TSI

TSI TECHNICAL NOTE 111781

ENGINEERING REPORT

ON

AMPACITY TEST FOR 600 VOLT POWER CABLES

INSTALLED IN A FIVE FOOT LENGTH OF TWO INCH CONDUIT

PROTECTED WITH

THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

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PROTECTED WITH

THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

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AMPACITY TEST FOR 600 VOLT POWER CABLES

INSTALLED IN A FIVE FOOT LENGTH OF TWO INCH CONDUIT

PROTECTED WITH

THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

1.0 PURPOSE OF TEST

The purpose of this test was to determine the effect of the application of a 1/2 inch minimum dry film thickness of THERMO-LAG 330-1 Subliming Coating on the temperature rise and ampacity of a 600 Volt #00 AWG power cable installed in a five foot length of two inch conduit. This test was conducted in accordance with AIEE Pub. No. S-135-2, IPCEA Pub. No. P-46-426 "Power Cable Ampacities".

2.0 TEST SET UP

The test was conducted at the laboratory facilities of TSI, Inc., 3260 Brannon Avenue, St. Louis, Missouri (63139), on October 23 and October 24, 1981.

For test purposes, the conduit test assembly was placed on two 2" x 4" wooden blocks within a 4' by 5' wide by 29½" deep test chamber constructed of 3/8" plywood. The test chamber, in turn, was placed on the surface of a laboratory bench.

The desired level of ambient temperature was provided within the test chamber by means of three heat lamps located in the top of the enclosure, and two hot plates located at the bottom of the enclosure. The entrance and exit openings for the power cables, at one end of the test enclosure, were sealed by means of a 2" shroud of ceramic wool. Likewise, the entire surface of all power cables, entering the test enclosure from the junction with their power supply and power cables leaving the test enclosure all the way to the energizing variac, were covered with a 2" ceramic wool shroud in order to minimize heat losses.

2.1 Conduit Test Assembly

The conduit test assembly was constructed of a five foot* section of 2" Schedule 40 rigid steel conduit. The inside diameter of the rigid steel conduit was 2.10" and the cross section area of the conduit was 3.46 square inches. The test assembly was used for the unprotected baseline conduit tests. A separate but identical conduit assembly was protected with the THERMO-LAG 330-1 Subliming Coating Envelope System.

2.2 Power Cables

A 21 foot length of #00 AWG power cable was folded into two loops and then installed in each five foot length of two inch conduit. The power cable was approximately 0.562 inches in diameter, had 0.25 square inches in the cross sectional area, and was made of 19 strands of 0.0827 inch diameter copper wire.

A schematic, which shows the cable tray test section mounted in the test chamber together with the location of the ambient temperature thermocouples within the test chamber, is presented in Figure 2.1.

2.3 Power Source

A 200 volt, single phase, power source was used to energize the #00 AWG power cable conduit. The power source was equipped with a variac and a current transformer as shown in Figure 2.2.

2.4 Heat Loss Reduction

The two ends of the conduit together with the cables emerging from the conduit ends were wrapped with a 2 inch thick piece of THERMO-LAG 330-70 Ceramic Blanket. The ceramic blanket wrap was then secured to the conduit and the cables by wrapping it with duct tape. This step was taken to reduce the amount of heat loss from within the conduit section and from the cable lengths that were not located within the conduit section.

2.5 Instrumentation

The test instruments and devices used during the ampacity test consisted of three thermocouples, a thermocouple temperature recorder, an ammeter, a voltmeter, a digital readout and a current transformer.

*See Addenda for explanation of 5 ft. length.

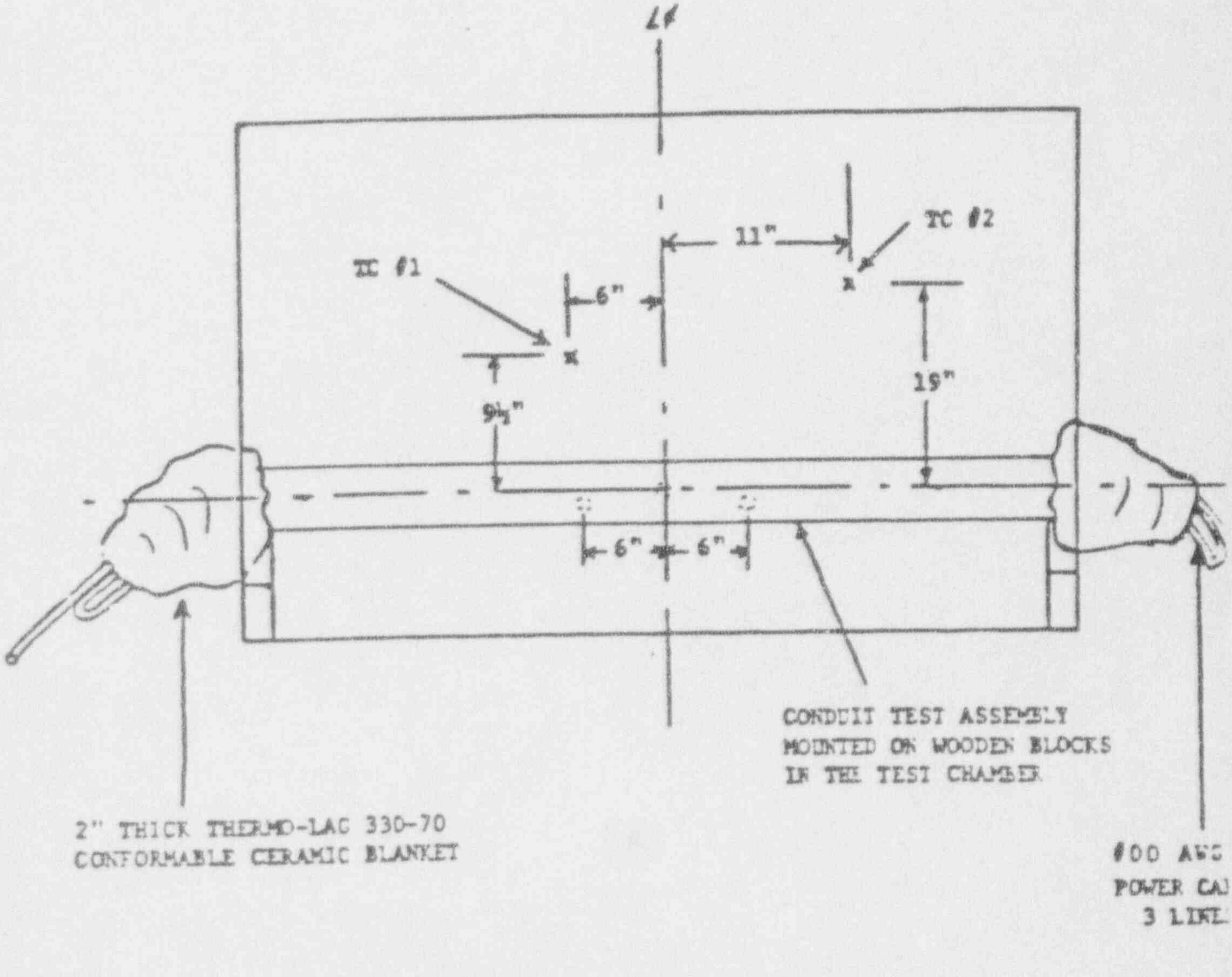

FIGURE 2.1 LOCATION OF TEST ASSEMBLY AND AMBIENT TEMPERATURE THERMOCOUPLES IN TEST CHAMBER

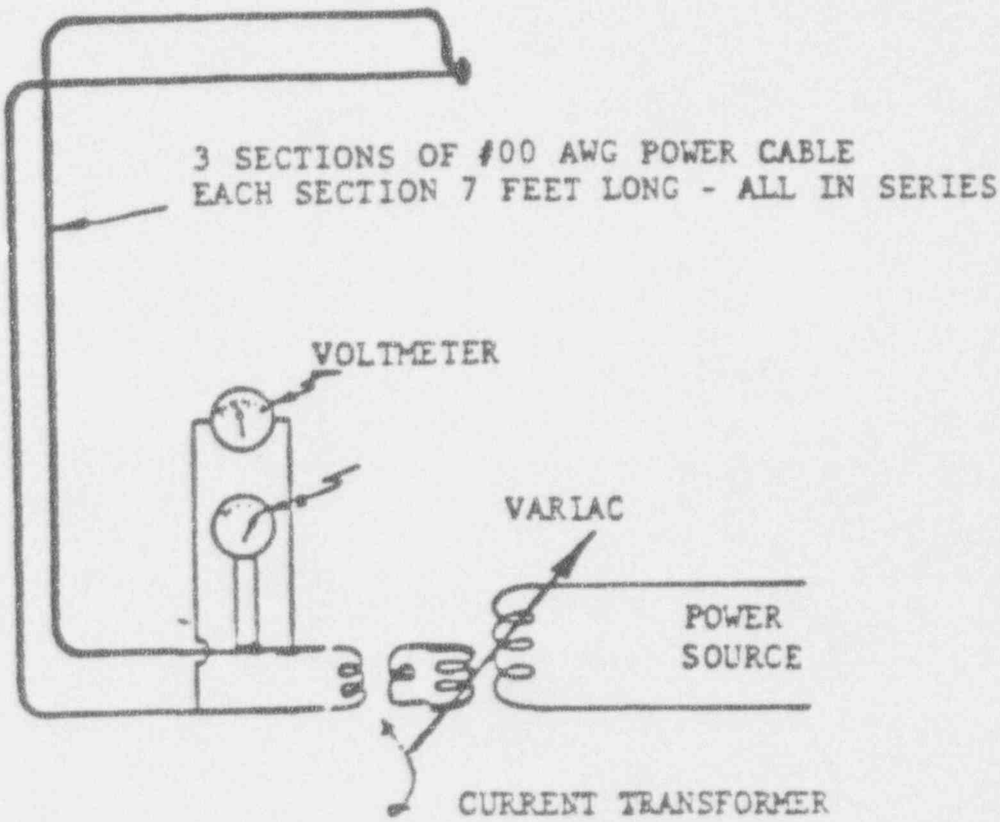

FIGURE 2.2 SCHEMATIC CIRCUIT DIAGRAM

2.5.1 Thermocouples

Three (3) thermocouples were installed in the center of the 2" conduit section. The first two thermocouples were located six inches on each side of the midpoint along the length of the conduit and the third was located an additional six inches away from the midpoint. They were embedded in slits made in the cable insulation.

The location, of the three thermocouples within the test assembly, is shown in Figure 2.3.

2.5.2 Thermocouple Recorder

A Brown Multipoint Thermocouple Recorder was used to record the temperature of the power cable circuit at the locations previously described.

Calibration of each thermocouple was checked against a standard thermometer by comparing the thermocouple readings at room temperature and in boiling water. The deviation was less than 1°C from the known temperature in each case.

2.5.3 Ammeter

The ammeter used to measure current in the power cable circuit was placed in series with the power cable and one of the output lines from the current transformer. The ammeter was a General Electric Unit with a readout range from 0-300 amperes. The current transformer was a Westinghouse Unit with a maximum output of 400 amperes.

2.5.4 Voltmeter

The voltmeter used in the #00 AWG power cable circuit had a readout range of 0-50 amperes.

2.5.5 Ambient Temperature Digital Readout

An Omega Engineering Unit was used to provide a digital readout of the ambient temperature during the test.

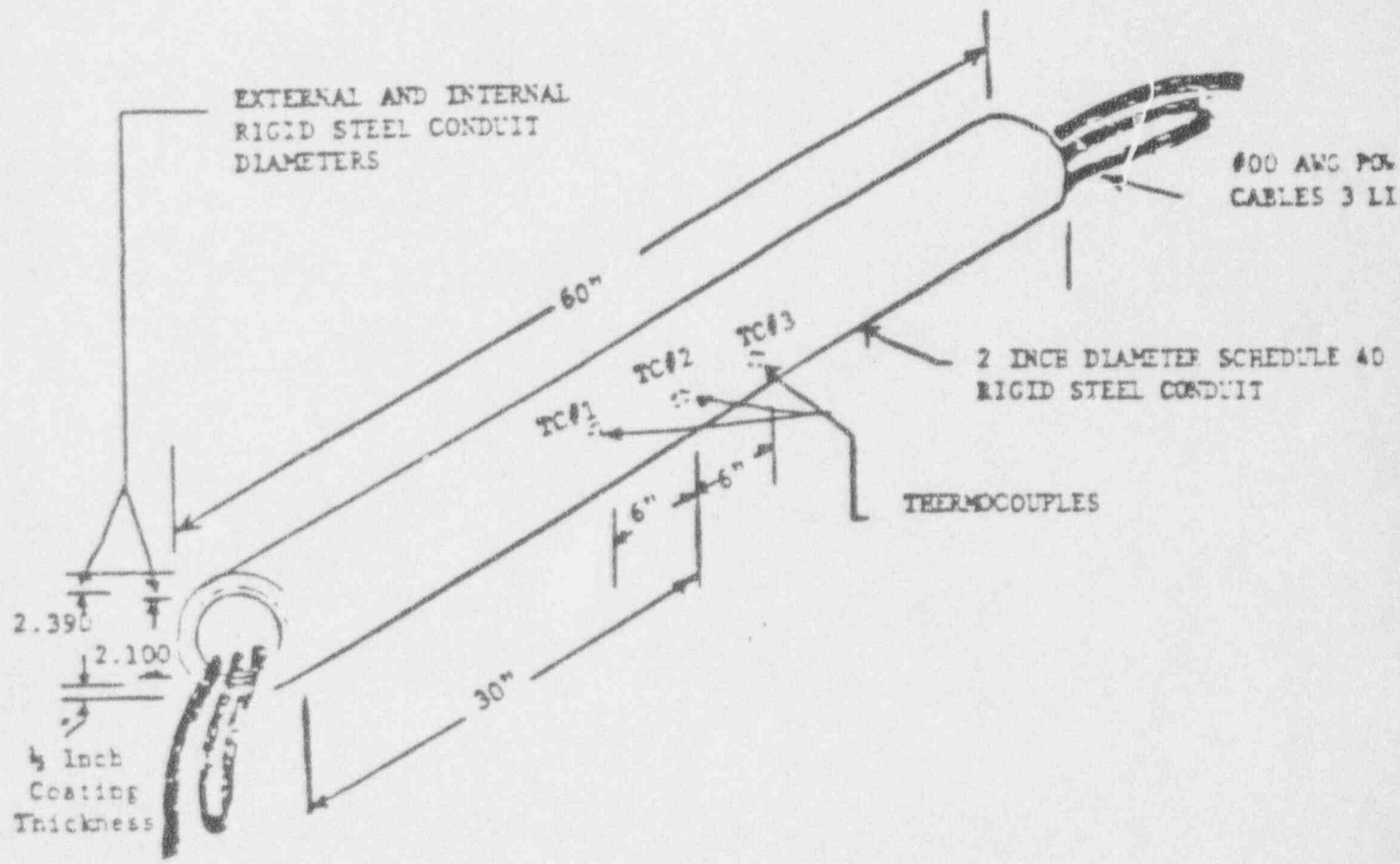

FIGURE 2.3 LOCATION OF THERMOCOUPLES WITHIN THE TEST ASSEMBLY

3.0 TEST PROCEDURE

The ampacity test was conducted in two separate but interrelated phases. The first phase consisted of establishing a base line ampacity for the power cables when installed in the unprotected conduit test assembly. The second phase consisted of determining the amperage derating which occurs when the conduit test assembly is enclosed by a protective envelope of THERMO-LAG 330-1 Subliming Coating Envelope System. These two test phases are described in the following paragraphs.

3.1 Unprotected Conduit Test Assembly

The base line ampacity test was started by energizing the power sources to produce an initial amperage of 160 amperes in the #00 AWG power cable circuit. This amperage level was then maintained in the power circuit until one of the thermocouple temperatures stabilized within the designated temperature band of 194 ± 3°F (90 ± 2°C). The elapsed time for this pre-test period was circa four hours.

Throughout this and the subsequent one hour test phase, the ambient temperature within the test enclosure was maintained at 104 ± 5°F (40 ± 3°C).

Once the base line test was initiated, it was continued for one hour. During the test the amperages, in the power cable, the hot spot cable thermocouple temperature, and the ambient temperature, were recorded at 5 minute intervals.

The recorded base line amperage of 152 amperes was then corrected to reflect a 40°C ambient temperature test condition and a 90°C conductor temperature, using the correction tables presented in the AIEE Pub. No. S-135-2, IPCEA Pub. No. P-46-426 entitled: "Power Cable Ampacities".

After correction, the base line amperage became 153.16 amperes.

The base line test amperage and temperature together with the amperage correction calculations are shown in Table 1.

TABLE 1

BASE LINE TEST DATA

Time	Average Ambient Temperature °F	Maximum Cable Temperature °F	#00 AWG Power Cable Amperage
3:00 PM	106	194	152
3:05 PM	106	194	152
3:10 PM	105	194	152
3:15 PM	105	193	152
3:20 PM	105	193	152
3:25 PM	105	193	152
3:30 PM	104	193	152
3:35 PM	105	193	152
3:40 PM	105	193	152
3:45 PM	105	193	152
3:50 PM	104	193	152
3:55 PM	104	193	152
4:00 PM	104	193	152
4:05 PM	104	193	152

Average Ambient Temperature: 104.79°F (40.44°C)

Average Cable Temperature: 193.21°F (89.56°C)

Temperature Correlation Per IPCEA P-46-426:

$$I = 152\sqrt{\frac{90 - 40}{89.56 - 40.44} \times \frac{234.5 + 89.56}{234.5 + 90}}$$

I = 152 (1.01) = 153.16 Amperes

3.2 Conduit Test Assembly Protected With A Subliming Coating

Upon completion of the base line test, the other conduit test assembly, coated with 1/2 inch minimum dry film thickness of THERMO-LAC 330-1 Subliming Coating, was installed in the test fixture.

The test was started with the current flow established at 155 amperes in the power cable circuit. This current level, which was developed in the first test phase, was maintained until the temperature limit of 194°F (90°C) was reached by the hottest cable thermocouple. At this point, the amperage was gradually reduced until the hottest cable thermocouple stabilized within the designated temperature band of 194 ± 3°F (90 ± 2°C).

After the temperature had stabilized for one hour, the test run was initiated and continued for another hour. During the test run, the circuit amperages, the hot spot cable thermocouple temperature and the ambient temperature were recorded at 5 minute intervals.

The test amperage of 142 amperes was then corrected to reflect a 40°C ambient temperature condition and a 90°C conductor temperature test condition using the correction table presented in the AIEE Pub. No. S-135-2, IPCEA Pub. No. P-46-426 entitled: "Power Cable Ampacities".

After correction, the test amperage became 141.72 amperes.

The test amperages and temperatures together with the amperage condition factors are shown in Table 2.

4.0 ANALYSIS OF TEST RESULTS

The hottest cable thermocouple temperature, together with the ambient temperatures and power cable amperage readings, were recorded at 5 minute intervals during each of the tests. These test results, which are shown in Table 1 and Table 2, are analyzed and discussed in the following paragraphs.

TABLE 2

TEST DATA FOR A FIVE FOOT LENGTH OF TWO INCH CONDUIT

PROTECTED WITH THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

Time	Average Ambient Temperature °F	Maximum Cable Temperature °F	#00 AWG Power Cable Amperage
2:30 PM	102	193	142
2:35 PM	102	193	142
2:40 PM	102	193	142
2:45 PM	103	193	142
2:50 PM	103	193	142
2:55 PM	103	193	142
3:00 PM	103	193	142
3:05 PM	103	193	142
3:10 PM	103	193	142
3:15 PM	103	193	142
3:20 PM	103	193	142
3:25 PM	103	193	142
3:30 PM	103	193	142
3:35 PM	103	193	142

Average Ambient Temperature: 102.786°F (39.33°C)

Average Cable Temperature: 193°F (89.44°C)

Temperature Correlation Per IPCEA P-46-426:

$$I = 142\sqrt{\frac{90 - 40}{89.44 - 39.33} \times \frac{234.5 + 89.44}{234.5 + 90}}$$

I = 141.72 Amperes

4.1 Unprotected Conduit Test Assembly

The temperature readings for the hot spot thermocouple remained within the 194 ± 3°F (90 ± 2°C) temperature range during the one hour test period. The temperature ranged between 193 and 194°F during the test.

The power cable current remained constant at 152 amperes throughout the one hour test. The ambient temperature within the test enclosure average 104.79°F with all temperature readings falling within the prescribed test range of 104 ± 5°F (40 ± 3°C) during the test.

4.2 Conduit Test Assembly Protected With A Subliming Coating

The temperature reading for the hottest thermocouple rose to 193°F (90°C) when the power cable circuit was energized at the 155 amperes level established in the base line test. The power cable current then was reduced to 142 amperes and the temperature readings from this thermocouple stabilized at 193°F for the remainder of the test.

The power cable current remained at 142 amperes throughout the one hour test period. The ambient temperature within the test chamber average 102.786°F within the prescribed test range of 104 ± 5°F (40 ± 3°C) during the test.

5.0 CONCLUSIONS

The test results indicate that the ampacity of three lengths of #00 AWG power cable, installed in a 2 inch diameter rigid steel conduit, should be derated by 7.47% when the conduit is protected with a 1/2 inch minimum dry film thickness of THERMO-LAC 330-1 Subliming Coating Envelope System.

This derating factor was calculated by subtracting the test ampacity of 141.72 amperes from the base line amperage of 153.16, dividing by the base line value of 153.16% and then multiplying by 100. On this basis, the derating factor was determined to be 7.47%.

The derating factors apply to the thickness of the THERMO-LAC 330-1 Subliming Coating Envelope System as tested, and tolerances employed in this test program which was 0.625" ± 0.125", dry.

The test results obtained for derating the #00 AWG power cable may be used for all sizes of cable with similar material. This is based on J. Stolpe's work which indicates that derating should be independent of cable size.

ADDENDA

Recent IEEE draft bulletins for ampacity derating tests, suggest the use of raceway sections larger than the 5 foot section used for this test. Since this test was conducted in November 1981, the IEEE raceway length could not be anticipated. However, the 5 foot raceway used in this test will not in any way invalidate the test results.

The length of raceway will affect two parameters:

1) The temperature oscillations in both the cable conductor and the surrounding ambient air in the test box.

2) End effects where the cable enters and exits the test box.

Each of these parameters will be considered below:

1) Temperature Oscillations

The temperature oscillations are a function (among other things) of the air volume between the raceway and the test box, and the total area of fire barriers on the raceway - both of which are a linear function of the raceway length. During the tests, the temperature variations for both the conductor temperature and the ambient test box temperature were within the allowable ± 2°C during the one hour test period. In addition, the average value for conductor temperature and test box ambient temperature were normalized to the base 90°C/40°C using the current correction formula given in IPECA Publication No. P-46-426 (1962) on page III, equation (5).

2) End Effects

A short raceway will be vulnerable to end effects which are caused by the localized hot spots where the raceway enters and exits the test box. These hot spots are caused by the ceramic fiber packing, and are typically in the range of 5°C temperature rise. The hot spots will cause a temperature gradient in both the inward and outward direction. The temperature gradient will exist for only several inches into the test box, not enough to affect the test results, since the conductor thermocouple locations are well into the test box.

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ATTACHMENT C

I. T. L. REPORT NO. 84-10-5

ENGINEERING REPORT ON AN AMPACITY TEST FOR 600 VOLT POWER CABLES INSTALLED IN A FIVE FOOT LENGTH OF TWO INCH CONDUIT PROTECTED WITH A THREE HOUR FIRE RATED DESIGN OF THE THERMO-LAG 330 FIRE BARRIER SYSTEM

ISSUED: OCTOBER 1984

INDUSTRIAL TESTING LABORATORIES inc.

I.T.L. REPORT NO. 84-10-5

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INDUSTRIAL TESTING LABORATORIES inc.

I. T. L. REPORT NO. 84-10-5

TEST DATE: 29 SEPTEMBER 1984

TEST: AMPACITY TEST FOR 600 VOLT POWER CABLES INSTALLED IN A FIVE FOOT LENGTH OF TWO INCH CONDUIT PROTECTED WITH A THREE HOUR FIRE RATED DESIGN OF THE THERMO-LAG 330 FIRE BARRIER SYSTEM

APPROVED BY:

ALLAN M. SIEGEL, P.E.
DIRECTOR

INDUSTRIAL TESTING LABORATORIES, INC.
2350 SEVENTH BOULEVARD
ST. LOUIS, MISSOURI 63104

OCTOBER 1984

I. T. L. REPORT NO 84-10-5

TEST ATTENDEES

Test Date: 29 September 1984

Supervising the test for Industrial Testing Laboratories, Inc.

Donald L. Storment, P.E.

Witnessing the test for Thermal Science, Inc.

Rubin Feldman, President

Operating the test equipment for Thermal Science, Inc.

Wilbur Paddock, Vice President of Operations

INDUSTRIAL TESTING LABORATORIES Inc.

I.T.L. REPORT NO. 84-10-5

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INDUSTRIAL TESTING LABORATORIES inc.

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INDUSTRIAL TESTING LABORATORIES Inc.

I. T. L. REPORT NO 84-10-5

ENGINEERING REPORT ON AN AMPACITY TEST FOR 600 VOLT POWER CABLES INSTALLED IN A FIVE FOOT LENGTH OF TWO INCH CONDUIT PROTECTED WITH A THREE HOUR FIRE RATED DESIGN OF THE THERMO-LAG 330 FIRE BARRIER SYSTEM

1.0 PURPOSE

The purpose of the test was to determine the effect of the application of a three hour fire rated design (one inch (1") minimum dry film thickness) of the THERMO-LAG 330 Fire Barrier System, on the temperature rise and ampacity of a 600 volt #00 AWG power cable, installed in a five foot length of two inch conduit. This test was conducted in accordance with AIEE Publication No. S-1135-2, IPCEA Pub. No. P-46-426 (1962) entitled: "Power Cable Ampacities."

2.0 TEST LOCATION

The test was conducted at the laboratory facilities of Thermal Science, Inc. ("TSI") in St. Louis, Missouri, on 29 September 1984, and witnessed by a representative of Industrial Testing Laboratories, Inc. in St. Louis, Missouri. The duration of the ampacity derating test was one hour. The data from this test was compared to the base line test data obtained from the test conducted at TSI's laboratory on [illegible] October 198[illegible], on the same unprotected test assembly.

3.0 TEST SET UP

For test purposes, the conduit test assembly was placed on two 2"x4" wooden blocks with a 4' by 5' wide by 29½" deep test chamber constructed of 3/8" plywood. The test chamber, in turn, was placed on the surface of a laboratory bench..

The desired level of ambient temperature was provided within the test chamber by means of three heat lamps located in the top of the enclosure and two hot plates located at the bottom of the enclosure. The entrance and exit openings for the power cables, at one end of the test enclosure, were sealed by means of a 2" shroud of ceramic wool. Likewise, the entire surface of all power cables, entering the test enclosure from the junction with their power supply and power cables leaving the test enclosure all the way to the energizing variac, were covered with a 2" ceramic wool shroud in order to minimize heat losses.

3.1 Conduit Test Assembly

The conduit test assembly was constructed of a five foot* section of 2" schedule 40 rigid steel conduit. The inside diameter of the rigid steel conduit was 2.10 inches and the cross-sectional area of the conduit was 3.46 square inches. The test assembly was used for the unprotected base line conduit tests. A separate but identical conduit assembly was protected with a three hour fire rated design of the THERMO-LAG 330 Fire Barrier System Preshaped Conduit Sections.

3.2 Power Cables

A 21 foot length of #00 AWG cable was folded into two loops and then installed in each five foot length of two inch conduit. The power cable was approximately 0.562 inches in diameter, had 0.25 square inches in the cross-sectional area, and was made of 19 strands of 0.0827 inch diameter copper wire.

A schematic which shows the conduit test section mounted in the test chamber together with the location of the ambient temperature thermocouples within the test chamber is shown in Figure 1.

3.3 Power Source

A 200 volt, single phase power source was used to energize the #00 AWG power cable conduit. The power source was equipped with a variac and a current transformer as shown in Figure 2.

*See addenda for explanation of 5 foot length.

FIGURE 1

LOCATION OF TEST ASSEMBLY AND AMBIENT TEMPERATURE

THERMOCOUPLES IN TEST CHAMBER

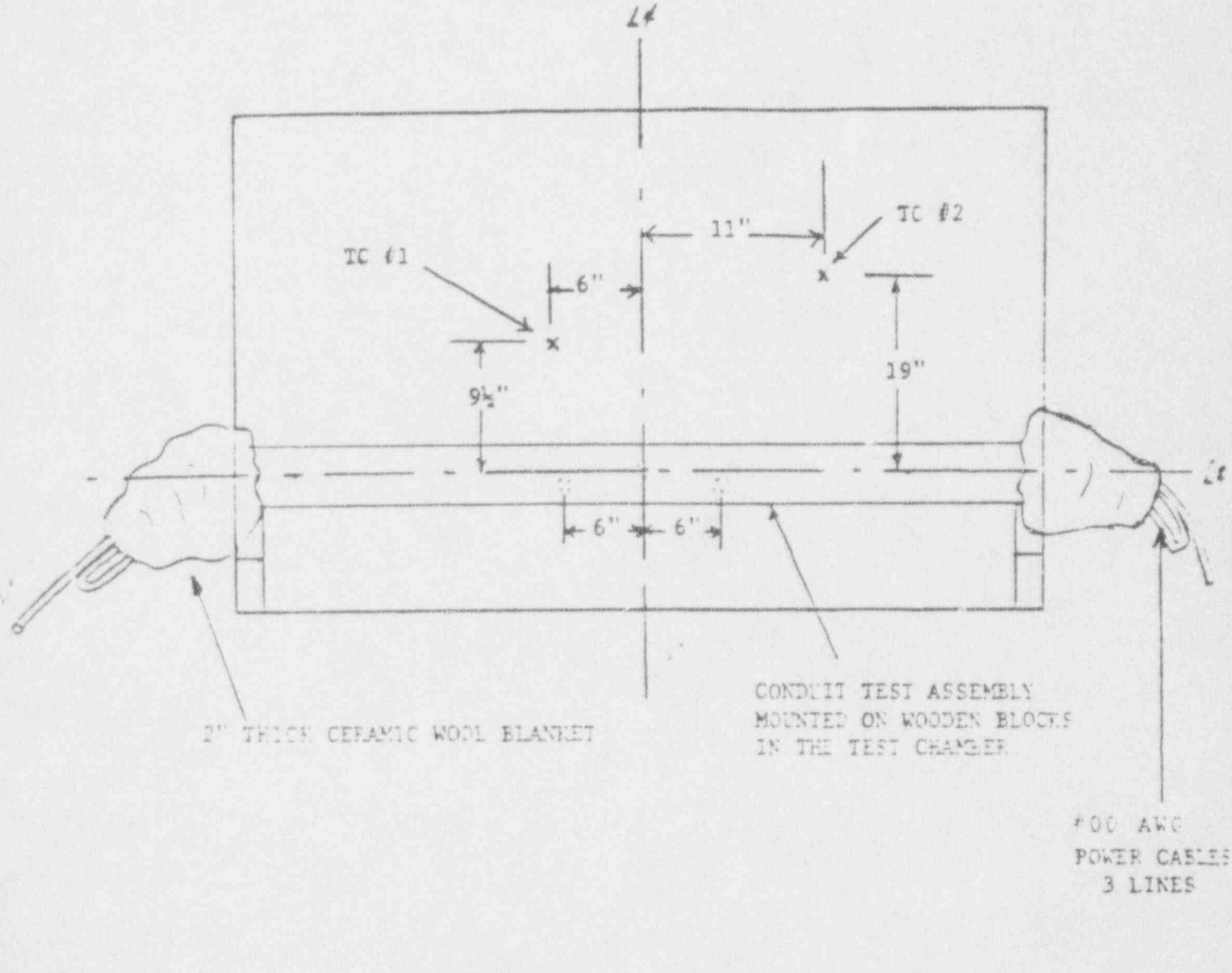
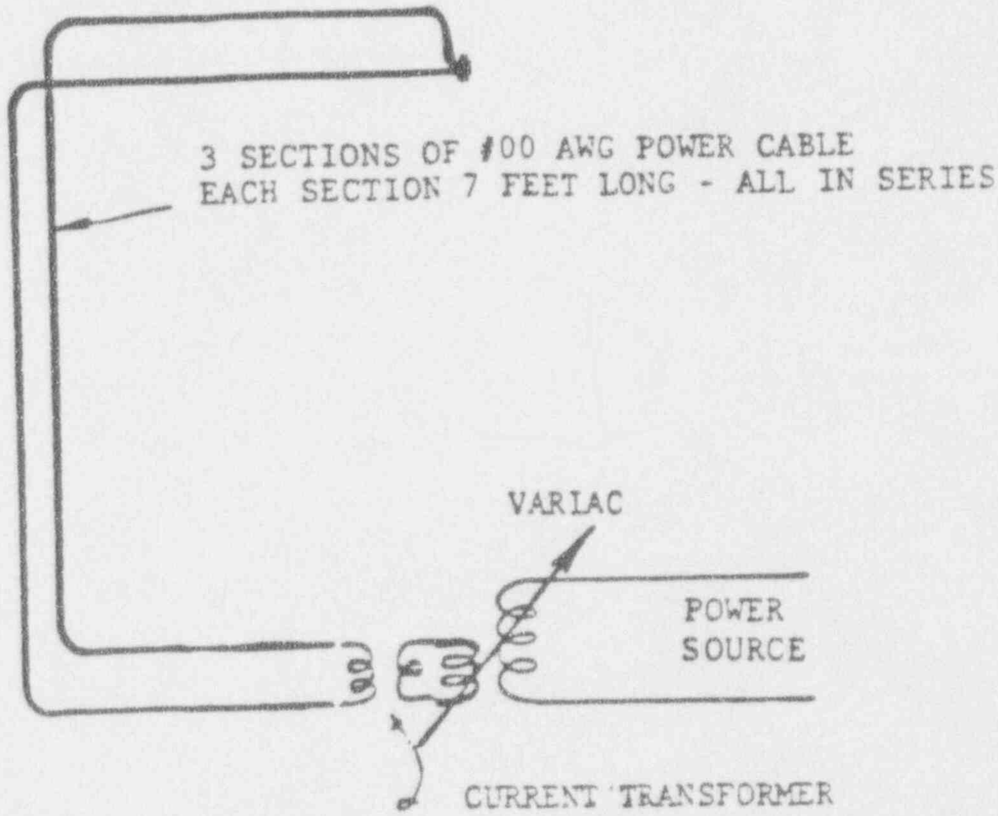


FIGURE 2

SCHEMATIC CIRCUIT DIAGRAM



3.4 Heat Loss Reduction

The two ends of the conduit, together with the cables emerging from the conduit ends, were wrapped with a 2 inch thick piece of ceramic wool. The ceramic blanket wrap was then secured to the conduit and the cables by wrapping it with duct tape. This step was taken to reduce the amount of heat loss from within the conduit section and from the cable lengths that were not located with the conduit section.

3.5 Instrumentation

The test instruments and devices used during the ampacity test consisted of three thermocouples, a thermocouple temperature recorder, an ammeter, a digital readout and a current transformer.

3.5.1 Thermocouples

Three (3) Thermocouples were installed in the center of the 2" conduit section. The first two thermocouples were located six inches on each side of the midpoint along the length of the conduit and the third was located an additional six inches away from the midpoint. They were embedded in slits made in the cable insulation.

The location of the three thermocouples with the test assembly is shown in Figure. 3.

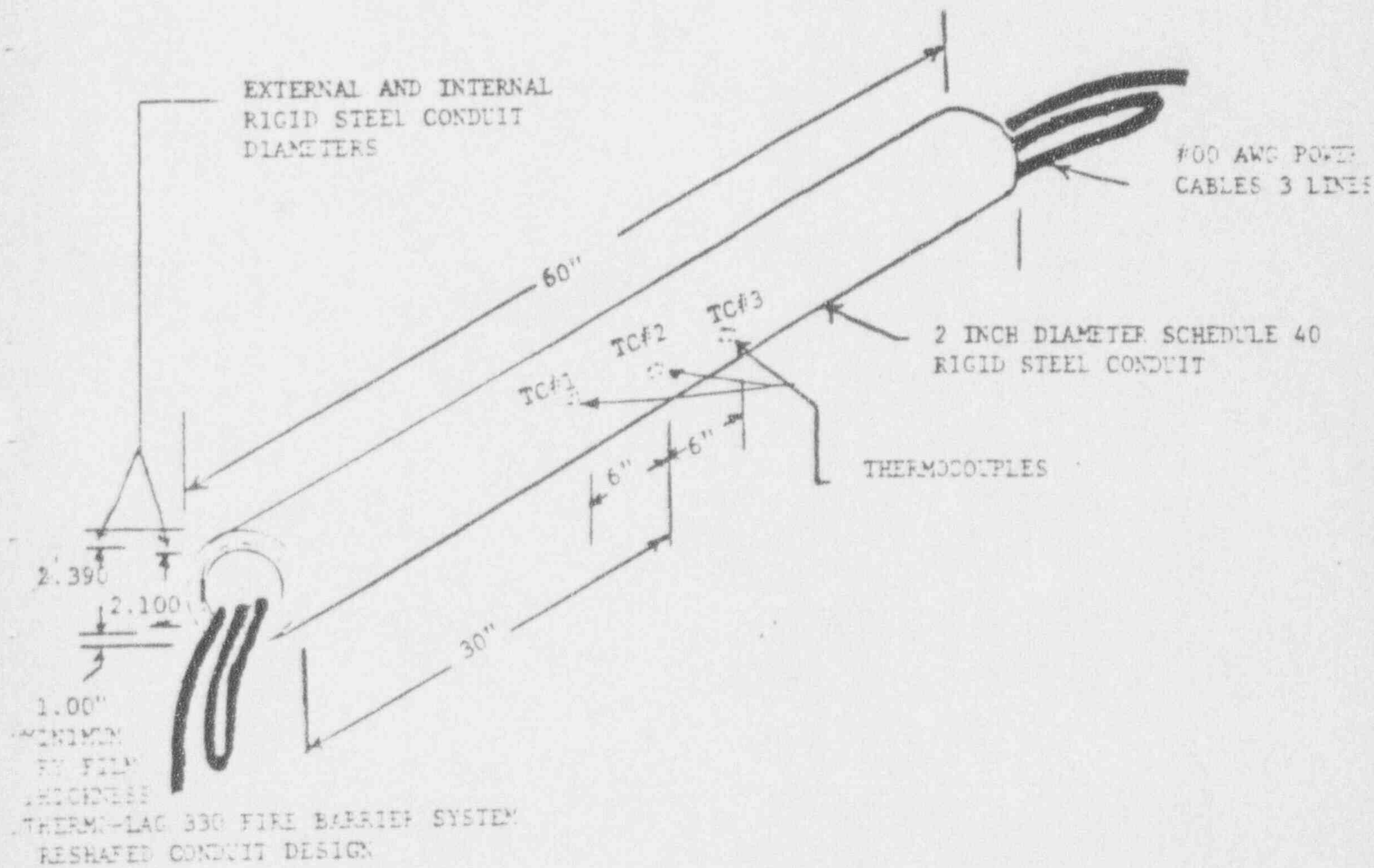
3.5.2 Thermocouple Temperature Recorder

A Brown Multipoint Thermocouple Temperature Recorder was used to record the temperature of the power cable circuit at the locations previously described.

Calibration of each thermocouple was checked against a standard thermometer by comparing the thermocouple readings at room temperature and in boiling water. The deviation was less than 1C from the known temperature in each case.

FIGURE 3

LOCATION OF THERMOCOUPLES WITH THE TEST ARTICLE



3.5.3 Ammeter

The ammeter used to measure current in the power cable circuit was placed in series with the power cable and one of the output lines from the current transformer. The ammeter was a General Electric Unit, with a readout range from 0-300 amperes. The current transformer was a Westinghouse Unit with a maximum output of 400 amperes.

3.5.4 Ambient Temperature Digital Readout

An Omega engineering unit was used to provide a digital readout of the ambient temperature during the test.

4.0 TEST PROCEDURE

The ampacity test was conducted in two separate but inter-related phases. The first phase consisted of establishing a base line ampacity for the power cables when installed in the unprotected conduit test assembly. The second phase consisted of determining the amperage derating which occurs when the conduit test assembly is enclosed by a three hour rated design of the THERMO-LAG 330 Fire Barrier System Preshaped Conduit Sections.

During both test phases, the ambient temperature was maintained at 40 +/- 2C, and the maximum conductor temperatures were maintained at 90 +/- 2C. These two test phases are described in more detail in the following paragraphs.

4.1 Unprotected Conduit Test Assembly

The base line ampacity test was conducted on the two inch conduit test assembly prior to enclosure with the protective fire barrier at the laboratory facilities of TSI in St. Louis, Missouri on 23 Oct. 1981.

The base line ampacity test was started by energizing the power sources to produce an initial amperage of 160 amperes in the #00 AWG power cable circuit. This amperage level was then maintained in the power circuit until one of the thermocouple temperatures stabilized within the designated temperature band of 194 +/- 3F (90 +/- 2C). The elapsed time for the pre-test period was circa four hours.

Throughout this and the subsequent one hour test phase, the ambient temperature within the test enclosure was maintained at 104 +/- 3F (40 +/- 2C).

Once the base line test was initiated, it was continued for one hour. During the test, the amperages in the power cable, the hot spot cable thermocouple temperature, and the ambient temperature, were recorded at 5 minute intervals.

The recorded base line amperage of 152 amperes was then corrected to reflect a 40C ambient temperature test condition and a 90C conductor temperature, using the correction formula presented in IPCEA Pub. No. P-46-426 (1962), Page III, Equation (5).

After correction, the base line amperage became 153.52amperes. The base line test amperage and temperature, together with the amperage correction calculations are shown in Table 1.

4.2 Protected Conduit Test Assembly

A three hour fire rated design of the THERMO-LAG 330 Fire Barrier System Preshaped Conduit Section was installed on the two inch conduit test assembly. Installation of the System involved cutting and mounting 3 foot long preshaped conduit sections on the test assembly, using approved stainless steel tie wires.

The preshaped conduit section design was installed on the test assembly in accordance with procedures set out in TSI's Technical Note 20684 entitled: "THERMO-LAG 330 Fire Barrier System, Installation Procedures Manual, Nuclear Plant Applications", Revision II, April 1984.

The test was started with the current flow established at 155 amperes in the power cable circuit. This current level, which was developed in the first phase, was maintained until the temperature limit of 194F (90C) was reached by the hottest cable thermocouple. At this point, the amperage was gradually reduced until the hottest cable thermocouple stabilized within the designated temperature band of 194 +/- 3F (90 +/- 2C).

After the temperature had stabilized for one hour, the test run was initiated and continued for another hour. During the test run, the circuit amperages, the hot spot cable thermocouple temperature and the ambient temperature were recorded at 5 minute intervals.

The test amperage of 140 amperes was then corrected to reflect a 40C ambient temperature condition and a 90C conductor temperature test condition using the correction formula presented in the IPCEA Pub. No. 46-426 (1962), Page III, Equation (5).

After correction, the test amperage became 138.60 amperes. The test amperages and temperatures, together with the amperage condition factors are shown in Table 2.

TABLE 1

BASE LINE TEST DATA

Time	Average Ambient Temperature F	Maximum Cable Temperature F	#00 AWG Power Cable Amperage
3:00 PM	106	194	152
3:05 PM	106	194	152
3:10 PM	105	194	152
3:15 PM	105	193	152
3:20 PM	105	193	152
3:25 PM	105	193	152
3:30 PM	105	193	152
3:35 PM	104	193	152
3:40 PM	105	193	152
3:45 PM	105	193	152
3:50 PM	104	193	152
3:55 PM	104	193	152
4:00 PM	104	193	152
4:05 PM	104	193	152

Average Ambient Temperature: 104.79F (40.44C)

Average Cable Temperature: 193.21F (89.56C)

Temperature Correlation Per IPCEA Pub. No. P-46-426:

$$I = 152 \; \frac{90 - 40}{89.56 - 40.44} \times \frac{234.5 + 89.56}{234.5 + 90}$$

$$I = 152\,(1.01) = 153.52 \text{ Amperes}$$

TABLE 2

TEST DATA FOR A FIVE FOOT LENGTH OF TWO INCH CONDUIT PROTECTED WITH A THREE HOUR FIRE RATED DESIGN OF THE THERMO-LAG 330 FIRE BARRIER SYSTEM

Time	Average Ambient Temperature F	Maximum Cable Temperature F	#00 AWG Power Cable Amperage
11:06 AM	105	197	140
11:11 AM	105	196	140
11:16 AM	105	196	140
11:21 AM	105	196	140
11:26 AM	105	197	140
11:31 AM	105	197	140
11:36 AM	105	197	140
11:41 AM	105	197	140
11:46 AM	105	197	140
11:51 AM	105	197	140
11:56 AM	105	197	140
12:01 PM	105	197	140
12:06 PM	105	197	140

Average Ambient Temperature: 105F (40.56C)

Average Cable Temperature: 196.79F (91.55C)

Temperature Correlation Per IPCEA Pub. No. P-46-426:

$$I = 140 \quad \frac{90 - 40}{91.55 - 40.56} \times \frac{234.5 + 91.55}{234.5 + 90}$$

$$I = 140\,(0.99) = 138.60 \text{ Amperes}$$

Ampacity Derating = 153.52 - 138.60/153.52 x 100 = 9.72%

5.0 ANALYSIS OF TEST RESULTS

The hottest cable thermocouple temperature, together with the ambient temperatures and power cable amperage readings, were recorded at 5 minute intervals during each of the test phases. These test results, which are shown in Tables 1 and 2, are analyzed and discussed in the following paragraphs.

5.1 Unprotected Conduit Test Assembly

The temperature readings for the hot spot thermocouple remained within the 194 +/- 3F (90 +/- 2C) temperature range during the one hour test period. The temperature ranged between 19[illegible] and 194F during the test.

The power cable current remained constant at 152 amperes throughout the one hour test. The ambient temperature within the test enclosure average 104.79F with all temperature readings falling within the prescribed test range of 104 +/- 3F (40 +/- 2C) during the test.

5.2 Protected Conduit Test Assembly

The temperature reading for the hottest thermocouple rose to 194F (90C) when the power cable circuit was energized at the 155 amperages level established in the base line test. The power cable current was then reduced to 140 amperes and the temperature readings from this thermocouple stabilized between 196 and 197F prior to the start of the test.

The power cable current remained at 140 amperes throughout the one hour test. The ambient temperature with the test chamber averaged 105F within the prescribed test range of 104 +/- 3F (4[illegible] - - 2C) during the test.

6.0 CONCLUSIONS

The test results indicate that the ampacity of three lengths of #00 AWG power cable installed in a two inch diameter rigid steel conduit, should be derated by 9.72% when the conduit is protected with a three hour fire rated design of the THERMO-LAG 330 Fire Barrier System Preshaped Conduit Section.

This derating factor was calculated by subtracting the test ampacity of 138.60 amperes from the base line amperage of 153.52, dividing the base line value of 153.52, and then multiplying by 100. On this basis, the derating factor was determined to be 9.72%.

The derating factor applies to the thickness of the THERMO-LAG 330 Fire Barrier System Material as tested, and tolerances employed in this test program which was 1.250" +/- 0.250", dry.

The test results obtained for derating the #00 AWG power cable may be used for all sizes of cable with similar material. This is based on J. Stolpe's work which indicates that derating should be independent of cable size.

ADDENDA

Recent IEEE draft bulletins for ampacity derating tests suggest the use of raceway sections larger than the 5 foot section used for this test. Since the base line test was conducted in October of 1981, the IEEE raceway length could not be anticipated. However, the 5 foot raceway used in this test will not in any way invalidate the test results.

The length of the raceway will affect two parameters;

1) The temperature oscillations in both the cable conductor and the the surrounding ambient air in the test box.

2) End effects where the cable enters and exits the test box.

Each of these parameters will be considered below:

1) Temperature Oscillations

The temperature oscillations are a function (among other things) of the air volume between the raceway and the test box, and the total area of fire barriers on the raceway - both of which are a linear function of the raceway length. During the tests, the temperature variations for both the conductor temperature and the ambient test box temperature were well within the allowable +/- 2C during the one hour test period. In addition, the average value for conductor temperature and test box ambient temperature were normalized to the base 90C/40C using the current correction formula given in IPCEA Publication No. P-46-426 (1962) on page III, equation (5).

2) End Effects

A short raceway will be vulnerable to end effects which are caused by the localized hot spots where the raceway enters and exits the test box. These hot spots are caused by the ceramic fiber packing, and are typically in the range of 5C temperature rise. The hot spots will cause a temperature gradient in both the inward and outward direction. The temperature gradient will exist for only several inches into the test box, not enough to effect the test results, since the conductor thermocouple locations are well into the test box.