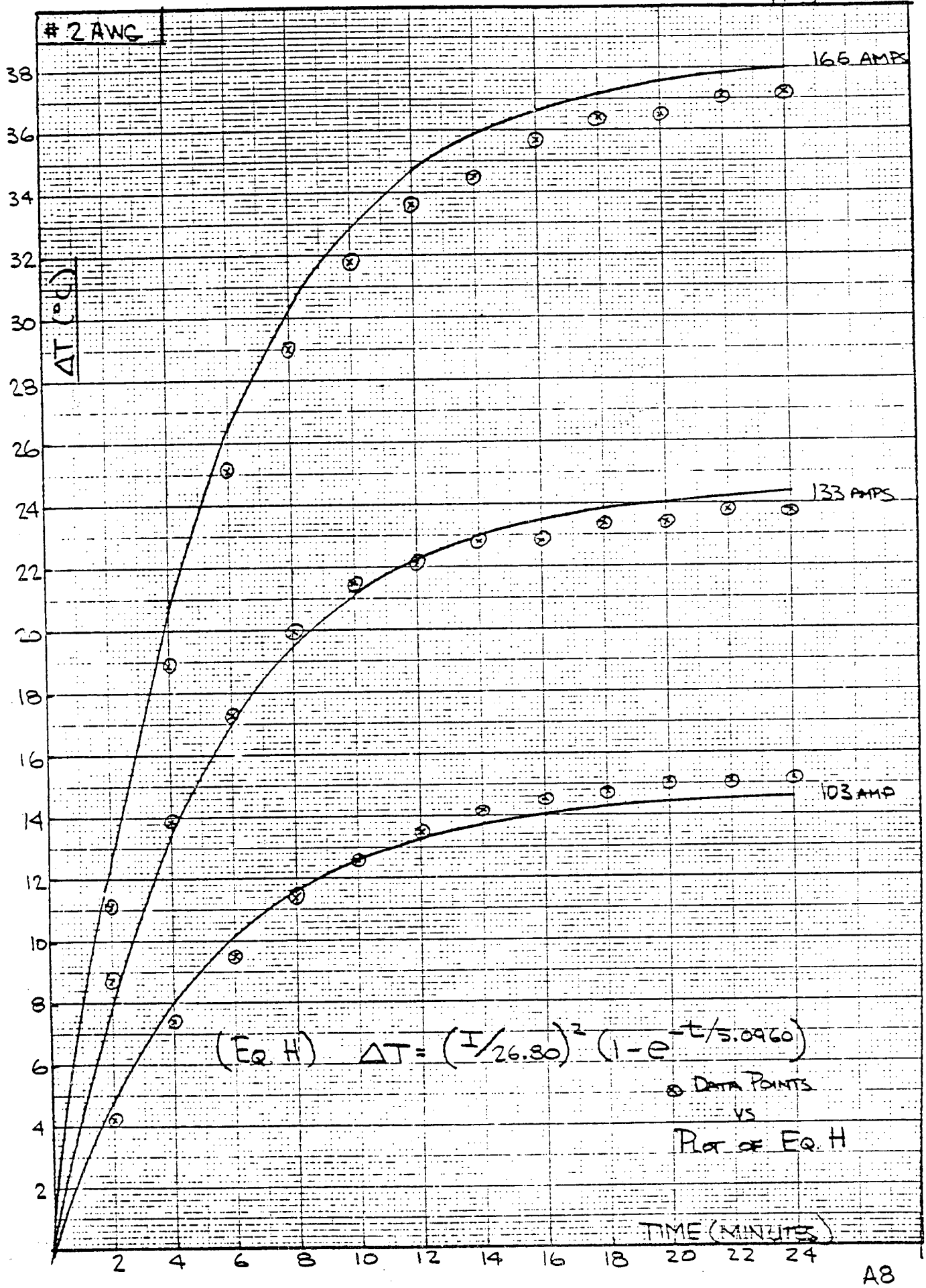


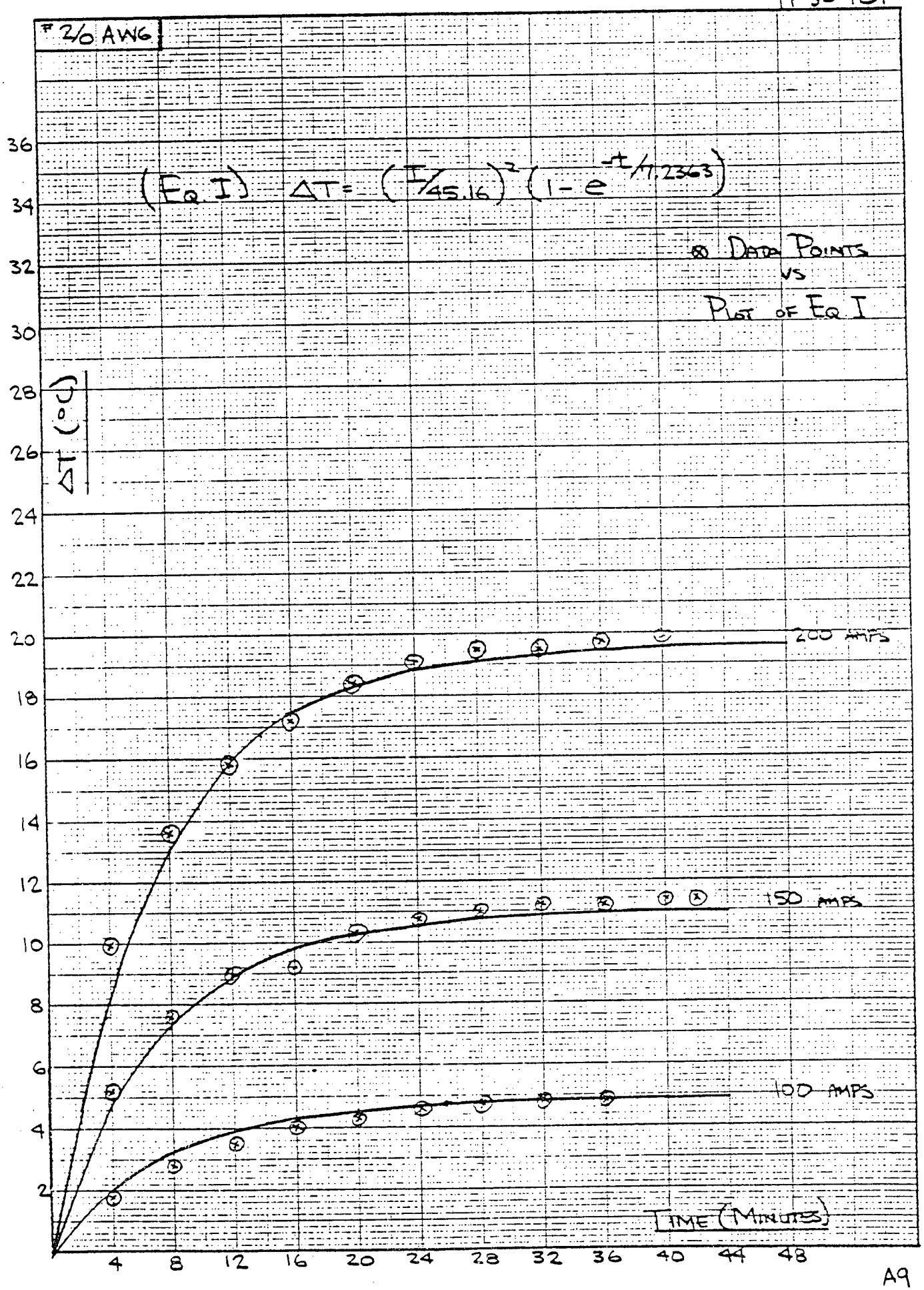
SQUARE 20 × 20 1 INCH
AS-0810 01


#6 AWG
(Eq.F) $\Delta T = \left(I/13.40\right)^2 \left(1 - e^{-t/3.2099}\right)$
⊗ Data Points
vs
Plot of Eq. F
ΔT (°C)
26
24
22
20
18
16
14
12
10
8
6
4
2
57 AMPS
42 AMPS
Time (Minutes)
1
2
3
4
5
6
7
8
9
10
11
12

IPS-701


#4 AWG
(Eq. G) $\Delta T = \left(\frac{I}{8.95}\right)^2 \left(1 - e^{-t/4.0444}\right)$
⊗ Data Points vs Plot of Eq. G
ΔT (°C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
103 AMPS
80 AMPS
62 AMPS
Time (Minutes)
2
4
6
8
10
12
14
16
18
20
22
24

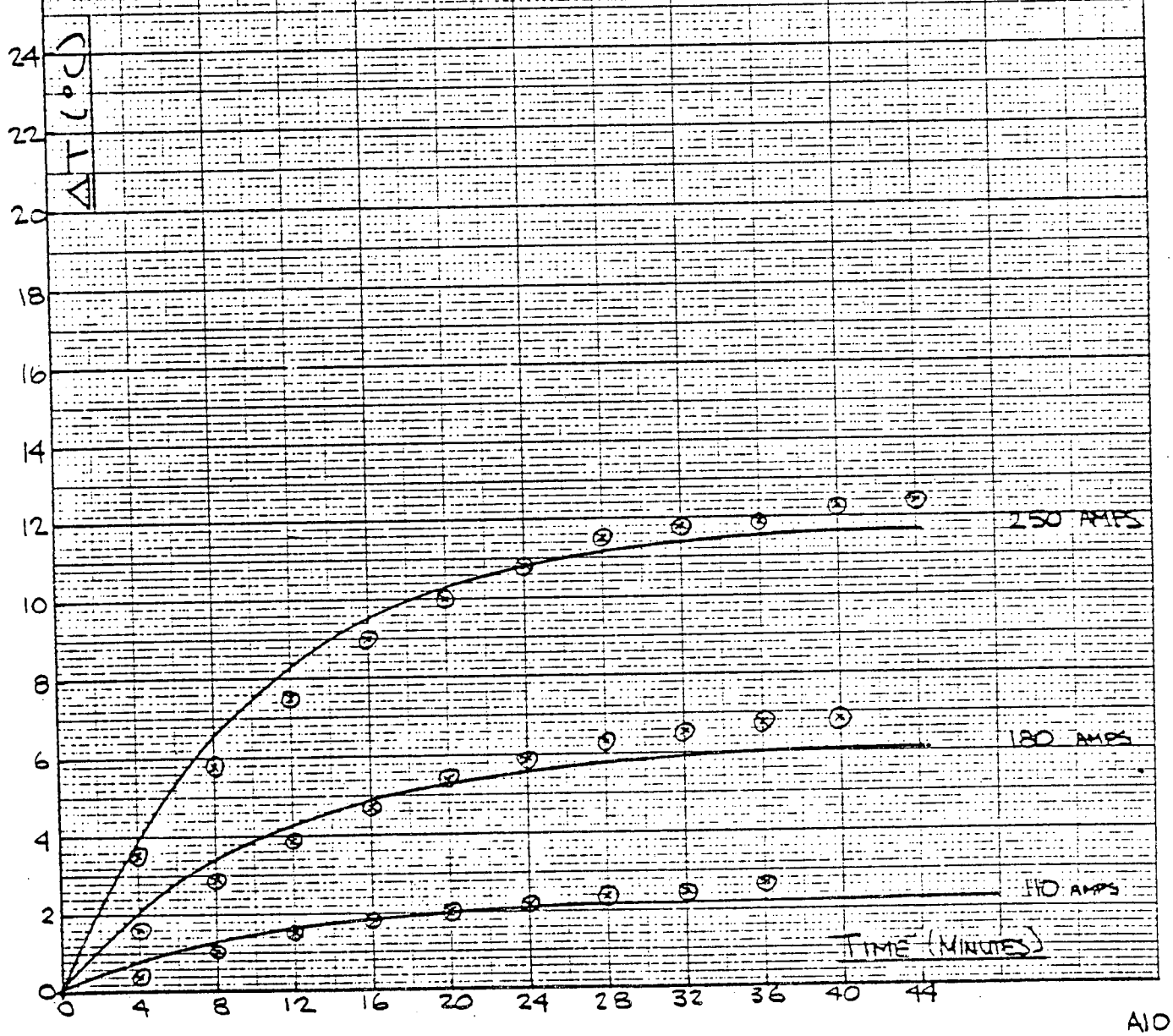

#2 AWG
166 AMPS
133 AMPS
103 AMP
ΔT (°C)
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
2
4
6
8
10
12
14
16
18
20
22
24
TIME (MINUTES)
(EQ H) ΔT = (I/26.80)² (1 - e^(-t/5.0960))
DATA POINTS
VS
PLOT OF EQ H


#2/0 AWG
(Eq I) $\Delta T = \left(I/45.16\right)^2 \left(1 - e^{-t/1.2363}\right)$
⊗ Data Points vs Plot of Eq I
ΔT (°C)
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
200 AMPS
150 AMPS
100 AMPS
Time (Minutes)
4
8
12
16
20
24
28
32
36
40
44
48

250 MCM

(Eq J) $\Delta T = \left(\frac{I}{72.46}\right)^2 \left(1 - e^{-t/9.9182}\right)$

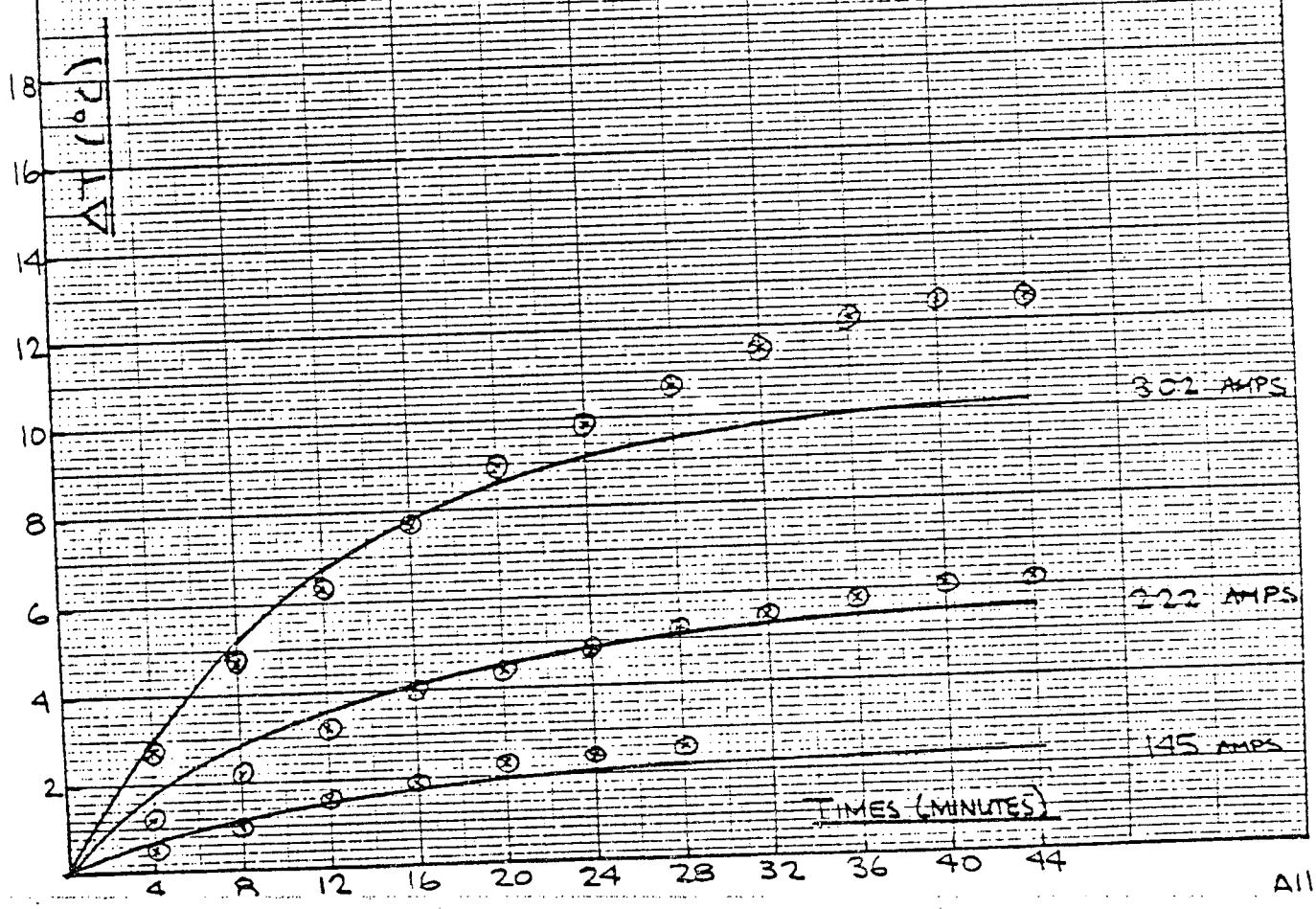
⊗ Data Points vs Plot of Eq. J

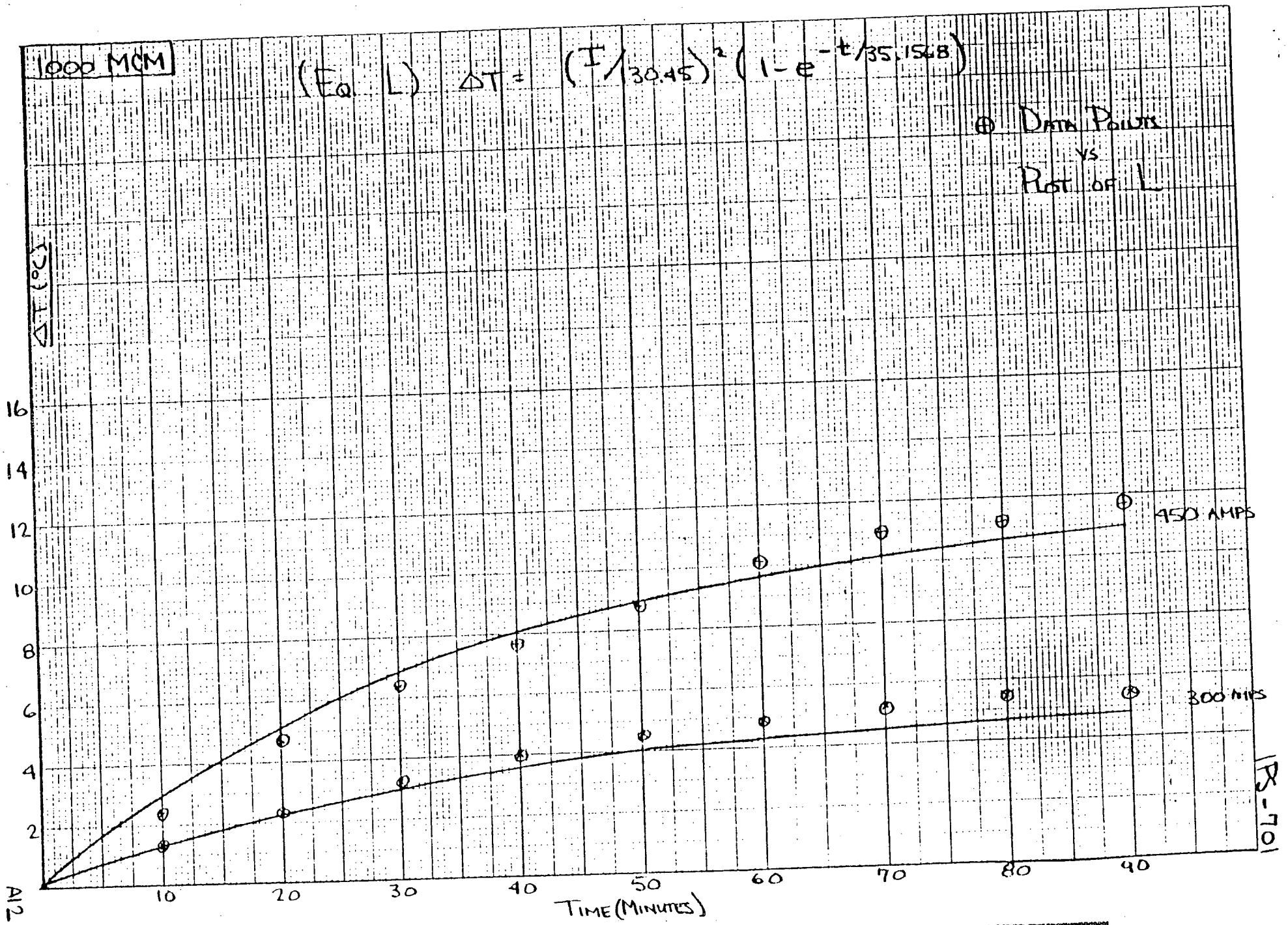


350 MCM

(Eq. K) $\Delta T = \left(\frac{I}{93.26}\right)^2 \left(1 - e^{-t/11.7352}\right)$

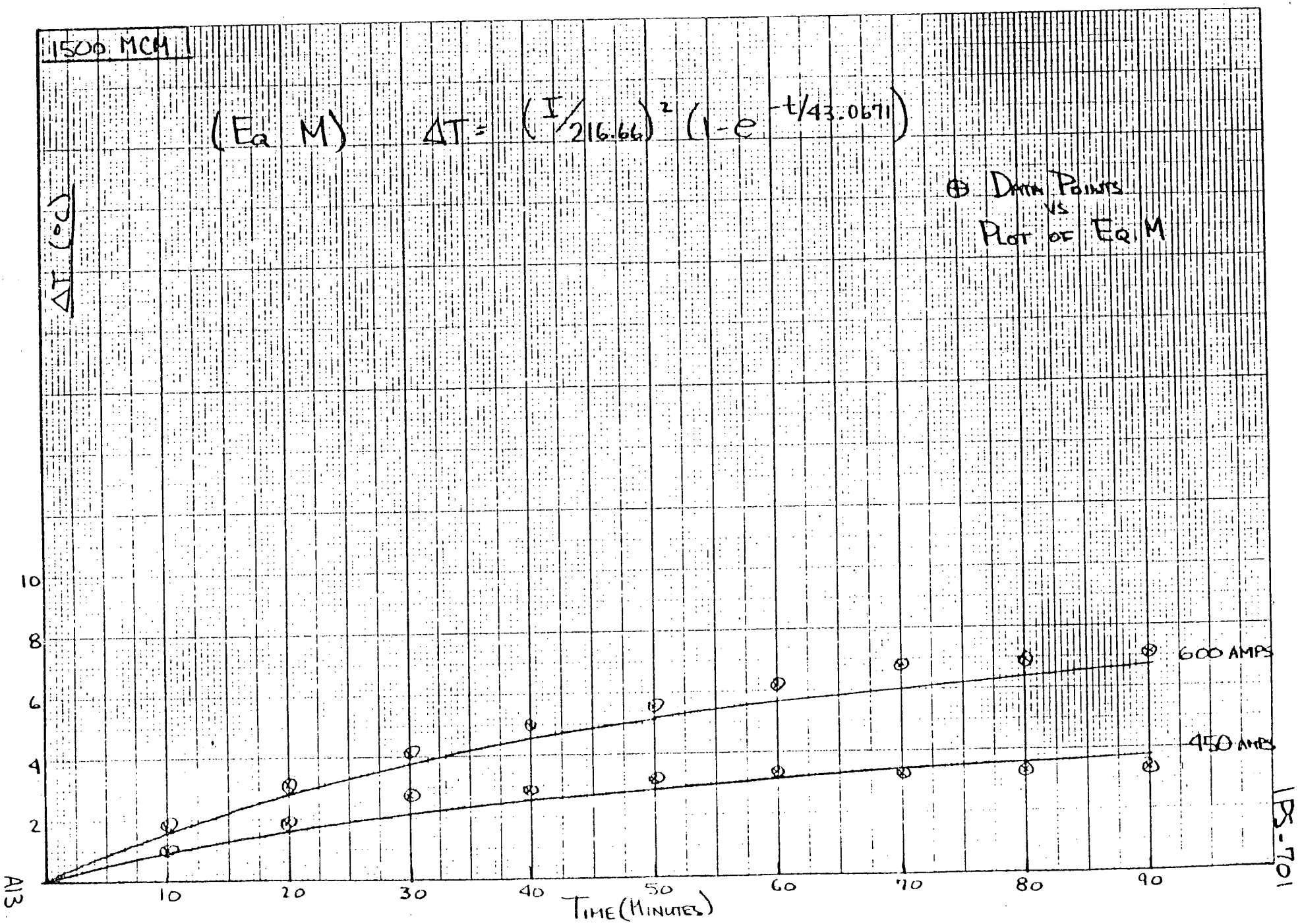
⊗ Data Points vs Plot of Eq. K




1000 MCM
(Eq. L) ΔT = (I/30.45)² (1 - e^(-t/35.1568))
⊕ Data Points vs Plot of L
ΔT (°C)
16
14
12
10
8
6
4
2
10
20
30
40
50
60
70
80
90
Time (Minutes)
450 AMPS
300 AMPS

A12

R-70


1500 MCM
(Eq M) $\Delta T = \left(I/216.66\right)^2 \left(1 - e^{-t/43.0671}\right)$
⊕ Data Points vs Plot of Eq. M
ΔT (°C)
10
8
6
4
2
600 AMPS
450 AMPS
10
20
30
40
50
60
70
80
90
Time (Minutes)

A13

B-701

Appendix B

Pre-Test Evaluation
Data Sheets

FORM NO. 0055

DATA SHEET A
NON-DESTRUCTIVE TESTS

CUSTOMER DESIGNATION N/A CONAX P/N 25K-2186-01

CUSTOMER P.O. N.P. TEST CONAX W.O. 2-92700 SHEET 1 OF 1

IPS-4 PARA.	9.1 VISUAL INSPECTION		9.2 LEAK RATE	9.3 CONDUCTOR CONTINUITY	9.4.1 DIELECTRIC STRENGTH	9.5 INSULATION RESISTANCE
FEEDTHRU QUANTITY	DRAWING CONFORMANCE	CLEANLINESS	75±PSIG HE 2×10^{-8} STD CC/SEC MAX.		ONE MINUTE SIZE 10 AWG SERVICE 600V	10^8 OHMS MINIMUM
4	73	73	Hg T 4			

SIGNATURES:

CONAX TECHNICIAN [signature] DATE 1-19-81

CONAX Q.C. [signature] DATE 1-19-81

2300 WALDEN AVENUE
BUFFALO, NEW YORK 14225

NO. IPS 701

REV. P (IPS 4)

B1

FORM NO. 0056

2300 WALDEN AVENUE
BUFFALO, NEW YORK 14225

IPS NO. 701

KEY 1 (IPS 4)

DATA SHEET A
NON-DESTRUCTIVE TESTS

CUSTOMER DESIGNATION N/A CONAX P/N 25K-2184-01

CUSTOMER P.O. N.P. TEST CONAX W.O. 7-92700 SHEET 1 OF 1

IPS-4 PARA.	9.1 VISUAL INSPECTION		9.2 LEAK RATE	9.3 CONDUCTOR CONTINUITY	9.4.1 DIELECTRIC STRENGTH	9.5 INSULATION RESISTANCE
FEEDTHRU QUANTITY	DRAWING CONFORMANCE	CLEANLINESS	75±PSIG HE 2×10^{-8} STD CC/SEC MAX.		ONE MINUTE SIZE 14 AWG SERVICE 600V	10^8 OHMS MINIMUM
4	[illegible]	[illegible]	Hr. T 4	N.P. 8	N.A. 8	N.P. 8

SIGNATURES:

CONAX TECHNICIAN [illegible] DATE 1-19-81

CONAX Q.C. [illegible] DATE 1-19-81

FORM NO. 0056

DATA SHEET A
NON-DESTRUCTIVE TESTS

CUSTOMER DESIGNATION N/A CONAX P/N 25K-2185-01

CUSTOMER P.O. N. P. TEST CONAX W.O. 7-92700 SHEET 1 OF 1

IPS-4 PARA.	9.1 VISUAL INSPECTION		9.2 LEAK RATE	9.3 CONDUCTOR CONTINUITY	9.4.1 DIELECTRIC STRENGTH	9.5 INSULATION RESISTANCE
FEEDTHRU QUANTITY	DRAWING CONFORMANCE	CLEANLINESS	75±PSIG HE 2×10^{-8} STD CC/SEC MAX.		ONE MINUTE SIZE 12 AWG SERVICE 600V	10^8 OHMS MINIMUM
4			Hs. T 4	N.P. 8	N.P. 8	N.P. 8

SIGNATURES:

CONAX TECHNICIAN F. W. Jamolsky DATE 1-19-81

CONAX Q.C. [illegible] DATE 1-19-81

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BUFFALO, NEW YORK 14225

NO. IPS-701

REV. F (IPS4)

FORM NO. 0056

DATA SHEET A
NON-DESTRUCTIVE TESTS

CUSTOMER DESIGNATION N/A CONAX P/N 25K-2187-01

CUSTOMER P.O. N.P. TEST CONAX W.O. [redacted] 7-92700 SHEET 1 OF 1

IPS-4 PARA.	9.1 VISUAL INSPECTION		9.2 LEAK RATE	9.3 CONDUCTOR CONTINUITY	9.4.1 DIELECTRIC STRENGTH	9.5 INSULATION RESISTANCE
FEEDTHRU QUANTITY	DRAWING CONFORMANCE	CLEANLINESS	75±PSIG HE 2×10^{-8} STD CC/SEC MAX.		ONE MINUTE SIZE 8 AWG SERVICE 600V	10^8 OHMS MINIMUM
4	73	73	Hs. 1	N.P. 8	N.P. 4	N.P. 8

SIGNATURES:

CONAX TECHNICIAN F.W. Jamelsky DATE 1-19-81

CONAX Q.C. [illegible] DATE [illegible]

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BUFFALO, NEW YORK 14225

P.O. IPS-701

REV. P (IPS 4)

B4

FORM NO. 0056

DATA SHEET A
NON-DESTRUCTIVE TESTS

CUSTOMER DESIGNATION N/A CONAX P/N 25K-2183-01

CUSTOMER P.O. N.P. TEST CONAX W.O. 2-92700 SHEET 1 OF 1

IPS-4 PARA.	9.1 VISUAL INSPECTION		9.2 LEAK RATE	9.3 CONDUCTOR CONTINUITY	9.4.1 DIELECTRIC STRENGTH ONE MINUTE SIZE 16 AWG SERVICE 600V	9.5 INSULATION RESISTANCE 10^8 OHMS MINIMUM
FEEDTHRU QUANTITY	DRAWING CONFORMANCE	CLEANLINESS	75±PSIG HE 2×10^{-8} STD CC/SEC MAX.			
4	✓	✓	H.L.T.	N.P.	N.P.	N.P.

SIGNATURES:

CONAX TECHNICIAN J. W. Jamieson DATE 1-19-81

CONAX Q.C. [illegible] DATE

2300 WALDEN AVENUE
BUFFALO, NEW YORK 14225

NO. IPS-701

REV. P (IPS-4)

CONAX

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2300 Walden Ave., Buffalo, New York 14225

Appendix C

Temperature & Leak Rate
Data Sheets

IPS-701

F/T 36/C #16-D I^2t DATE 3/25/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 2.5×10^{-10} sccs inbd
1.6×10^{-9} sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320°F	149°F	154 °F	158°F	14.5 AC AMPS

TEST CURRENT 72 AC AMPS TEST DURATION 10 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	351	184	---
0	547	344	*
4	601	386	*
7	649	424	*
10	696	461	*
13	655	422	0
16	612	387	
19	579	361	

* Sensor lead to data logger broken, currents were 74, 72, 71 and 73 respectively. Fluke model 8022A - serial number 2455563 Calibrated 8-80 1 year 8-81. Stop watch used to assure full 10 sec. duration.

REMARKS: End sealant bubbled at inboard end at exit point of adjacent current carrying conductors #3 and #18 in outer ring.

C1

IPS-701

F/T 36/C #16-A I^2t DATE 3/25/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 8×10^{-11} sccs inbd
5.2×10^{-10} sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320°F	149 °F	154 °F	158°F	14.5 AC AMPS

TEST CURRENT 30 AC AMPS TEST DURATION 100 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	345	184	---
0	359	197	30.7
6	372	209	30.2
12	382	218	30.1
18	389	225	30.1
24	395	231	30.4
30	399	235	30.2
36	402	238	30.1
42	405	241	30.4
48	408	244	30.3
55	409	246	30.2
61	411	247	30.4
67	412	249	30.3
73	413	250	30.4
79	414	250	30.4
85	414	251	30.4
91	415	252	30.3
97	415	252	30.3

REMARKS: No deterioration of end sealant at inboard end.

C2

IPS-701

F/T 36/C #16-B I^2t DATE 3/26/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $<10^{-10}$ sccs inbd
$<10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320°F	149°F	154°F	158°F	14.5 AC AMPS

TEST CURRENT 27 AC AMPS TEST DURATION 200 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	346	186	---
0	360	197	27.4
10	374	210	26.9
21	383	218	27.1
30	388	222	27.1
40	392	226	27.1
51	395	229	27.3
60	397	231	27.2
70	399	232	27.2
81	400	233	27.1
90	401	234	27.2
100	402	234	27.1
111	402	235	27.2
120	403	235	27.1
130	403	235	27.2
141	403	236	27.1
150	403	236	27.1
160	404	236	27.2
171	404	236	27.2
180	404	237	27.2
190	405	237	27.1
201	405	237	0.08

REMARKS: No deterioration of end sealant at inboard end.

IPS-701

F/T 36/C #16-C I^2t DATE 3/26/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 1.2×10^{-10} sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320°F	151 °F	151 °F	158 °F	14.5 AC AMPS

TEST CURRENT 25 AC AMPS TEST DURATION 1,000 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	341	186	---
0	349	194	25.5
50	379	221	25.2
100	383	225	25.2
150	384	226	25.2
200	384	227	25.2
250	385	227	25.1
300	385	228	25.1
350	385	228	25.1
400	386	229	25.2
450	386	229	25.1
500	386	229	25.0
550	386	229	25.2
600	387	230	25.2
650	387	230	25.1
700	387	230	25.2
750	387	230	25.1
800	388	230	25.0
850	387	230	25.0
900	388	231	25.1
950	388	231	25.1
1000	388	231	25.0

REMARKS: No deterioration of end sealant at inboard end.

IPS-701

F/T 30/C #14-A I^2t DATE 3/26/81

POST I^2t (?) LEAK RATE @ 75 PSIG DRY HELIUM 2×10^{-11} scds inbd
6×10^{-11} scds otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320 °F	149°F	153 °F	158 °F	20 AC AMPS

TEST CURRENT 110 AC AMPS TEST DURATION 10 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	347	189	---
0	487	295	106.5
3	554	345	106.0
6	619	395	106.9
9	678	439	25.0
12	636	408	.005
15	594	381	.000
18	561	358	.000
Stop watch used to assure full 10 sec. duration.			

REMARKS: No deterioriation of end sealant at inboard end.

C5

IPS-701

F/T 30/C #14-D I^2t DATE 3/27/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $< 10^{-10}$ sccs inbd
2×10^{-11} sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
324 °F	149 °F	153°F	158 °F	20 AC AMPS

TEST CURRENT 43 AC AMPS TEST DURATION 100 sec.

ELAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	355	187	---
0	366	197	42.7
6	378	208	43.3
10	385	214	42.8
16	394	222	42.8
20	398	227	43.0
25	403	231	42.9
31	409	236	43.2
36	411	239	43.0
42	416	243	42.9
46	418	245	43.2
51	420	247	43.2
57	423	249	42.9
61	424	251	42.9
67	426	253	43.0
71	427	254	43.1
76	428	255	43.0
82	429	256	42.9
86	430	257	43.0
91	430	258	43.0
97	431	259	42.8

REMARKS: No deterioration of end sealant at inboard end.

C6

IPS-701

F/T 30/C #14-B I^2t DATE 3/27/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 2.8×10^{-10} sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
324 °F	149 °F	154 °F	158 °F	20 AC AMPS

TEST CURRENT 38 AC AMPS TEST DURATION 200 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	354	186	---
0	361	191	37.8
10	377	203	37.8
21	387	212	38.0
30	394	218	37.9
40	400	223	38.0
51	405	227	38.0
60	407	229	37.8
70	410	231	38.0
81	412	233	38.0
90	413	234	37.9
100	415	235	38.1
111	416	235	38.0
120	416	236	38.0
130	417	237	38.1
141	418	237	38.2
150	418	237	38.2
160	419	238	38.1
171	419	238	38.1
180	419	239	38.1
190	420	239	38.1
201	419	238	

REMARKS: No deterioration of end sealant at inboard end.

C7

IPS-701

F/T 30/C #14-C I^2t DATE 3/27/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $< 10^{-10}$ sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
324 °F	149 °F	154 °F	158 °F	20 AC AMPS

TEST CURRENT 35 AC AMPS TEST DURATION 1,000 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	355	187	---
0	359	193	35.7
50	390	222	35.1
100	397	228	35.1
150	399	230	35.2
200	399	231	35.1
250	400	231	35.1
300	401	232	35.3
350	401	233	35.2
400	401	233	35.2
450	402	233	35.3
500	402	234	35.1
550	402	234	35.0
600	402	234	35.0
650	402	234	35.1
700	403	234	35.2
750	403	234	35.0
800	403	235	35.1
850	403	235	35.1
900	403	235	35.1
950	403	235	35.0
1000	403	235	35.2

REMARKS: No deterioration of end sealant at inboard end.

C8

IPS-701

F/T 24/C #12-A I^2t DATE 3/30/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $< 10^{-10}$ sccs inbd
1.8×10^{-10} sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320 °F	149 °F	154 °F	158 °F	27 AC AMPS

TEST CURRENT 173 AC AMPS TEST DURATION 10 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	344	186	---
0	446	284	172.7
3	519	349	168.1
6	593	418	172.9
9	661	472	0.06
12	622	439	0
15	593	413	0

Stop watch used to assure full 10 second duration.

REMARKS: Very slight bubbling of end sealant at inboard end at exit point of current carrying conductor #20 (in outer ring).

C9

IPS-701

F/T 24/C #12-B I^2t DATE 3/30/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 7.2×10^{-10} scds inbd
2.0×10^{-9} scds otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320 °F	149 °F	154 °F	158 °F	27 AC AMPS

TEST CURRENT 64 AC AMPS TEST DURATION 100 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	339	186	---
0	349	194	64.9
3	356	199	64.4
6	362	205	63.7
11	371	212	63.9
17	380	220	64.0
22	387	226	64.0
27	394	232	64.1
32	400	237	64.0
37	405	242	64.0
42	409	246	64.0
47	414	250	64.2
52	417	253	63.9
57	421	256	64.2
62	424	258	64.2
67	427	261	63.9
72	429	263	63.9
77	431	265	64.1
82	432	267	63.9
87	434	268	64.2
92	435	270	64.1
97	437	271	64.0

REMARKS: No deterioriation of end sealant at inboard end.

C10

IPS-701

F/T 24/C #12-C I^2t DATE 3/31/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 6×10^{-11} sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320 °F	149 °F	154 °F	158 °F	27 AC AMPS

TEST CURRENT 54 AC AMPS TEST DURATION 200 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	345	187	---
0	351	193	54.6
10	365	206	54.1
20	376	215	54.1
30	384	222	53.9
40	390	227	54.0
50	395	231	54.1
60	398	234	53.8
70	401	237	54.0
80	404	239	54.2
90	406	241	54.0
100	407	242	54.1
110	409	243	54.0
120	409	244	54.2
130	410	245	54.0
140	411	245	54.1
150	412	246	54.0
160	413	246	54.1
170	413	247	54.1
180	414	247	54.2
190	414	247	54.0
200	414	248	54.0

REMARKS: No deterioration of end sealants at inboard ends.

C11

IPS-701

F/T 24/C #12-D I^2t DATE 3/31/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $< 10^{-10}$ sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
323 °F	149 °F	154 °F	158 °F	27 AC AMPS

TEST CURRENT 48 AC AMPS TEST DURATION 1,000 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	345	181	---
0	348	185	50.5
50	377	209	48.1
100	386	216	48.4
150	389	219	48.2
200	390	219	48.2
250	391	220	48.2
300	392	221	48.3
350	392	221	48.2
400	392	222	48.1
450	393	222	48.4
500	393	223	48.4
550	394	223	48.3
600	394	223	48.4
650	394	223	48.3
700	394	224	48.1
750	395	224	48.1
800	394	224	48.1
850	394	224	48.2
900	394	224	48.2
950	395	224	48.0
1000	395	224	48.2

REMARKS: No deterioration of end sealants at inboard ends.

IPS-701

F/S 19/C #10-A I^2t DATE 4/1/81

POST I^2t LEAK RATE @ 75 PSIG DRY HELIUM 5.8×10^{-10} sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320°F	149°F	154°F	158°F	35 AC AMPS

TEST CURRENT 247 AC AMPS TEST DURATION 10 sec.

ELAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	347	184	---
0 - 254	417	235	*
3 - 245	483	283	*
6 - 252	541	330	*
9 - 248	593	368	*
12	583	363	
15	568	355	

* Overload on data logger - 4 volt scale - required 40 volt scale. Currents were 254, 245, 252 and 248 respectively.
Fluke model 8022A - serial 2455563 calibrated 8-80
1 year 8-81 Stop watch used to assure full 10 sec. duration

REMARKS: No deterioration of end sealant at inboard end.

C13

IPS-701

F/T 19/C #10-B I^2t DATE 4/1/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 7.6×10^{-10} sccs inbd
4.8×10^{-10} sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
321 °F	149 °F	154°F	158 °F	35 AC AMPS

TEST CURRENT 88 AC AMPS TEST DURATION 100 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	332	184	---
0	338	190	89.1
6	347	198	88.8
10	354	204	88.7
16	363	211	88.4
20	369	216	88.0
26	376	222	88.3
30	381	226	88.3
36	387	231	88.6
40	392	235	88.3
46	397	239	88.3
50	401	242	88.3
56	405	246	88.3
60	409	248	88.3
66	413	251	88.1
70	415	253	88.2
76	419	256	88.2
80	421	258	88.0
85	423	259	88.4
90	428	261	88.2
95	427	262	88.2

REMARKS: Slight bubbling of end sealant at inboard end at exit point of current carrying conductor #6 in outer ring.

IPS-701

F/T 19/C #10-D I^2t DATE 4/1/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 2×10^{-11} sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
322 °F	154 °F	165 °F	167 °F	35 AC AMPS

TEST CURRENT 72 AC AMPS TEST DURATION 200 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	342	184	---
0	345	189	73.6
10	355	199	72.7
20	364	207	72.4
30	371	213	72.5
40	377	217	72.6
50	381	221	72.3
60	385	224	72.4
70	387	226	72.2
80	390	229	73.0
90	393	231	72.7
100	394	232	72.3
110	396	233	72.5
120	397	234	72.2
130	398	235	72.7
140	399	235	72.2
150	400	236	72.6
160	400	237	72.6
170	401	237	72.6
180	401	237	72.5
190	402	238	72.3
200	402	238	72.2

REMARKS: No deterioration of end sealant at inboard end.

C15

IPS-701

F/T 19/C #10-C I^2t DATE 4/1/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $< 10^{-10}$ sccs inbd
8×10^{-11} sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
322 °F	154 °F	165 °F	167 °F	35 AC AMPS

TEST CURRENT 62 AC AMPS TEST DURATION 1,000 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	339	184	---
0	342	185	65.0
51	367	205	62.5
101	376	211	61.9
151	380	214	62.2
201	382	215	62.4
251	384	216	62.4
301	385	217	62.3
351	386	217	62.6
401	387	218	62.6
451	387	218	62.2
501	388	219	62.3
551	388	219	62.5
601	389	219	62.5
651	389	219	62.2
701	389	220	62.0
751	390	220	62.3
801	390	220	62.2
851	390	220	62.2
901	390	221	62.3
951	391	221	62.5
1001	391	221	62.2

REMARKS: No deterioration of end sealant at inboard end.

IPS-701

F/T 12/C #8-A I^2t DATE 4/1/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM 2×10^{-11} sccs inbd
1.2×10^{-10} sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
323 °F	154 °F	165 °F	167 °F	47 AC AMPS

TEST CURRENT 371 TEST DURATION 10 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	340	187	---
0	380	227	103.1
3	430	271	106.6
6	486	319	101.9
9	539	362	97.1
12	548	364	.04
15	544	359	.03
18	536	353	.03
Stop watch used to assure full 10 second duration.			

REMARKS: End sealant bubbled at inboard end at exit point of current carrying conductor #7.

IPS-701

F/T 12/C #8-B I^2t DATE 4/2/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $< 10^{-10}$ sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
323 °F	154 °F	165 °F	165 °F	47 AC AMPS

TEST CURRENT 127 AC AMPS TEST DURATION 100 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	344	191	---
0	351	195	128.4
5	363	201	127.3
10	371	208	127.1
15	381	215	127.2
20	387	220	127.2
25	395	226	126.9
30	401	230	127.6
35	408	236	127.1
40	413	239	127.1
45	419	240	127.2
50	423	247	127.8
55	428	251	127.3
60	432	254	126.7
65	436	258	127.1
70	439	260	127.4
76	443	263	127.7
80	445	266	127.6
86	449	268	127.5
90	451	270	127.2
96	453	272	127.9
100	452	272	1.42

REMARKS: End sealant bubbled at inboard end at exit point of current carrying conductor #1.

IPS-701

F/T 12/C #8-C I^2t DATE 4/2/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $<10^{-10}$ sccs inbd
$<10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
323 °F	154 °F	165 °F	165 °F	47 AC AMPS

TEST CURRENT 101 AC AMPS TEST DURATION 200 sec.

LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	347	190	---
0	350	194	102.6
11	361	203	101.7
21	369	210	101.2
31	377	215	101.3
41	383	220	101.3
51	388	224	101.2
61	392	228	101.3
71	396	231	101.4
81	398	234	101.3
91	401	236	101.4
101	403	238	101.3
111	405	239	101.5
121	406	240	101.4
131	408	242	101.3
141	409	243	101.7
151	410	244	101.6
161	411	245	101.6
171	412	246	101.3
181	412	246	100.6
191	413	246	100.3
201	413	247	100.3

REMARKS: End sealant cracked at inboard end at exit point of current carrying conductor #5.

IPS-701

F/T 12/C #8-D I^2t DATE 4/2/81

POST I^2t GAS LEAK RATE @ 75 PSIG DRY HELIUM $< 10^{-10}$ sccs inbd
$< 10^{-10}$ sccs otbd

INBOARD AMBIENT	INTERMED AMBIENT	INTERMED AMBIENT	OUTBOARD AMBIENT	STABILIZED CURRENT
320 °F	154 °F	163 °F	165 °F	47 AC AMPS

TEST CURRENT 82 AC AMPS TEST DURATION 1,000 sec.

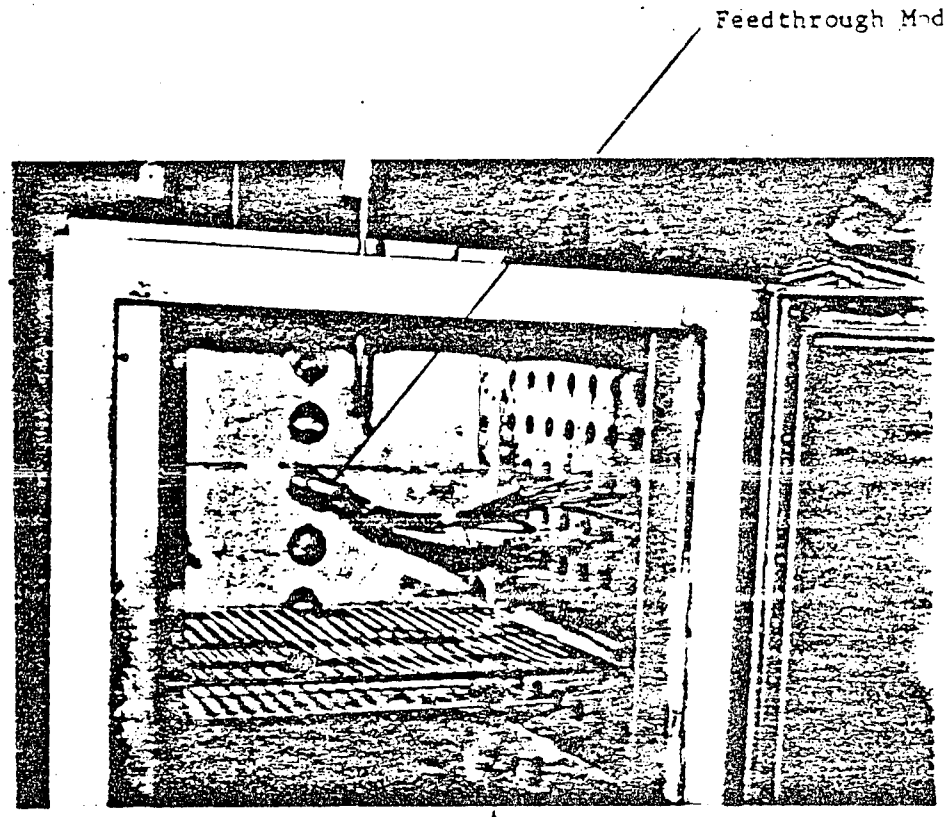
LAPSED TIME IN SECONDS	INBOARD COND TEMP IN °F	OUTBOARD COND TEMP IN °F	I^2t CURRENT IN AC AMPS
STABILIZATION	340	190	---
0	342	192	84.7
50	363	211	82.2
100	372	220	81.8
150	376	224	83.0
200	379	227	83.0
250	381	228	82.7
300	382	229	82.7
350	382	230	82.5
400	383	230	82.3
450	383	231	82.2
500	384	231	82.3
550	384	231	82.4
600	385	232	82.4
650	385	232	82.3
700	385	232	82.4
750	386	233	82.5
800	386	233	82.3
850	386	233	82.2
900	386	233	82.2
950	386	233	82.3
1000	387	234	82.2

REMARKS: End sealant bubbled at inboard end at exit point of current carrying conductor #5.

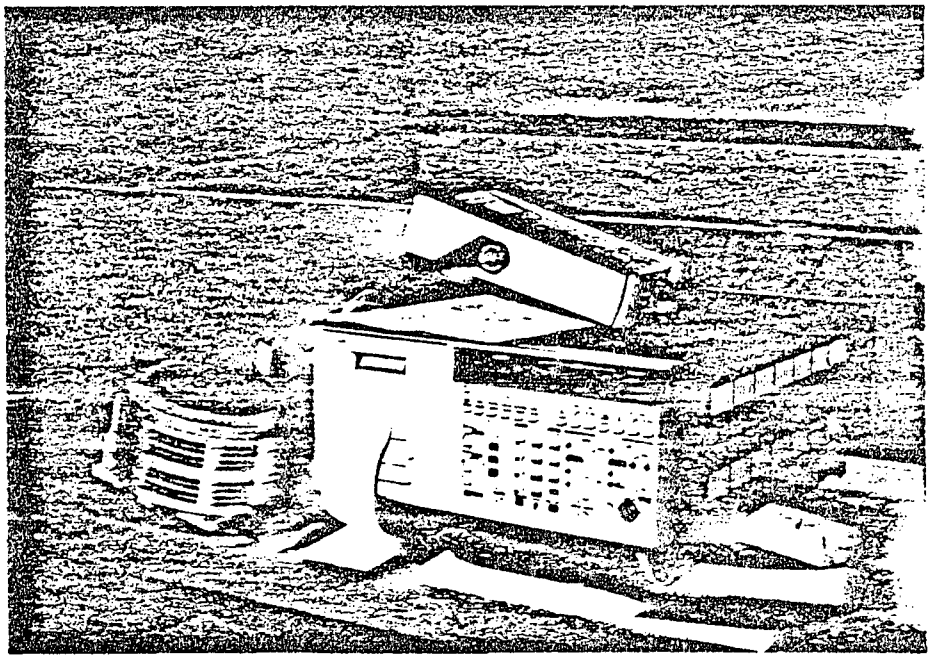
C2C

APPENDIX D

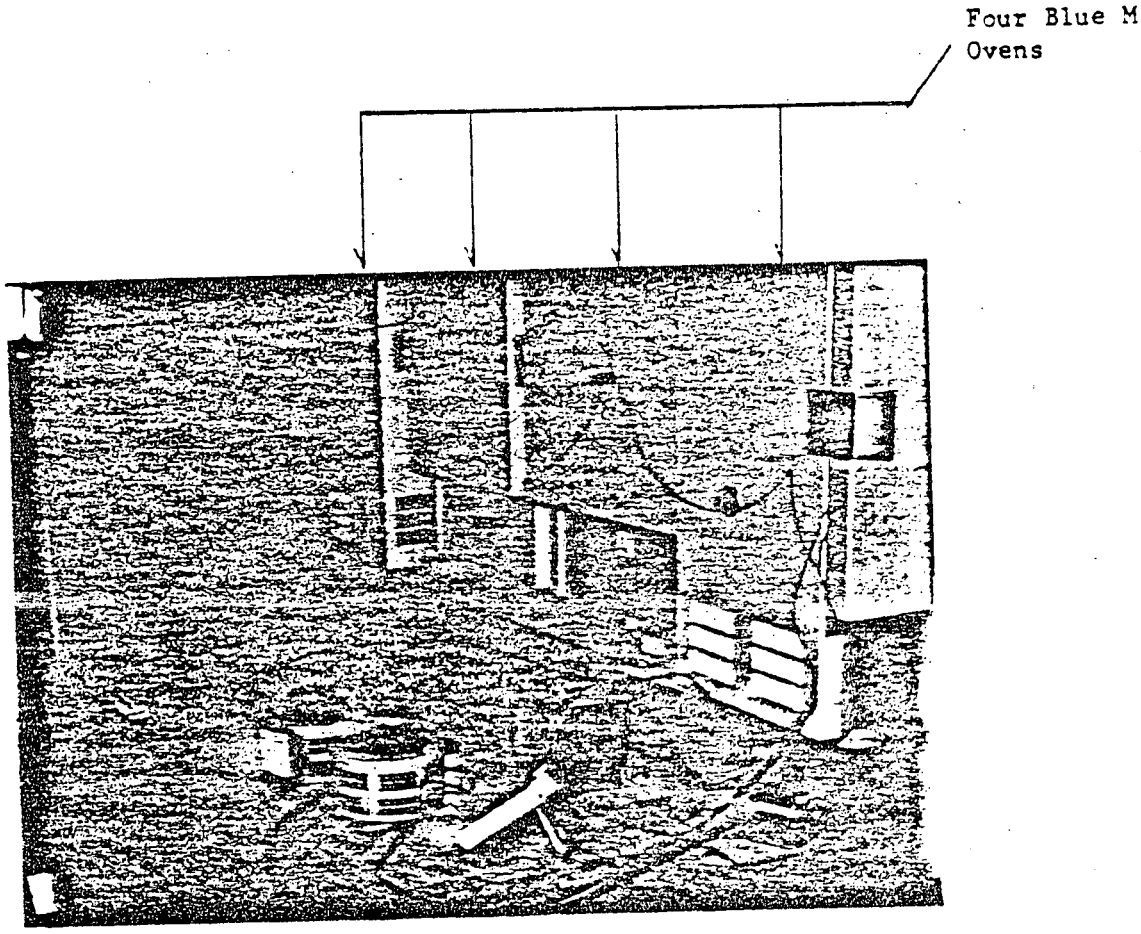
Photographs



TEST SETUP - FINAL PHASE TESTING
(View of inboard Blue M oven)

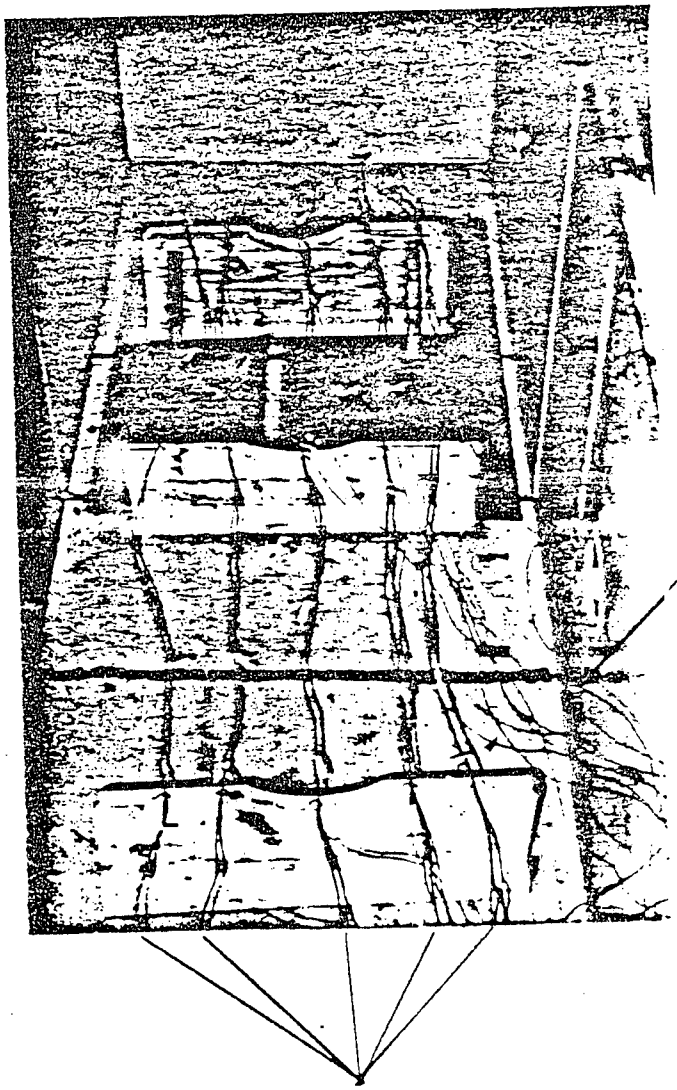


Data Logger Used to Monitor Test



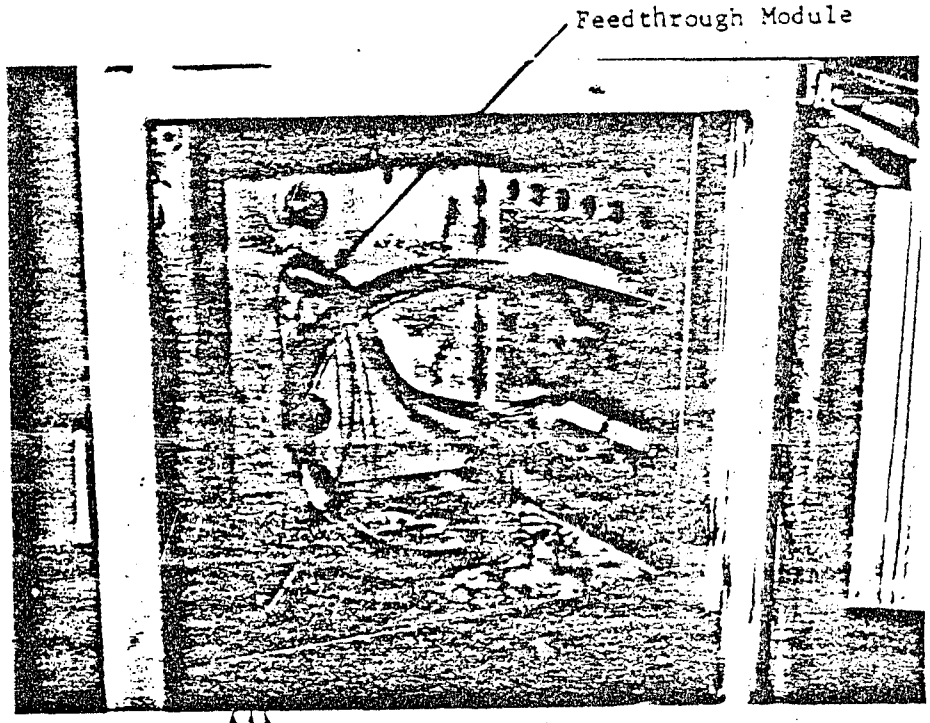
Associated Test Equipment

TEST SETUP - FINAL PHASE TESTING

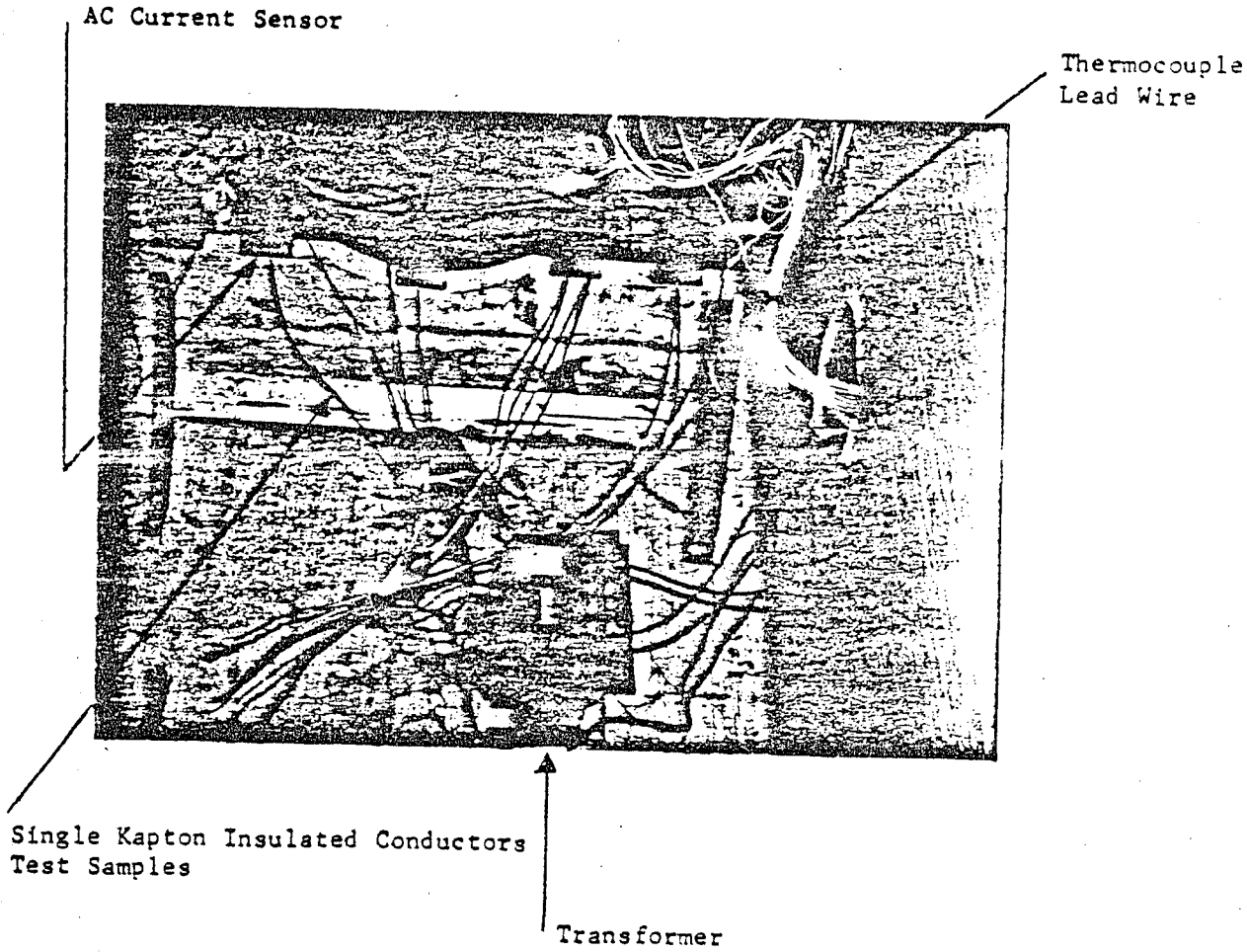


Single Kapton Insulated Conductor
Test Samples

TEST SETUP- PHASE ONE TESTING



TEST SETUP - FINAL PHASE TESTING
(View of outboard Blue M oven)



TEST SETUP - PHASE ONE TESTING

A27 830511 027

cpo

400 Chestnut Street Tower II

May 11, 1983

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Chief
Licensing Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Ms. Adensam:

SEE RPTS

In the Matter of the Application of) Docket No. 50-390
Tennessee Valley Authority) 50-391

Enclosed are three copies of the Black and Veatch final report on Watts Bar Nuclear Plant provided to you initially by Black and Veatch on April 18, 1983. As requested by the NRC Project Manager for Watts Bar, we will forward an additional eleven copies as soon as reproduction is complete.

If you have any questions concerning this matter, please get in touch with D. P. Ormsby at FTS 858-2682.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Licensing

Sworn to and subscribed before me
this 11th day of May 1983
Paulette H. White
Notary Public
My Commission Expires 9-5-84

18 754-057
18759-362

RHS:DPO:KEH
Enclosure (3)
cc: U.S. Nuclear Regulatory Commission
Region II
Attn: Mr. James P. O'Reilly Administrator
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30303

cc: ARMS, 640 CST2-C
J. W. Anderson, M155G MIB-K
H. N. Culver, 249A HBB-K
H. J. Green, 1750 CST2-C
T. Heatherly, Watts Bar-NRC
R. L. Lumpkin, 401 UBB-C (2)
J. A. Raulston, W10C126 C-K
H. S. Sanger, Jr., E11B33 C-K
F. A. Szczepanski, 417 UBB-C

(Copies of enclosure unavailable for distribution)

COORDINATED: TKenyon/NRC

B00 15