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ACCESSION NBR:9703260168 DOC.DATE: 97/03/20 NOTARIZED: NO DOCKET #
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50-316 Donald C. Cook Nuclear Power Plant, Unit 2, Indiana M 05000316
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SUBJECT: Responds to 961202 RAI to resolve concerns re thermo-lag related ampacity derating issues.

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March 20, 1997

AEP:NRC:0692DL

Docket Nos.: 50-315
50-316

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

Donald C. Cook Nuclear Plant Units 1 and 2
ADDITIONAL INFORMATION REGARDING THERMO-LAG RELATED
AMPACITY DERATING ISSUES (TAC NOS. M85538 AND M85539)
IN RESPONSE TO A REQUEST FOR ADDITIONAL INFORMATION

References:

1. Letter AEP:NRC:0692CV, RAI regarding generic letter 92-08, "Thermo-Lag 330-1 Fire Barriers", E. E. Fitzpatrick to USNRC Document Control Desk, February 4, 1994.

2. Letter AEP:NRC:0692DA, follow-up to RAI regarding generic letter 92-08, "Thermo-Lag 330-1 Fire Barriers", E. E. Fitzpatrick to USNRC Document Control Desk, December 21, 1994.

3. Letter AEP:NRC:0692DD, response to follow-up to RAI regarding generic letter 92-08, "Thermo-Lag 330-1 Fire Barriers", E. E. Fitzpatrick to USNRC Document Control Desk, March 29, 1995.

4. Letter AEP:NRC:0692DF, additional information regarding thermo-lag related ampacity derating calculations, TAC nos. M85538 and M85539, E. E. Fitzpatrick to USNRC Document Control Desk, May 12, 1995.

By your letter of December 2, 1996, we were requested to supply additional information needed to resolve concerns regarding the ampacity derating factor determinations for Cook Nuclear Plant units 1 and 2. These concerns are addressed in the six attachments to this letter.

Attachment 1 provides responses to your requests. Attachment 2 provides a table that depicts the correlation between the predicted and measured ampacities. Attachment 3 provides the model computer code. Attachment 4 provides test report CL-492, "Ampacity Test for Power Cables in Randomly Filled Trays". Attachment 5 contains comparison tables that provide base information regarding trays and

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conduits, cable full load amperes, and comparison of calculated ampacities vs ICEA ampacities. Attachment 6 provides an "Ampacity vs Depth of Fill Plot for #12 AWG Copper Wire".

Sincerely,

A-Alan Blind for

E. E. Fitzpatrick
Vice President

vlb

Attachments

cc: A. A. Blind
A. B. Beach
MDEQ - DW & RDP
NRC Resident Inspector
J. R. Padgett

ATTACHMENT 1 TO AEP:NRC:0692DL

RESPONSE TO REQUEST FOR
ADDITIONAL INFORMATION REGARDING
THERMO-LAG RELATED AMPACITY DERATING ISSUES
FOR COOK NUCLEAR PLANT
(TAC NOS. M85538 and M85539)

1.0 BACKGROUND

The initial Request for Additional Information (RAI) response, AEP:NRC:0692CV, Attachment 2, included a list of Appendix R safe shutdown cables covered with Thermo-Lag 330-1 Barriers (Thermo-Lag) at Cook Nuclear Plant (CNP). This cable population was comprised of control, instrumentation, and power cables.

The focus of the ampacity derating analysis presented in this response has been reduced to strictly power cables. Control and instrumentation cables would have to be derated 73% or more in order for their loadings to be a concern, therefore they are not considered as part of this derating analysis. Additionally, junction boxes and tray junction pans are not considered as part of this derating analysis due to the large enclosure surface areas available for heat dissipation compared to the raceways that carry these same cables.

Also listed in AEP:NRC:0692CV, Attachment 2 were six installations where four inch conduit is embedded in concrete forming a vertical conduit bank. This bank is attached to a wall and the outer sides are covered with Thermo-Lag. Based on a review of each cable in these banks, including a comparison between each circuit Full Load Amperes (FLA) versus maximum ampacity of the cable (per design guidelines), a minimum margin of 25% was identified. We believe this margin is sufficient for any derating due to installation of Thermo-Lag on the vertical conduit banks. Therefore these installations have also been excluded from this derating analysis.

The following is a list of raceways that contain the power cables that are considered in this derating analysis. These power cables are identified in Attachment 5.

Appendix R Raceways

Trays	Conduits
1-AI-P1	8003R-1
1-AI-P2	8004R-1
1-AI-P4	8004G-1
1-AZ-P8	8026R-1
1-AZ-P9	8505R-1
1-A-P20	8506R-1
2-AZ-P3	8003R-2
	8004R-2
	8004G-2
	8154G-2
	8155G-2
	8744R-2

Non-Appendix R Trays

2-A-P2
2-AZ-P10

"Non-Appendix R Trays" are defined as those power trays (containing non-Appendix R cables) that are commonly wrapped with Appendix R control trays.

2.0 QUESTIONS

2.1 General modeling concerns

2.1.1 Request

Although the licensee submitted the results of its analysis for one cable tray and several conduits, there was no overall summary provided to assess the full range of fire barrier configurations installed at CNP. The licensee is requested to provide a summary of all ampacity derating assessment results for all Thermo-Lag enclosed raceway configurations (e.g. tray, conduit, air drop) installed at CNP.

Response

Summary ampacity derating assessment results for all the Thermo-Lag enclosed raceway configurations listed above are provided in Attachment 5. This attachment lists the ampacity derating of each cable within these raceways as the difference between FLA and ICEA ampacities as a percentage of the ICEA ampacity (% margin). As a verification that the loaded raceway generates less heat (watts per foot - w/ft) than what would be required to reach the cable qualification temperature, modelled and actual w/ft values are also listed.

It is our position that the cables listed in Attachment 5 have been appropriately derated given the large % margins and the differences between the predicted and actual heat values. Information on the development of Attachment 5 is provided in sections 2.3.2, 2.4.7 and 2.4.8.

2.1.2 Request

The level of documentation provided is not adequate to complete a full evaluation of your ampacity assessments. In general, there is no discussion of how the two parts of the licensee analysis methodology are made to work together, the example calculations do not provide enough information to verify the calculations, and the experiments purported to support validation of the thermal models are either not provided, or no direct one-to-one comparison of the experiments to modeling results is provided. The licensee is requested to provide further documentation in the areas stated above.

Response

A description of how the analysis methodology works is provided in section 2.3.2. Additionally, Attachment 2 demonstrates how the CNP thermal model was applied to a representative tray and conduit from the 1983 AEP Canton Test Lab tests. Applying the thermal model to tested raceways allowed for direct one-to-one comparisons to be made between predicted and actual values. The results of the comparisons demonstrated that there is a correlation between the predicted and actual calculated heat generated (w/ft) for both tray and conduit. Details of the comparison are provided both in section 2.3.2 and Attachment 2.

2.1.3 Request

No discussion was provided as to how in-plant cable service loads were determined, which cables have been considered in the analysis, and the basis for the elimination of other cables from consideration. The licensee is requested to clarify how the above information was treated in its analysis.

Response

In-plant cable service loads are determined from the nameplate rating of the service load itself.

The cables considered in this derating analysis are listed, by their raceway, in Attachment 5. The "Background" section of this submittal contains the basis for the elimination of other cables from consideration.

2.2 Part 1 Analysis, Appendix A of Attachment 4

2.2.1 Request

The staff agrees with its contractor, SNL, that the information provided to date does not provide an adequate basis for validation of its assumption that the overall heat rejection capacity of a sparsely loaded cable tray can be partitioned to individual cables in proportion to the cable diameter. The limited information provided by the licensee (one plot with no supporting data and no indicated units) is unconvincing given the potential for minor errors in the calculation could lead to larger error in the final estimation of ampacity limits. The licensee has cited a set of experiments as the basis for this plot, and hence, for the validation of this methodology (see reference of Appendix C in Attachment 4). However, this documentation of these experiments was not provided for staff review. The licensee is requested to provide Appendix C as well as any other documentation to support the validation of the experiments cited in the licensee analysis.

Response

AEP test report #CL-492 is included as Attachment 4 of this letter. This test report is the Appendix C identified in AEP:NRC:0692DF, Attachment 4. A detailed physical description of the test and testing protocol can be found in section III "Test Method" of the attached test report #CL-492. The summary is included in section IV "Test Results" as well as the test data section, Appendix A, of test report #CL-492.

The purpose of the test was to determine the ampacity of power cables in randomly filled trays and show the relation of I vs. $(d/R_{ac})^{1/2}$ for various tray configurations. Figure A-1 (AEP:NRC:0692DF, Attachment 4) was plotted using the results of three tested tray configurations. The Y axis represents current, in amperes, for the cables tested in each tray configuration. The X axis represents $(d/R_{ac})^{1/2}$, where d is diameter of each cable and R_{ac} is the a.c. resistance.

2.3 Part 2, Analysis, Appendix B of Attachment 4

2.3.1 Request

The assumption of equivalent annular regions appears to give inadequate treatment to the importance of surface area in heat transfer calculations. The actual rates of heat transfer are directly proportional to surface area; hence it is important that the thermal model use actual available surface areas in its formulation. The licensee should provide examples which encompass all raceway types installed to illustrate the effective heat transfer areas assumed for each of the layers in its modeling and compare those assumed areas to the actual heat transfer areas available in the physical system.

Response

All raceways considered in this assessment are either conduit or 12" x 6" ventilated, open top tray. These raceways are covered with 1 hour rated Thermo-Lag. Each raceway has been modelled in its equivalent circular form. When modelling tray, the tray itself is not considered as a thermal layer since it is ventilated with an open top. Therefore the only non-circular thermal layer modelled in the CNP raceway system is the Thermo-Lag that encases tray. This thermal layer is treated as circular by calculating its equivalent circular diameter.

Therefore, a 12" x 6" thermal layer would be modeled as a cylinder of diameter d = 2 x (h + w) /Π or 11.46". Modelling with such equivalent diameters does not change the actual surface areas in the physical system. This approach has been supported for CNP applications by the correlations noted between the thermal model and the 1983 Canton Test Lab data, described in section 2.3.2 and Attachment 2.

It should be noted that 12" x 6" ventilated tray is the only type utilized at CNP for power cable applications. Cable derating standards assume more "plate-like" tray (24" x 4") construction.

2.3.2 Request

The analysis as provided in the submittal dated May 12, 1995, provided no meaningful validation of its analysis method for calculating cable ampacity limits and cable tray limiting heat rejection capacities. The licensee should provide for the direct comparison of predicted cable ampacity limits to those measured in experiments on the corresponding system in order to validate its calculations.

Response

Validation of model

In applying the thermal model to tested raceways representative of those considered in this assessment, the model would prove to be conservative if it <u>predicted</u> a w/ft value that is below what is calculated to be the <u>actual</u> w/ft of the tested raceway. This is considered conservative since this predicted value establishes the "limit" for which other identical raceways must be below to be considered acceptable. Candidate raceways having a total heat value less than this "limit" ensures that the heat generated is less than the heat corresponding to a known temperature for actual loadings that is less than 90°C.

The CNP thermal model algorithm (Attachment 3) has been used to model a tray and conduit tested in 1983 at the AEP Canton Test Lab. Having applied this thermal model to previously tested raceways has validated that the model generates conservative results for CNP applications. The conclusion that the model generates conservative results is based on the rationale described in the previous paragraph applied to the modelling results provided in Attachment 2. Specifically what has been demonstrated is that the model generates predicted values that are below the calculated actual w/ft values that correspond to known temperatures for actual loadings that are less than the cable qualification temperature of 90°C.

It is important to note where modelled (predicted) ampacities and corresponding heat values are listed, that they correspond to a particular tray fill width of a given cable size using only a single layer of fill. Therefore, care must be taken when comparing modelled ampacities with those published in national standards.

Further, the ampacity and w/ft values generated by the computer model should not be interpreted as derating values endorsed by CNP design standards. Rather they are calculated values that would be required for a given fill width, of a particular size cable, to generate the maximum qualified cable temperature (90°C). Such values are used only for review and acceptance purposes.

Application of model in the review of raceways

The model algorithm is used to predict a heat generated value (w/ft) that corresponds to a given conductor temperature rise, for a given set of cables, in a given raceway. This value can be used as a "limit" for which other identical raceways can be compared to for acceptance (i.e. - those identical candidate raceways must have a total heat value less than this limit thereby ensuring that the heat generated is less than the heat corresponding to a known temperature).

For those raceway configurations where there is only one size cable (e.g. conduit), the predicted w/ft may be taken directly from the program output. This w/ft value is then compared to the actual total w/ft for the subject raceway for review and acceptance purposes.

For those raceway configurations where there is more than one size cable (e.g. tray), the program is to be run for each different size cable with the number of cables specified as (actual fill width ÷ subject cable diameter). The program will return a modelled ampacity (per conductor) and a corresponding modelled w/ft value (for entire tray) based on the tray loaded exclusively with the subject cable size. This process is repeated for each different size cable contained within the tray. The lowest modelled w/ft value is conservatively selected as the limit for which the actual total w/ft will be compared to for review and acceptance purposes. Selecting the lowest modelled w/ft value is considered conservative as it is less than the sum that could be calculated to accurately account for cables of varying size.

For each raceway considered in this ampacity derating assessment, the predicted and actual w/ft values are listed are listed in Attachment 5. Inspection of these values for each raceway shows that the actual heat generated for each raceway is less than 50% of the predicted heat generated.

2.3.3 Request

The thermal model for the subject analysis is based on heat transfer correlations which were originally published in the 1929-1933 time frame. These correlations are badly dated, and the impact of using more modern correlations in the model should be assessed by the licensee.

Response

Given the correlation between the CNP thermal model and the 1983 AEP Canton Test Lab test results, as discussed in section 2.3.2, we do not believe that using more modern correlations would prove to be effective.

2.3.4 Request

It is stated by the submittal AEP:NRC:0692DF, in the development of correlation for heat transfer from the cables to the surrounding air gap, that "the thermal resistance per conductor will be the total number of conductors divided by the total thermal conductance" (see the first sentence in the paragraph immediately preceding Equation 20 of the licensee analysis). The licensee should further explain and clarify the basis, intent, and impact of this statement.

Response

The basis for implementing equation 20 listed in AEP:NRC:0692DF, is that this equation is performed on cables of identical diameter. This prevents anomalies from being introduced by analyzing more than one cable size at a time.

The intent of implementing equation 20, listed in AEP:NRC:0692DF, is to account for the contribution of the raceway airspace in the overall partitioning of total thermal resistance to individual conductors. This permits conductor ampacity for a group of cables, with a given fill width and size, to be calculated. This ampacity is then used to calculate the predicted heat generated (w/ft) for the entire tray.

2.3.5 Request

Directly related to the comment regarding the heat transfer correlation from the cables to the surrounding air gap, the correlations for "the thermal resistance through relatively thin cylinders (i.e., cable jacket, tray, fire barrier)" (Equation 16 per the licensee Analysis) and for the "thermal resistance from the last surface to ambient" (Equation 21 per the licensee Analysis) each include a factor (n') described as "the number of conductors within the section." This would appear to be, in effect, a thermal partitioning factor which is based on a simple conductor count and, as such, may be in direct conflict with the stated assumptions of the model described in "Appendix A" of Licensee

Attachment 4 (where it is assumed that surface area will be the basis for thermal partitioning). The licensee should clarify the basis, intent, and implementation of this factor (n') as it is applied to each of these two equations and how this factor is applied when cables of different physical dimensions are present in a common cable trays.

Response

The basis for implementing equations 16 and 21, listed in AEP:NRC:0692DF, is that these equations are performed on cables of identical diameter. This prevents anomalies from being introduced by analyzing more than one cable size at a time.

The intent of implementing equations 16 and 21, listed in AEP:NRC:0692DF, is to account for the contribution of the material thermal layers in the overall partitioning of total thermal resistance to individual conductors. This permits conductor ampacity for a group of cables, with a given fill width and size, to be calculated. This ampacity is then used to calculate the predicted heat generated (w/ft) for the entire tray.

2.3.6 Request

The subject analysis treats all cable tray systems using a model based on circular geometries. This practice is said to have been validated based on the "excellent correlation between computer data and test data." However, no evidence of such validation has been provided in the subject submittal. The licensee is requested to provide the technical justification which validates its assumptions in this regard.

Response

Section 2.3.2 and Attachment 2 provide test results and calculations which validate the correlation between the computer data (thermal model) and the test data (1983 AEP Canton Test Lab data). This has been demonstrated for a typical tray and conduit configuration at CNP. Therefore we believe that modelling cable tray systems using the circular geometry approach detailed in section 2.3.1 is appropriate for CNP applications.

2.3.7 Request

The correlation cited for the thermal resistance between the outer surface of the barrier and the ambient environment (Licensee Equation 21) applies only to pipes. These correlations should not be applied to flat plate surfaces such as those which would be experienced around a cable tray.

Response

Given the geometry of our tray, the single layer fill practices and the correlation between the thermal model and test data, the adequacy of modeling our 12" x 6" tray in its equivalent circular form has been demonstrated to be appropriate for CNP applications. This has been demonstrated in section 2.3.2 and Attachment 2, where the predicted heat generated in a cable tray was found to be less than the actual calculated heat generated.

2.3.8 Request

The analysis model provides no treatment of the effects of spacing on the radiative heat transfer behavior of the cables. Reduced view factors due to cable proximity might significantly reduce the predicted rates of radiant heat transfer. The licensee is requested to address how the effects of spacing should be accounted for in the radiative heat transfer correlations.

Response

No credit is taken for space between cables when implementing the CNP thermal model. In each run of the thermal model, the fill width is assumed to be a solid mass of cables. That is to say, that for a tray with a total fill width of 4.2" that is comprised of cables of 0.2" O.D., the tray would have 4.2"/0.2" or 21 cables with no spaces between them.

2.3.9 Request

The licensee is requested to provide information on the specific inputs used in any example case as well as any computer code which process the subject calculations.

Response

The code and inputs for example raceways are included as Attachments 3 and 2 respectively.

The computer program requires the following as input:

a. ambient temperature

b. number of heat transfer layers
   parameters for each layer
      equivalent outside diameter of layer
      thickness of layer
      dead airspace outside layer
      emissivity of surface
      thermal resistivity of layer

c. number of cables
   parameters for each cable
      temperature rating
      electrical resistivity of conductor
      specific inductive capacitance of insulation
      power factor of insulation
      thickness of jacket
      thermal resistance of jacket
      number of conductors per cable
      circular inch area of conductor
      conductor diameter
      insulation diameter
      thermal resistivity of insulation
      AC/DC ratio
      emissivity of cable surface
      diameter of cable
      line to line voltage (KV)
      inferred temperature of zero resistance of conductor

The ampacities and w/ft values generated by the computer model should not be interpreted as derating values endorsed by CNP design standards. Rather they are predicted values that would be required for a given fill width, of a particular size cable, to generate the maximum qualified cable temperature (90°C).

2.3.10 Request

The licensee has apparently applied one or both of its thermal models to the analysis of cables in conduits as well as those in trays. The applicability of both licensee analysis models to conduits needs to be further clarified by the licensee. Specifically, the thermal model for cable trays is based on the unique configuration of "maintained spacing" for its power cables in cable trays. This same factor cannot generally be assumed to exist for cables in conduits. The licensee should provide an explicit discussion of the applicability of its two thermal models (the "Appendix A" surface area based heat load partitioning model and the "Appendix B" direct thermal analysis model) to conduits, and should discuss how these models were implemented for conduit analyses.

Response

The thermal model is based on current carrying conductors housed in cylindrical raceways. As explained in 2.3.7, cable tray is treated as a cylindrical raceway, therefore the thermal model is directly applicable to both cables housed in conduit and cable trays.

The design standard for conduit at CNP is such that only <u>one</u> power cable may be run in any conduit, therefore the matter of maintaining separation between cables is not a concern with respect to conduit.

2.4 Attachment 5, Representative Calculation Results

2.4.1 Request

A nominal comparison between the licensee ampacity predictions and those obtained using more conventional approaches to the ampacity assessment showed that the CNP estimated ampacity limits were non-conservative. In the case of the conduits, the licensee estimated ampacity limits including derating for the fire barrier system which were in excess of the tabulated ampacity limits for cables in conduits without a fire barrier as set forth in the NEC tables, even given the most generous interpretation of the conduit loadings (only a single cable per conduit with no more than three conductors). These results indicate that the subject thermal model may be generating unrealistic and non-conservative estimates of actual cable ampacity limits. The licensee is requested to address these discrepancies.

Response

A nominal comparison between CNP modelled ampacities, FLA and the tabulated ampacity limits for cables in conduits without a fire barrier, as set forth in the IPCEA/NEC tables, is provided in a table on page 10 of Attachment 5. An inspection of this table indicates that the CNP modelled ampacities and FLA are less than the limit values in the tables identified in the request. These IPCEA and NEC ampacity limits were chosen as they correspond to the triplex and 3TC non-jacketed cables used at CNP for power cable applications. As a result of our modelled ampacities being less than those depicted in national standards, we do not believe that our model is generating non-conservative estimates, therefore no discrepancies are believed to exist.

The ampacities and w/ft values generated by the computer model should not be interpreted as values endorsed by CNP design standards. Rather they are predicted values that would be required for a given fill width, of a particular size cable, to generate the maximum qualified cable temperature (90°C).

2.4.2 Request

As a part of the validation process, the licensee should provide a direct comparison of its own modeling results to the results obtained using more conventional ampacity derating approaches.

Response

Given the correlation between our thermal model and the 1983 test results (discussed in section 2.3.2, with supporting calculations provided in Attachment 2), we do not believe that using more conventional ampacity derating approaches (for raceways enclosed in a thermal barrier) would prove to be useful.

The ampacities and w/ft values generated by the computer model should not be interpreted as derating values endorsed by CNP design standards. Rather they are predicted values that would be required for a given fill width, of a particular size cable, to generate the maximum qualified cable temperature (90°C).

2.4.3 Request

In any future submittal, the licensee should also provide a sufficient base of information (i.e. more detailed descriptions of the physical characteristics of each system, and the characteristics of the installed fire barrier system) regarding specific applications.

Response

We agree that a more sufficient base of information should have been previously provided. In this submittal, Attachment 5 provides base information on the physical characteristics of each raceway system considered in this derating analysis. This information includes number of cables per tray, size of cables, cable material, FLA, and rating of fire barrier.

2.4.4 Request

The example results for conduits predicted the exact same ampacity limits down to four significant figures (25.85A) for a 3/C #12AWG cable in both a 1/2" conduit (cable 8026R) and a 1" conduit (cable 8505R for example). While the ampacity tables would not distinguish between these two cases, given the differences in the physical configurations, the thermal model certainly should provide different results. This licensee is requested to identify the source of, and resolve, this discrepancy.

Response

The noted discrepancy was attributed to the physical parameters used to model the 1/2" conduit. Provided in Attachment 5 are the ampacities of the Appendix R conduits as they are reflected in the latest revision of the Appendix R conduit ampacity calculations. As noted in the request, a difference does exist between the modelled ampacities for a 3/C #12AWG cable in a 1/2" conduit (24.38 amperes) and a 1" conduit (26.01 amperes).

2.4.5 Request

The full load amperes (FLA) for the equipment as shown appears low.

Motor	Voltage	FLA	FLA Per NEC Table 430-150
2hp	460 V	2.6	3.4
3hp	460 V	3.8	4.8
15hp	460 V	16	21
20hp	460 V	20	27

Provide the basis for the full load current projections. The nameplate FLA which is at rated voltage and rated load is acceptable provided the loads are not operating at an overload condition or at a service factor greater than one and the rated voltage is maintained at the load terminals. Provide a discussion about the impact of overload conditions, the service factor of the load and the voltage availability at the load terminals given the stated ampacity derating margins.

Response

The identification of the ampacities, as outlined in NEC Table 430-150, is correct for a distribution voltage of 480 (nominal), however the distribution voltage at CNP is 600 (nominal). Listed below are the same horsepower values and a comparison of the ampere values used vs. NEC Table 430-150.

Motor	Voltage	FLA	FLA Per NEC Table 430-150
2hp	575 V	2.6	2.7
3hp	575 V	3.8	3.9
15hp	575 V	16	17
20hp	575 V	20	22

The small differences between the FLA used and Table 430-150 of the NEC can be attributed to the actual nameplate ampacity. We do not design motor installations to operate the motor either in an overload condition or into the service factor. Cables are sized to 125% of their FLA to account for any short term overload or low voltage condition.

2.4.6 Request

The allowable ampacity as calculated for #12AWG in Appendix R trays is extremely high. ICEA Standard P-54-440, "Ampacity of Cables in Open-Top Cable Trays' allows only 15 A (maximum) for 1.0" depth of fill and cable diameter of 0.49". The cable used in this calculation has a diameter of 0.32". For 0.32" diameter cable, the allowed ampacity per ICEA Standard P-54-440 will be (0.32/0.49) x 15 = 9.79 amps. This amperes would be reduced further due to fire wrap material (Thermo-Lag).

Response

The prorating of ampacities, using the ICEA derating tables, for different fill depths as well as different cable diameters cannot be applied in direct proportion as identified in the request.

For example, per section 2.2 of ICEA-54-440 standard, the total number of #12 AWG installed cables for a 12" wide tray with 1" fill will be:

$$n = \frac{1 \times 12}{d \times d}$$

for a 0.49" diameter cable n= 49 cables

for a 0.32" diameter cable n= 117 cables

However, per AEP design guidelines, only one layer of power cables are placed in a tray up to a maximum 75% width of the tray, therefore the maximum number of cables installed for the same scenario above would be:

$$n = \frac{12}{d \times 1.33}$$

for a 0.49" diameter cable n= 18 cables

for a 0.32" diameter cable n= 28 cables

As shown, CNP design guidelines limit the loading to less than 28/117 or 24% for the example presented in the request, therefore the proportional conversion suggested is not appropriate.

For comparison purposes, a graphical representation using ICEA-54-440 table 3.6, "Cable Ampacity Data For a #12 AWG Cable", is shown in Attachment 6. The plot is projected to accommodate CNP design for a 1/2" tray fill. The plot depicts the projected ampacity for 1/2" tray fill to be approximately 20.5 amperes. CNP design guidelines applied to this configuration result in a more conservative loading as they allow a maximum design ampacity of 15 amperes for a fully loaded tray (75% of its width). Therefore we believe that our design standards for a tray of this configuration are not extremely high as stated.

The ampacities and w/ft values generated by the computer model should not be interpreted as derating values endorsed by our design standards. Rather they are predicted values that would be required for a given fill width, of a particular size cable, to generate the maximum qualified cable temperature (90°C).

2.4.7 Request

Provide a comparison of the calculated allowable ampacity for Appendix R trays versus the allowed ampacity without the Thermo-Lag as published in ICEA P-54-440 for <u>open-top tray</u> considering cable diameter and depth of fill adjustments. The staff believes that the calculated ampacity for wrapped trays must be less than that obtained from ICEA Standard P-54-440. The licensee should provide adequate justification for ampacity values exceeding ICEA Standard P-54-440.

Response

For each tray, Attachment 5 provides a comparison of FLA, modelled ampacity and the allowed ampacity without the Thermo-Lag as published in ICEA P-54-440 for open-top tray (considering cable diameter and depth of fill adjustments). This attachment also lists the ampacity derating margin available of each cable within these trays as the difference between FLA and ICEA ampacities as a percentage of the ICEA ampacity (% margin). In all cases, the FLA and the modelled ampacity were found to be less than the adjusted allowable ICEA ampacities.

The ampacities and w/ft values generated by the computer model should not be interpreted as derating values endorsed by CNP design standards. Rather, they are predicted values that would be required for a given fill width, of a particular size cable, to generate the maximum qualified cable temperature (90°C).

The open tray ampacity values listed in Attachment 5 were adjusted using equation 9 and figure 4 from the Stolpe paper (70-TP 557-PWR). This paper is the basis for the ICEA P-54-440 ampacity tables. The ICEA ampacity calculations were developed using a minimal 10% fill value (the lower limit of the plot contained in Stolpe paper, figure 4), with adjustments made to reflect actual tray fill conditions. The actual fill for all trays except one (1AI-P2) is less than 10%, however a 10% ICEA fill value was used for most cases as a conservative comparison.

All trays at CNP are 12" wide x 6" deep and are installed horizontally as well as vertically. Each tray is individually wrapped with 1 hour rated Thermo-Lag except three trays (1AI-P1, 1AI-P2 and 1AI-P4) which are wrapped with an adjacent control tray (side by side proximity) in a common enclosure. These adjacent control trays do not contribute significant heat loads. On the contrary, they significantly increase surface area for heat dissipation (CNP power cable trays are ventilated).

The following is a per tray discussion on how the ICEA ampacity limits were adjusted (if adjusted at all) for cable diameter and depth of fill .

Tray # 1AI-P1
The calculated allowable ampacities for all cables in the tray are found to be lower than the calculated ICEA allowed ampacities. The actual tray fill is only 3.95%, which provides additional margin for ICEA calculated ampacities.

Tray #1AI-P2
The calculated allowable ampacities for all cables in the tray are found to be lower than the calculated ICEA allowed ampacities.

Tray # 1AI-P4
The calculated allowable ampacities for all cables in the tray are found to be lower than the calculated ICEA allowed ampacities. This particular tray carries three (3) cables only. Two cables, size 3TC #12 CU, carry a connected load of 0.4 amperes each and the third cable, 3TC# 6AL, is used for a welding receptacle circuit with a switch rating of 60 amperes. Connected load for the # 6 AL cable is much smaller and non-continuous type. Further, the actual tray fill is found to be only 0.95%. Therefore, a 4% fill criterion is used in calculating the ICEA ampacities for 3TC #12 CU cable.

Tray # 2AZ-P3
The calculated allowable ampacities for all cables in the tray are found to be lower than the ICEA allowed ampacities. The ICEA ampacities are based on 9% tray fill. Although motor operated valve load is considered in the analysis, this load does not contribute to any heat load with respect to the long-time cable degrading issue due to short stroke time for valve operation.

Tray # 1AZ-P8
The calculated allowable ampacities for all cables in the tray are found to be lower than the ICEA allowed ampacities. The actual fill is found to be 2.62%, therefore, a 4% fill criterion is used in calculating the ICEA ampacities for 3TC #12 CU cable. Although motor operated valve load is considered in the analysis, this load does not contribute to any heat load with respect to the long-time cable derating issue due to short stroke time for valve operation.

Tray # 1AZ-P9
The calculated allowable ampacities for all cables in the tray are found to be lower than the ICEA allowed ampacities. The actual fill is found to be 3.60%. Therefore, a 4% fill criterion is used in calculating the ICEA ampacities for 3TC #12 CU cable.

Tray # 1A-P20
The calculated allowable ampacities for all cables in the tray are found to be lower than the ICEA allowed ampacities. The ICEA ampacities are based on 9% tray fill except as noted.

Tray # 2AZ-P10
The calculated allowable ampacities for all cables in the tray are found to be lower than the ICEA allowed ampacities.

Tray # 2A-P2
The calculated allowable ampacities for all cables in the tray are found to be lower than the ICEA allowed ampacities. The actual fill is found to be 2.48%. Therefore, a 4% fill criterion is used in calculating the ICEA allowed ampacities for 3TC #12 CU cable.

2.4.8 Request

Provide a comparison of calculated allowed ampacity in Appendix R conduit versus allowed ampacity in conduit as published in ICEA Standard P-46-426 (including factors for the number of conductors, grouping factors for cables in exposed or enclosed conduit in air, etc.). Provide sufficient details (cable type, cable diameter, number of conductors, conduit size, percent fill, temperature, etc.) to assess ampacity rating for the example cases. The staff believes that the calculated ampacity for wrapped conduits must be less than that obtained from ICEA Standard P-46-426. The licensee should provide adequate justification for ampacity values exceeding ICEA Standard P-46-426.

Response

A nominal comparison between FLA, modelled ampacities and ampacity limits for cables in conduits, as set forth in IPCEA P-46-426 and the NEC tables, is tabulated in Attachment 5. This table includes cable type, cable diameter, number of conductors and conduit size. An inspection of this table indicates that the FLA and modelled ampacities are below the limit values provided in IPCEA P-46-426 and the NEC. These IPCEA and NEC ampacity limits were chosen as they correspond to the triplex and 3TC non-jacketed cables used at CNP for power cable applications.

The ampacities and w/ft values generated by the computer model should not be interpreted as values endorsed by CNP design standards. Rather they are predicted values that would be required for a given fill width, of a particular size cable, to generate the maximum qualified cable temperature (90°C).2

ATTACHMENT 2 TO AEP:NRC:0692DL

TABLE DEPICTING CORRELATION BETWEEN
THE PREDICTED AND MEASURED AMPACITIES

Calculation to support the verification of the CNP Thermal Model applied to tray

Test (Fill Width)	Cable Type (Diameter)	Test Loading (A)	No. of Runs (Contributing Width)	Highest Measured Temperature (°C)	Predicted Ampacity (A)	Predicted Watts/Ft (w/ft)
1 (4.12")	3TC#12CU (0.32")	3.8	7 (2.24")	45.6	6.96	3.34
	3TC#12CU (0.32")	20.0	3 (0.96")	59.7	13.41	13.01
	3TC#2AL (0.92")	60.0	1 (0.92")	55.7	49.58	9.87

* Predicted values are based on the highest measured temperature as the conductor temperature. Predicted values are also based on the fill width being comprised totally of the respective cable type.

Calculated heat generated per conductor by resistive heating = # of conductors x I^2 x R_{ac}
where I = connected load (A)
R_{ac} = AC resistance (Ω/ft)

Applied to the modelling of Test 1 using the predicted ampacities, the modelled heat generated is:

3TC#12CU = 21 x 6.96^2 x 177.8E-5* = 1.81 W/ft
3TC#12CU = 9 x 13.41^2 x 184.27E-5* = 2.98 W/ft
3TC#2AL = 3 x 49.58^2 x 29.84E-5* = 2.2 W/ft

Total modelled heat generated = 6.99 W/ft

Applied to the actual loading in Test 1 above, the total actual heat generated is:

3TC#12CU = 21 x 3.8^2 x 177.8E-5* = 0.5391 W/ft
3TC#12CU = 9 x 20^2 x 184.27E-5* = 6.634 W/ft
3TC#2AL = 3 x 60^2 x 29.84E-5* = 3.223 W/ft

Total actual heat generated = 10.4 W/ft

* Resistances have been adjusted to correspond to their respective measured temperatures listed above

A comparison of the predicted heat generated (6.99 W/ft) and the actual heat generated (10.4 W/ft) for the given test case above demonstrates that the CNP thermal modelling approach is conservative. This is considered conservative since this establishes the "limit" for which other identical raceways can be compared to for acceptance (i.e. - those identical candidate raceways must have a total heat value less than this limit thereby ensuring that the heat generated is less than the heat corresponding to a known temperature).

The predicted values listed in Test 1 have been generated from the computer model using the following input:

INPUTS	3TC#12CU	3TC#12CU	3TC#2AL
# of cables*	12.875	12.875	8.04
# of thermal layers	1	1	1
o.d. of layer I (inches)	13.34	13.34	13.34
thickness of layer I (inches)	0.5	0.5	0.5
dead air space outside layer I	1	1	1
emmisivity of layer I	0.9	0.9	0.9
thermal resistivity of layer I (°C cm/W)	578.03	578.03	578.03
conductor temperature (°C)	45.6	59.7	55.7
ambient temperature (°C)	40	40	40
electrical resistivity of conductor (circ mil Ω/ft @20°C)	10.371	10.371	17.002
inferred temperature of zero resistance of cond.(°C)	234.5	234.5	228.1
line to line voltage (KV)	0.6	0.6	0.6
specific inductive capacitance of insulation	2.3	2.3	2.3
power factor of insulation	0.035	0.035	0.035
thickness of jacket (inches)	0	0	0
thermal resistance of jacket (°C cm/W)	0	0	0
# of conductors per cable	3	3	3
circular inch area of conductor	0.00653	0.00653	0.06636
conductor diameter (inches)	0.092	0.092	0.292
insulation diameter (inches)	0.1488	0.1488	0.4279
thermal resistivity of insulation (°C cm/W)	450	450	450
AC/DC ratio	1	1	1
emmisivity of cable surface	1	1	1
diameter of cable (inches)	0.32	0.32	0.92

* # of cables = fill width + cable diameter

The predicted values listed in Test 5 have been generated from the computer model using the following input:

INPUTS	3TC#2AL
# of cables	1
# of thermal layers	2
o.d. of layer I (inches)	4.5/6
thickness of layer I (inches)	0.237/0.5
dead air space outside layer I	0.25/1
emmisivity of layer I	0.055/0.9
thermal resistivity of layer I (°C cm/W)	2.2/578.03
conductor temperature (°C)	65
ambient temperature (°C)	40
electrical resistivity of conductor (circ mil Ω/ft @20°C)	17.002
inferred temperature of zero resistance of cond.(°C)	228.1
line to line voltage (KV)	5
specific inductive capacitance of insulation	2.3
power factor of insulation	0.035
thickness of jacket (inches)	0.02
thermal resistance of jacket (°C cm/W)	450
# of conductors per cable	3
circular inch area of conductor	0.06636
conductor diameter (inches)	0.292
insulation diameter (inches)	0.530
thermal resistivity of insulation (°C cm/W)	450
AC/DC ratio	1
emmisivity of cable surface	1
diameter of cable (inches)	1.14

ATTACHMENT 3 TO AEP:NRC:0692DL

MODEL COMPUTER CODE

```
10 REM ***************************************************
20 REM ****** DISPLAY PROGRAM DESCRIPTION AND PROMPT USER ***
30 REM ****** FOR INPUTS.                                 ***
40 REM ***************************************************
50 CLS
60 PRINT "QUICK?"
70 INPUT Q9$
80 IF Q9$="Y" THEN 580
90 PRINT "FIRE BARRIER AMPACITY DERATING-II (FBAD2)"
100 PRINT "DO YOU NEED HELP? (Y OR N)"
110 INPUT Q1$
120 IF Q1$="Y" THEN 140
130 GOTO 620
140 PRINT
150 PRINT "THIS PROGRAM IS DESIGNED TO CALCULATE THE AMPACITY OF"
160 PRINT "CABLES IN RACEWAY ENCLOSED IN FIRE BARRIER MATERIAL."
170 PRINT " THE MODEL USED TO DEVELOP THIS PROGRAM APPROXIMATES"
180 PRINT " THE THERMAL CHARACTERISTICS OF VARIOUS RACEWAY AND"
190 PRINT "  FIRE BARRIER CONFIGURATIONS BY USING THE EQUATIONS OF"
200 PRINT "  HEAT FLOW THROUGH CYLINDRICAL SURFACES DEVELOPED"
210 PRINT "  BY NEHER AND MCGRATH IN THEIR 1957 AIEE PAPER."
220 PRINT
230 PRINT "SINCE HEAT TRANSFER IS LARGELY DEPENDENT ON THE SURFACE"
240 PRINT " AREA OF THE TRANSFER MEDIUM, THE EQUIVALENT DIAMETER"
250 PRINT " OF NON-CIRCULAR RACEWAY (I.E., TRAY AND FIRE BARRIER"
260 PRINT " SYSTEMS SHOULD BE DETERMINED BY USING THE PERIMETER,"
270 PRINT " NOT THE X-SECTIONAL AREA OF THE ENCLOSING MATERIAL."
280 PRINT " IN OTHER WORDS THE EQUIVALENT DIAMETER OF A 12 INCH BY"
290 PRINT " 6 INCH TRAY SHOULD BE  2x(H+W)/3.14 OR 11.46 INCHES."
300 PRINT
310 PRINT "PLEASE NOTE THAT THIS PROGRAM IS VALID ONLY IF TRAY FILL"
320 PRINT "DOES NOT VIOLATE THE AEP'S CRITERIA FOR POWER TRAY (I.E.-"
330 PRINT "75% OF TRAY WIDTH AND 1 LAYER DEEP)."
340 PRINT
350 PRINT "WHEN ENTERING N, THE NUMBER OF HEAT TRANSFER LAYERS,"
360 PRINT " DO NOT INCLUDE THE CABLE INSULATION OR JACKET AS A"
370 PRINT " LAYER. THIS WILL BE DONE BY THE PROGRAM."
380 PRINT
390 PRINT "DO YOU NEED HELP ENTERING THE DATA? (Y OR N)"
400 INPUT Q2$
410 IF Q2$="Y" THEN 430
420 GOTO 620
430 PRINT
440 PRINT
450 PRINT "DATA SHALL BE INDICATED AS BELOW"
460 PRINT
470 PRINT "DO YOU WANT A PRINT OUT OF DEFINITIONS? (Y OR N)"
480 INPUT Q4$
490 IF Q4$="Y" THEN 510
500 GOTO 530
510 N=1
520 GOTO 1890
530 PRINT
540 PRINT "DO YOU WANT TO ENTER DATA? (Y OR N)"
550 INPUT Q5$
560 IF Q5$="Y" THEN 1880
570 GOTO 620
580 IF Q9$<>"Y" THEN 620
590 PRINT "OUTPUT?"
600 INPUT Q3$
```

```
610 GOTO 640
620 PRINT "DO YOU WANT A LONG FORM OF THE OUTPUT? (Y OR N)"
630 INPUT Q3$
640 PRINT
650 PRINT "ENTER THE TYPE OF CABLE TO BE RUN"
660 INPUT B$
670 PRINT
680 PRINT "INPUT Y9 AND Z9, THE LIMITS OF CABLES"
690 INPUT Y9
700 INPUT Z9
710 REM *****************************************************
720 REM ********* READS DATA IN *******************************
730 REM *****************************************************
740 DIM D9(5),T(5),S(5),E9(5),P9(5),CP(5),M(5),A9(5),Z8(5),Y8(5),Q99(5),I9(20)
750 C1=0
760 READ N
770 FOR I=1 TO N
780     READ D9(I),T(I),S(I),E9(I),P9(I)
790     C1=C1+2
800     IF S(I)>0 THEN 820
810     C1=C1-1
820 NEXT I
830 READ T1,T2,P,T0,V,E1,F1
840 READ T5,P5
850 READ N1,C,D0,D1,P1,A,E5,D5
860 IF Q9$="Y" THEN 880
870 IF Q3$="Y" THEN 1890
880 C1=C1+3
890 IF T5>0 THEN 910
900 C1=C1-1
910 T3=(T1-T2)/C1
920 C1=0
930 REM ***********DC RESISTANCE
940 R=1.02*P/C*(T0+T1)/(T0+20)
950 REM ***********DIELECTRIC LOSS
960 XZZ=LOG(D1/D0)/LOG(10)
970 W=.00276*(V/1.73205)^2*E1*F1/XZZ
980 IJK=0
990 FOR J=Y9 TO Z9
1000 IF IJK=1 THEN 1750
1010  Q=1
1020 REM ***********NUMBER OF CONDUCTORS
1030  N3=J*N1
1040 REM ***********THERMAL RESISTANCE OF INSULATION
1050  R1=.012*P1*LOG(D1/D0)/LOG(10)
1060  C2=1
1070 IF T5=0 THEN 1110
1080 REM ************************THERMAL RESISTANCE OF JACKET
1090  C5=.0104*P5*N1*T5/(D5-T5)
1100 C2=C2+1
1110 C5=0
1120 REM ************************FILL WIDTH
1130  D5=D5*J
1140 REM ***************************AIRSPACE
1150  S5=D9(1)-T(1)-D5
1160  M5=T1-(C2*T3+T3/2)
1170  C2=C2+2
1180 REM ***************************THERMAL RESISTANCE OF AIRSPACE
1190  A5=N3/(.092*D5^.75*T3^.25/(1.39+D5/(D5+S5))+.0213/(LOG((D5+S5)/D5)/LOG(10)
)+.102*D5*E5*(1+.0167*M5))
```

```
1200 REM *************THERMAL RESISTANCE OF INSUL, JACKET AND AIRSPACE
1210 R0=R1+C5+A5
1220 REM ***************THERMAL LAYER RESISTANCES
1230 FOR I=1 TO N
1240 CP(I)=.0104*P9(I)*N3*T(I)/(D9(I)-T(I))
1250 NEXT I
1260 REM ****************THERMAL RESISTANCE OF AIRSPACE BETWEEN THERMAL LAYERS
1270 IF N<2 THEN 1390
1280 FOR I=1 TO N-1
1290 IF S(I) >0 THEN 1320
1300 C2=C2+1
1310 GOTO 1380
1320 E=1/(1/E9(I)+D9(I)/D9(1+I)*(1/E9(I+1)-1))
1330 IF Q>1 THEN 1360
1340 M(I)=T1-(C2*T3+T3/2)
1350 Q99(I)=T3
1360 A9(I)=N3/(.092*D9(I)^.75*Q99(I)^.25/(1.39+D9(I)/(D9(I)+S(I)))+.0213/LOG((D9
(I)+S(I))/D9(I))/LOG(10)+.102*D9(I)*E*(1+.0167*M(I)))
1370 C2=C2+2
1380 NEXT I
1390 IF Q>1 THEN 1420
1400 M(N)=T1-(C2*T3+T3/2)
1410 Q99(N)=T3
1420 A9(N)=15.6*N3/(D9(N)*((Q99(N)/D9(N))^.25+1.6*E9(N)*(1+.0167*M(N))))
1430 REM *************SUM ALL RESISTANCES
1440 FOR I=1 TO N
1450 R0=R0+CP(I)+A9(I)
1460 NEXT I
1470 REM *************CALCULATE RESULTS
1480 D=W*(R0-R1/2)
1490 I9(Q)=SQR((T1-(T2+D))/(R*A*R0))*1000
1500 W1=N3*I9(Q)^2*R*A/1000000!
1510 IF Q=1 THEN 1530
1520 IF ABS ((I9(Q)-I9(Q-1))/I9(Q))<.000001 THEN 1690
1530 T9=T1-(R1+C5)*W1/N3
1540 T8=T1-(R1+C5+A5)*W1/N3
1550 T3=T9-T8
1560 K8=0
1570 K9=0
1580 FOR I=1 TO N
1590       K9=K8+CP(I)
1600       K8=K9+A9(I)
1610       Z8(I)=T1-(R1+C5+A5+K9)*W1/N3
1620       Y8(I)=T1-(R1+C5+A5+K8)*W1/N3
1630          M(I)=(Z8(I)+Y8(I))/2
1640          Q99(I)=Z8(I)-Y8(I)
1650       NEXT I
1660       M5=(T9+T8)/2
1670       Q=Q+1
1680       GOTO 1190
1690       I1=I9(Q)
1700       IF Q3$="Y" THEN 2170
1710       PRINT
1720 CLS
1730       PRINT B$
1740       PRINT
1750       PRINT "NUMBER OF CABLES=",J
1760       PRINT "NUMBER OF CONDUCTORS=",N3
1770       PRINT  "ALLOWABLE AMPACITY=",I1
1780       PRINT "WATTS PER FOOT OF RACEWAY=",W1
```

```
1790        PRINT
1800        LPRINT
1810        PRINT
1820        PRINT
1830        D5=D5/J
1840        C2=0
1850     R0=0
1860 NEXT J
1870 LIST 2410-2450
1880 STOP
1890 PRINT N, "=N, THE NUMBER OF CABLE ENCLOSURE LAYERS"
1900 FOR I=1 TO N
1910     PRINT D9(I),"=EQUIVALENT OUTSIDE DIAMETER OF LAYER I"
1920     PRINT T(I),"=T(I), THICKNESS OF LAYER I"
1930     PRINT S(I),"=S(I), DEAD AIR SPACE  I9 (1 FOR AMBIENT)"
1940     PRINT E9(I),"=E9(I), EMISSIVITY OF SURFACE I"
1950     PRINT P9(I),"=P9(I), THERMAL RESISTIVITY OF LAYER I"
1960 NEXT I
1970 PRINT T1,"=T1, CONDUCTOR TEMPERATURE"
1980 PRINT T2,"=T2, AMBIENT TEMPERATURE"
1990 PRINT P,"=P, ELECTRICAL RESISTIVITY OF CONDUCTOR"
2000 PRINT T0,"=TO, INFERRED TEMP OF ZERO RESISTANCE OF CONDUCTOR"
2010 PRINT V,"=V, LINE TO LINE VOLTAGE IN KV"
2020 PRINT E1,"=E1, SPECIFIC INDUCTIVE CAPACITANCE OF INSULATION"
2030 PRINT F1,"=F1, POWER FACTOR OF INSULATION"
2040 PRINT T5,"=T5, THICKNESS OF JACKET"
2050 PRINT P5,"=P5, THERMAL RESISTANCE OF JACKET"
2060 PRINT N1,"=N1, NUMBER OF CONDUCTORS PER CABLE"
2070 PRINT C,"=C, CIRCULAR INCH AREA OF CONDUCTOR"
2080 PRINT D0,"=DO, THE CONDUCTOR DIAMETER"
2090 PRINT D1,"=D1, THE INSULATION DIAMETER"
2100 PRINT P1,"=P1, THERMAL RESISTIVITY OF INSULATION"
2110 PRINT A,"=A, THE AC\DC RATIO"
2120 PRINT E5,"=E5, EMISSIVITY OF THE CABLE SURFACE"
2130 PRINT D5,"=D5, DIAMETER OF THE CABLE"
2140 PRINT
2150 IF Q3$="Y" THEN 880
2160 GOTO 530
2170 PRINT R,"=R, DC RESISTANCE
2180 PRINT W,"=W, DIELECTRIC LOSSES"
2190 PRINT D,"=D, DELTA T DIELECTRIC"
2200 PRINT R1,"=R1, THERMAL RESISTANCE OF INSULATION"
2210 PRINT C5,"=C5, THERMAL RESISTANCE OF JACKET"
2220 PRINT A5,"=A5, THERMAL RESISTANCE FROM CABLE TO RACEWAY"
2230 PRINT M5,"=M5, MEAN TEMP. OF AIR IN RACEWAY"
2240 PRINT T3,"=T3, TEMP. AT SURFACE OF CABLE GROUP"
2250 PRINT T9,"=T9, TEMP. AT SURFACE OF CABLE GROUP"
2260 PRINT T8,"=T8, TEMP. AT INNER SURFACE OF RACEWAY"
2270 FOR I=1 TO N
2280     PRINT CP(I),"=CP(I), THERMAL RESISTANCE OF LAYER I"
2290     PRINT A9(I),"=A9(I), THERMAL RESISTANCE OF AIR SPACE I"
2300     PRINT M(I),"=M(I), MEAN TEMP. OF AIR SPACE I"
2310     PRINT Q99(I),"=Q99(I), TEMP. DROP THROUGH AIR SPACE I"
2320     PRINT Z8(I),"=Z8(I), TEMP. AT OUTER SURFACE OF LAYER I"
2330     PRINT Y8(I),"=Y8(I), OUTER TEMP. OF AIR SPACE I"
2340 NEXT I
2350 PRINT R0,"=RO, TOTAL THERMAL RESISTANCE"
2360 PRINT
2370 PRINT
2380 IJK=1
```

```
2390 GOTO 990
2400 REM ***************DATA SECTION
2410 DATA 1
2420 DATA 13.34,0.5,1,0.9,578.03
2430 DATA 90,40,10.371,234.5,0.6,2.3,0.035
2440 DATA 0,0
2450 DATA 3,0.00653,0.092,0.1488,450,1,1,0.32
2460 END
```