GPU Nuclear

Oyster Creek Evaluation of Thermo-Lag Fire Barriers

Report 102
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Authors: F. P. Barbieri Fred P. Barbieri
R. Baradaran
RASOOL BARADARAN

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Approvals:

SECTION MANAGER — DATE 12/4/95

DEPARTMENT DIRECTOR Joseph J. Colitz — DATE 12-12-95

DIRECTOR, TECHNICAL FUNCTIONS — DATE 12/13/95

ABSTRACT

The purpose of this report is to provide the methodology for establishing the fire endurance rating of installed Thermo-Lag fire barrier raceway systems. This report summarizes the results of the evaluations which establish the aforementioned fire endurance ratings and identifies those Thermo-Lag fire barrier raceway systems which meet the requirements of Appendix R, Section IIIG, those barriers which do not meet Appendix R and will be modified or upgraded to meet Appendix R, and those barriers which do not meet Appendix R and for which an evaluation will be performed to justify the fire endurance rating in an exemption request.

This report also provides the methodology used to evaluate the hazards in each fire area or fire zone where Thermo-Lag fire barrier raceway systems are installed. These hazard evaluations will be documented in exemption requests and will serve as the basis for supporting such exemptions where the fire endurance rating of the Thermo-Lag fire barrier raceway system does not meet the requirements of Appendix R, Section IIIG.

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1.0 PURPOSE

The purpose of this report is to provide the methodology for establishing the fire endurance rating (equivalent rating by test comparison) of installed Thermo-lag fire barrier raceway systems at Oyster Creek. Fire endurance rating is established by identifying the "Actual Fire Rating" or the rating consistent with the fire endurance test acceptance criteria as defined in NRC Generic Letter 86-10 Supplement 1, "Fire Endurance Test Acceptance Criteria for Fire Barrier Systems Used to Separate Redundant Safe Shutdown Trains Within the Same Fire Area". Fire endurance rating is also established by identifying the "Cable Qualification Rating" or the rating which is based upon establishing the maximum temperature inside a fire barrier envelope that is considered acceptable to demonstrate cable functionality. Use of the "Cable Qualification Rating" is a deviation from the GL 86-10 acceptance criteria but is acceptable based upon an engineering evaluation as described herein. Results of these evaluations are reported in Section 3.

This report also provides the methodology used to evaluate the hazards in each fire area or fire zone. The hazard evaluation will serve as the basis for supporting exemptions from Appendix R, Section IIIG.

2.0 METHODOLOGY

2.1 Establishing Actual Fire Rating

To assess material performance and provide a basis for evaluation of installed Thermo-Lag fire barriers, an industry fire endurance test program was conducted by the Nuclear Energy Institute (NEI). To address issues with the fire endurance capability of installed barrier configurations, the industry test program:

- Assessed current industry configurations through the use of survey data,
- Conducted tests to establish performance of various baseline and upgraded fire barrier system assemblies, and
- Developed a guideline to assist utilities in evaluating installed barrier configurations.

The guideline developed by NEI is known as the "NEI Application Guide for Evaluation of Thermo-Lag 330 Fire Barrier Systems" (Report no. 0784-00001-TR-02 Revision 1) or the "Application Guide". The Application Guide provides a process and data for evaluation of installed Thermo-Lag fire barrier configurations using information obtained from NEI and utility fire endurance test programs. GPU Nuclear has used this process to

- Establish the extent that installed barrier configurations can be bounded by previous tests,
- Determine the fire endurance capability (or "Actual Fire Rating") that installed barrier configurations, which are bounded by test, can be reasonably expected to provide, and
- Propose upgrades to installed barrier configurations where deemed necessary to achieve an acceptable fire rating.

In order to evaluate the extent that installed barrier conditions at Oyster Creek can be bounded by test configurations and data in the Application Guide, GPU Nuclear performed the following:

- A walkdown of the fire areas/zones was conducted to document the installed barrier configurations with digitized computer images.

- The parameters identified by NEI during the industry fire endurance test program which pertain to fire endurance capability as identified in the Application Guide were included by GPU Nuclear in an electronic database.

- Each fire barrier system was separated into individual segments or elements for evaluation purposes. Individual elements are constituted by one or more of the following distinguishing characteristics:

  1) change in barrier construction technique;
  2) significant change in protected raceway or contents;
  3) variation from applicable barrier installation requirements;
  4) change in type of barrier material; or
  5) change in orientation of protected raceway or change which necessitates a change in barrier construction technique.

- Data collected during the walkdown and collected by a review of the original fire barrier construction details were entered into the database to permit detailed comparisons of relevant parameters from the NEI, Texas Utilities (TU), and TVA programs.

- Each of the test assemblies in the industry test programs was separated into individual segments or elements for evaluation purposes as were the installed fire barrier systems and entered into the data base in order to permit the detailed comparisons of relevant parameters with the installed fire barrier systems.

- The quality of the barrier installation was originally verified by Quality Control during the installation process by continuous in-process inspections using checklists for consistency. Final inspections performed by GPUN Quality Control were documented in the work control packages. The use of checklists standardized the attribute verification and allowed no significant deviations from the original design/installation requirements. Repairs are performed to the same requirements as the initial installation. Repairs are performed either by or under the supervision of certified installers and are re-inspected by certified inspectors. Surveillance procedures ensure a refueling interval inspection to re-verify the integrity of the installed fire barrier envelopes. Additionally, QC does make inspections of opportunity and has caused repairs to be initiated.

  A Quality Control Program as defined in the Oyster Creek FHAR-Section 5 (and implemented by the GPUN Operational Quality Assurance Plan) was applied to the material, processes and installation and inspection personnel. GPUN did not contract this work out to a third party licensed by TSI. GPUN contracted TSI to train and certify GPUN personnel for both installation and inspection.

  GPUN's initial experience with TSI's material shipments resulted in returning large amounts of each shipment. All inspections were documented on receipt inspection reports. All line items of the contract were inspected. These inspections consisted of either 100% sampling using engineering approved inspection and sampling plans (Military Standard 105D was the prescribed sampling method). Some of the problems experienced were as follows:

THICKNESS

GPUN receipt inspectors verified thickness by taking readings on each piece. Any piece not meeting the minimum thickness was rejected and returned to TSI.

VOIDS AND CRACKS (resulting from bending/fabrication)

During receipt inspection, material which had voids or cracking beyond specified limits was returned. The material was subject to considerable field work (cut and fit). Any voids were filled with TSI trowel grade material during installation.

PHYSICAL DAMAGE

During receipt inspection, gouges, crushing and chipped edges could be repaired and accepted. Separation of the material from the stress skin was a cause for rejection and return of the material. Edges were verified to be straight and square for proper alignment and fit-up during installation.

To ensure receipt of consistent quality material from TSI, GPUN instituted QC checks by GPUN vendor surveillance at TSI's factory prior to release for shipment. Thorough receiving inspection checks were performed to established inspection plans to insure they maintained engineering requirements.

DETAILED EXAMINATIONS

GPU Nuclear performed detailed exams to confirm the accuracy of Quality Assurance records for important parameters which are not visible by walkdown. The initial exam consisted of dismantling a 3 hour conduit barrier. Additional exams as committed in GPUN letter C321-95-2277 dated September 22, 1995 were performed on 1 hour and 3 hour conduit barriers, 1 hour box configurations and the HVAC duct barrier. Parameters such as thickness, panel rib orientation, stress skin orientation, buttering of joints, joint gap width, unsupported spans and type of joint were confirmed and documented in Quality Verification Inspection Report PIR #950065 dated October 25, 1995. The results of these inspections confirmed conformance of installed Thermo-Lag with original installation and design requirements and provides a reasonable basis for reliance on Quality Assurance records and installation requirements for parameters which are not visible by walkdown.

In order to establish the actual fire rating of the installed fire barrier assemblies, the industry test data was evaluated. Actual fire rating is a term used to designate the fire endurance rating of the barrier consistent with the acceptance criteria contained in NFPA 251 (ASTM E-119), "Standard Fire Tests of Building Construction and Materials". NRC Generic Letter 86-10 Supplement 1, adapts the acceptance criteria of NFPA 251 to cable raceway fire barrier wraps.

In 86-10, Supp.1, the staff bases acceptability of a fire endurance qualification test for fire barrier materials applied directly to a raceway or component to be successful if the "average" unexposed side temperature of the fire barrier system, as measured on the exterior surface of the raceway or component did not exceed 250 deg F above its initial temperature and a visual inspection of cables inside the raceway should show no signs of degraded conditions. Also, individual temperature readings should not exceed the 250 deg F temperature rise by more than 30 percent, or 325 deg F above the initial temperature.

To establish the barrier rating (ACTUAL RATING) of a test assembly, GPU Nuclear reviewed the temperature data for the test and identified that point in time when the first individual temperature reading on the unexposed side of the fire barrier for the entire raceway in the test assembly, as measured on the exterior surface of the raceway or component, exceeded 325 deg F above the initial temperature. Note that this method establishes a rating for all elements of a particular raceway size based upon the weakest link in the raceway. While it is possible to establish individual ratings in a test involving straight conduit, radial bends and condulets based upon thermocouple readings restricted to these elements in a test assembly, it is conservative to establish a common rating for all elements of a raceway based upon the single high reading for the entire raceway.

To establish the actual rating for an installed configuration or element, the installed configuration's relevant parameters were compared with those of the industry tested configurations. If an acceptable match was found, it was selected and the installed configuration is considered bounded by an acceptable industry test configuration. The actual rating of the matching industry configuration becomes the actual rating of the installed configuration or element as documented by a detailed evaluation. The results of these detailed comparisons and evaluations will be listed in this submittal only. These results will be retained in the electronic database (Doc. No. TLDB-OC-814-1) and digitized computer image library mentioned previously and will be available for NRC review or audit.

2.2 Establishing Cable Qualification Rating

In addition to establishing the "Actual Fire Rating" as previously described, GPU Nuclear has utilized a combination of actual test data and theoretically derived data to document raceway temperatures inside the Thermo-Lag fire barrier envelopes which deviate from the acceptance criteria used for qualifying fire barrier configurations as outlined in Generic Letter 86-10 Supp. 1. This section outlines the method that serves as the basis for establishing the fire endurance rating of the barrier when considering the cable qualification temperature or the maximum temperature inside the fire barrier envelope that is considered acceptable to demonstrate cable functionality. The acceptable fire endurance rating is termed the "Cable Qualification Rating". GL 86-10 Supp. 1 permits an evaluation which demonstrates that cables would perform their intended function during and after a postulated fire exposure when the internal raceway temperatures exceed the GL 86-10 Supp.1 acceptance criteria. GPU Nuclear considers the Cable Qualification Rating directly comparable to the requirement of III.G for one hour or three hour fire barriers. In other words, a fire barrier having a cable qualification rating of at least 60 minutes is considered to be a one hour fire barrier as required by III.G. If less than 60 minutes, the cable qualification rating can be used to establish the basis for an exemption from the requirement for a one hour fire barrier.

In order to compare the internal raceway temperatures to cable failure temperatures, GPU Nuclear performed the following:

2.2a <u>Identification of Protected Circuits</u>

The Oyster Creek Fire Hazards Analysis Report (FHAR) Document No. 990-1746 Revision 7 was compared with the Thermo-Lag Installation Drawings to identify those circuits required for safe shutdown which are protected by the Thermo-Lag fire barriers.

2.2b <u>Identification of Cable Qualification Temperatures</u>
(Note this is not to be confused with environmental qualification temperatures)

Generic Letter 86-10, Supplement 1, Attachment to Enclosure 1, "Acceptable Methods for Demonstrating Functionality of Cables Protected by Raceway Fire Barrier Systems During and After Fire Endurance Test Exposure" provides the means for establishing the maximum temperature inside the fire barrier envelope that is considered acceptable to demonstrate cable functionality. GPU Nuclear used the recommended analysis of Section VI in the aforementioned attachment entitled "Cable Thermal Exposure Threshold" to perform this analysis.

After identifying the circuits required for safe shutdown as described in "2.2a" above, the cable manufacturer was identified and the thermal exposure threshold (TET) temperature limit or insulation failure threshold temperature limit was obtained from Sandia Test Report SAND90-0696 May, 1991 "An Investigation of the Effects of Thermal Aging on the Fire Damageability of Electrical Cables". Insulation damage leading to a short circuit per the tests conducted in the aforementioned investigation is defined as 15 milliamps (mA) leakage current with cable conductor temperatures at 90 deg C which means that the cable was tested at the equivalent of full load current. The insulation failure threshold temperature limit is the temperature beyond which the insulation is expected to degrade causing a short circuit. While not the same as the short circuit rating as defined in Generic Letter 86-10, Supplement 1, these tests conclusively demonstrate cable functionality at elevated temperatures since under fire conditions the endurance rating of the barrier is based upon the point in time when the threshold temperature is reached. The aforementioned Sandia tests on the other hand, subjected cables to the insulation failure threshold temperature for at least 80 minutes without failure. Fire endurance ratings do not assume sustained operation under these elevated temperature conditions. The rating is based upon the duration of the test and the point in the time of the test when the insulation failure threshold temperature is reached. This method is conservative because, as stated above, the Sandia tests subjected cables to the insulation failure threshold temperature for AT LEAST 80 MINUTES.

2.2c <u>Raceway Temperatures Inside Thermo-Lag Fire Barrier Envelopes</u>

In order to follow the guidance of Generic Letter 86-10, Supplement 1 for establishing maximum allowable raceway temperatures inside the fire barrier envelope, additional evaluation of industry test data and consideration of the operating cable temperatures within the fire barrier system at the onset of the fire exposure were performed. This is necessary in order to compare test results with the TET temperature limit and establish a "cable qualification rating" for the fire barrier envelope.

Industry test data which was used to establish the "actual" fire rating described previously was further evaluated to document internal raceway temperatures beyond NRC acceptance criteria as defined in GL 86-10. To be consistent, the evaluation was limited to the temperature readings on the unexposed side of the fire barrier as measured on the exterior surface of the raceway. The evaluation documented the temperatures and the duration of the fire test at the aforementioned locations in increments of approximately 100 deg F up to the point where the test was terminated. eg. for 3/4 in. conduit in NEI test 2-1, the actual rating is based upon a conduit surface temperature of 387 deg F at 27 minutes. Since the test was continued beyond this point, the following data was utilized to compare conduit surface temperatures with the insulation failure threshold temperature mentioned in 2.2b.

3/4" Conduit Outside Surface Temp (Maximum)

TIME (MIN)	TEMP (DEG F)
28	396
36	499
41	609
44	720

By reviewing the temperature data in this case it is apparent that the barrier failed to provide any protection after about 44 minutes. In the case of the 3/4" conduit, Thermo-Lag material was consumed directly exposing the conduit to test oven temperatures. According to NEI test report 2-1, no joint failures occurred.

If the test was terminated before a duration of 60 minutes, it was necessary to develop a multi-dimensional heat transfer model to extrapolate temperatures inside the raceway out to 60 minutes for the 2", 4" and 6" conduit assemblies since no temperature data was available. The model was verified against actual industry test data to establish confidence in its validity. Comparison with test data on NEI "upgraded" conduit raceway configurations (NEI test 1-6) was performed. This is considered legitimate since the upgrades consisted of joint reinforcement which was accomplished by adding stress skin and trowel grade material at joints; however, the thickness of the barrier remained the same at 1/2" except in the areas where the joints were reinforced. Burnthrough did not occur on the 1/2" Thermo-lag after 60 minutes. It is also assumed that the baseline joints of NEI test 2-1 would not have failed had the test run the full 60 minutes. As stated above, joint failure of the 3/4" conduit configurations did not occur. It is reasonable to assume that joint failure would not have occurred on the larger size raceways in NEI test 2-1 and that burnthrough would not have occured on 1/2" thick fire barriers on these raceways because another test (NEI Test 1-6) on the same nominal thickness for larger size raceways that went the full 60 minutes did not burnthrough. It is therefore considered reasonable to extrapolate internal raceway temperatures for NEI Test 2-1 out to 60 minutes for the purpose of comparison with cable qualification temperatures. The results of this model are documented in calculation C-9000-814-5310-002. This calculation is not included here but is available for NRC review or audit.

It is necessary to account for the initial temperature of the cable within the fire barrier prior to the onset of the fire as compared to the test configurations. As such, the cable qualification rating is established based upon the time it takes for the internal raceway temperature to get within no less than 70 deg F of the insulation failure threshold temperature. This 70 deg F value provides the margin to account for the differences between actual room ambient temperatures plus cable temperature rise due to the insulating effects of the barrier and those ambient temperatures measured during industry testing. The industry tests were performed with initial ambient temperatures no less than 50 deg F while the maximum design room ambient temperatures are 104 deg F at Oyster Creek. The additional temperature rise inside the fire barrier envelopes due to operating cables is 7 deg F maximum based upon test results documented in letter G/C/TMI-1CS/16503 dated September 15, 1988, J. Brendlen to J.W. Langenbach, "TSI Derating Check". While this test was conducted for installed cable tray barriers at TMI-1, it is reasonable to apply these results to Oyster Creek since the barrier thickness at Oyster Creek is the same as at TMI-1. The main factor impacting heat rise inside a raceway would be the thickness of the barrier and the number of circuits energized inside the raceway. The TMI-1 test was conducted in trays containing continuously energized power circuits which can be considered comparable to raceways at Oyster Creek. Both TMI-1 and Oyster Creek have barriers with a nominal thickness ranging from a minimum of 1/2 to 5/8 inch for one hour barriers and 1 to 1-1/8 inch for three hour barriers. Therefore using TMI-1 test results to factor into initial raceway temperatures at Oyster Creek is reasonable. The additional effect of the internal temperature of the raceway due to continuously energized power circuits is only about 10% of the factor being used. Adding the difference between the max room ambient temperature and the minimum ambient test temperature (104-50=54 deg F) to the temperature rise of 7 deg F yields a total factor of 61 deg F. The factor being used is 70 deg F. This establishes that the cable qualification rating is consistent with maximum cable operating temperatures. This meets the guidance in GL 86-10 for an engineering analysis to demonstrate the functionality of cables inside fire barrier envelopes.

2.3 Evaluating Fire Hazards

To evaluate the cable qualification ratings of the Thermo-Lag fire barriers which do not meet the requirements of Appendix R Section III.G (ie. less than 1 hour or 3 hour), two methods are employed. These methods consider the insitu and transient hazards in a fire area/zone. These are described as follows:

2.3a Method 1

The first method is typical of the "traditional approach". A comparison of the cable qualification rating with the overall fire loading is performed using 80,000 BTU/Ft2 as equivalent to a one hour fire to develop a fire load to rating factor herein referred to as the rating factor. A combustible loading of 80,000 BTU/Ft2 has been considered as equivalent to the heat release in an ASTM E-119 Test Oven for a one hour fire duration test. A source reference to support this assumption is Table 6-6a of the NFPA Fire Protection Handbook, Seventeenth Edition. If the Thermo-Lag fire barrier is located in a fire area/zone which is provided with an area wide fire suppression system, the aforementioned factor is multiplied by an additional factor of 3 to account for the additional margin provided by the suppression system. This factor is an assumption based upon the fact that Appendix R Section III.G.2.c reduces the requirement for a 3 hour barrier in III.G.2.a to 1 hour with the presence of a suppression and detection system; hence the additional factor of 3.

The rating factor is used for assessing the fire hazard with the actual rating of a raceway fire barrier that does not meet the requirements of Appendix R. No strict acceptance criteria is established as the acceptability of a rating factor must consider all fire hazard and fire protection features where the raceway fire barrier is located. Acceptability is therefore based upon engineering judgement.

The following reference point will be taken into consideration in judging the acceptability of a rating factor. The basis for this is drawn from the Oyster Creek FHAR, paragraph 1.3 "Delineation of Fire Areas/Zones". To summarize, this section of the FHAR established that reasonable assurance that a fire will not propagate from one fire zone to another is provided in the plant fire hazards analysis by passive and active fire protection features. Through this assurance, it can be justified that fire zones which may not consist of continuous wall to wall, floor to ceiling boundaries of fire rated construction can be analyzed by themselves. Fire zones are subdivisions of fire areas which take into consideration the physical boundaries which exist between one fire zone and another in the same fire area. Fire zone boundaries can consist of non-rated physical boundaries with penetrations sealed with materials installed in accordance with configurations similar to a one hour minumum fire barrier. The criteria for acceptability of such a configuration is that the combustible loading on either side of the boundary is less than 40,000 BTU/Ft2, or 1/2 the equivalent of a one hour fire duration as discussed above or a rating factor of 2.

The following example is provided to illustrate how the cable qualification rating factor (RF) is calculated for a 1" conduit having a cable qualification rating of 41 minutes in an area provided with automatic fire suppression having a fire loading of 20,223 BTU/FT2:

FIRE LOAD (FL)	CABLE QUAL. RATING (CQR)	RESULT (RF)=CQR/FL
15 min. (20,223 BTU/Ft2)	123 min. (= 41 min.x 3 w/suppression)	RF=8.2

NOTE THAT THIS METHOD IS CONSERVATIVE BECAUSE IT PRESUMES COMPLETE COMBUSTION OF ALL COMBUSTIBLES IN THE FIRE AREA OR ZONE OF CONCERN.

2.3b Method 2

The second method for evaluating the cable qualification ratings of the Thermo-Lag fire barriers with respect to the actual fire hazards is by the use of fire modelling.

GPU Nuclear has used EPRI's enhanced FIVE Fire modeling to approximate exposure time-temperature history for Thermo-Lag configurations in five of seven fire zones. The results are contained in the Appendices to this submittal. The following summarizes the EPRI technique and the results:

The source document for this discussion is EPRI Report Project 3385-05 "Methods for Evaluation of Cable Wrap Fire Barrier Performance". The fire hazard tool will calculate location dependent exposure time-temperature histories, as discussed above, resulting from defined fire scenarios. These scenarios are established by assessing the location and distribution of in-situ and transient hazards in the area under evaluation. Exposures can be determined at any selected location.

Fire growth and propagation are based on actual fire test data. The tool therefore provides estimates of fire exposures for installed raceway fire barrier envelopes including the time required for the fire to grow and propagate and the time to reach critical temperatures at the envelopes. The timing estimated by the tool provides a basis for quantitative assessment of important time dependent measures such as fire brigade response.

The fire modelling method is described in FIVE (EPRI's Fire Induced Vulnerability Evaluation, TR 100370), Section 10.4, April 1992. The model utilizes the FIVE plume/ceiling jet/hot gas layer correlations to determine pre-flashover conditions within the evaluated fire zone/area.

Enhancements to the FIVE fire modelling method, documented in the EPRI "Fire Risk Analysis Implementation Guide" (TR 104030), Draft January, 1994, are incorporated into the fire hazard tool. These enhancements are based on conservative interpretation of actual fire test data and provide the capability of calculating fire growth/propagation in addition to providing improved definition of the burning characteristics of combustible materials typically found in power plants. The fire hazard tool also uses data published by NEI regarding the burning characteristics of Thermo-Lag (NUMARC Thermo-Lag 330-1 Combustibility Evaluation Methodology Plant Screening Guide, September 1993).

The fire hazard tool calculates temperatures at specified time steps in order to define temperature exposure profiles at raceway fire barrier envelope locations. The temperatures at each time step, prior to fire zone/area compartment flashover, are determined from the FIVE equations considering the enhancements incorporated in the Fire Risk Analysis Implementation Guide. The temperature results are not sensitive to the size of the time step selected. Compartment flashover is conservatively assumed to occur when the hot gas layer reaches 1000 deg F. The temperature profile at tha time is taken as the ASTM E-119 time-temperature history at all locations within the fire zone/area compartment.

Field walkdowns are performed to identify and locate all potential fire ignition sources which could potentially impact Thermo-Lag raceway fire barrier envelopes. FIVE Table 1.2 is used as a guide in identifying the types of credible ignition sources.

The approach described in EPRI's Fire Risk Analysis Implementation Guide (pages 4-18 through 4-27 and Appendix E) is used to screen those ignition sources that do not result in damaging fires and define scenarios with potential for damage. The field walkdowns use pre-calculated critical distance values which are developed using the FIVE fire modelling methods (FIVE Section 10.4).

Ignition sources which are determined to have no potential to cause damage (other than to the ignition source itself) are eliminated from further consideration. Ignition sources which are determined to have the potential of igniting adjacent cable, Thermo-Lag or other combustibles are identified for detailed fire modelling to be performed as described below.

FIVE analyses are performed using computerized Excel spreadsheets similar in format to FIVE worksheets 1,2 and 3. Time-temperature histories are developed by inputting the heat release rate (HRR) and total heat content of the fuel (Q Tot) for the fire source into the FIVE equations at the appropriate time steps.

Most material specific parameters pertinent to fire growth and propagation are extracted directly from FIVE. Physical configurations are conservatively determined from the walkdowns. There are conservatisms built into the model. One example of the conservatism of the fire model is the assumption that the fire begins to burn at its peak release rate at time=0. This assumption results in the shortest time to reach peak temperatures (in the plume, ceiling jet and hot gas layer). This is conservative as it maximizes the incident heat flux and temperatures at the target raceway fire barrier envelope. NOTE ALSO THAT THE MODEL TAKES NO CREDIT FOR THE PRESENCE OF AUTOMATIC SUPPRESSION OR ANY MANUAL FIRE FIGHTING ACTIVITIES.

Implementation of the fire hazard tool is accomplished as follows:

Equipment is selected for evaluation as a fixed ignition source based on criteria contained in the FIVE methodology guide. Equipment that does not meet the selection criteria may be included for evaluation as an ignition source if it is in close proximity to an important piece of equipment or associated cable.

Fire modelling of fixed ignition sources is performed in a stepwise fashion using the FIVE methodology and Fire Risk Analysis Implementation (FPRA) methodologies developed by EPRI. The detailed steps involved in modelling are provided below. Not all steps of the fire modelling were necessary to identify and evaluate the effect of each ignition source on other cables and equipment. In most cases, the conclusion that the ignition source causes no adverse impact was reached upon completion of the deterministic steps 1 through 9.

1. Determine the physical characteristics of the fire zone. This requires floor area, ceiling height, room volume, maximum fire zone ambient temperature and identification of any features that could affect the analysis. This informa-tion is obtained from plant design documents.

2. Identify all fixed ignition sources in the fire zone. This information is collected from plant databases and verified by walkdown of the zone. During the course of the walkdown, any material storage locations are also identified. These locations are treated as fixed ignition sources.

3. Select an appropriate heat loss factor. The heat loss factor accounts for heat absorbed into the fire zone floor ceiling and walls. A figure of 0.94 is utilized in modelling based on guidance in the EPRI Report Project 3385-05 "Methods for Evaluation of Cable Wrap Fire Barrier Performance". Longer duration scenarios (greater than 5 minutes) such as the formation of a damag-ing hot gas layer, have been experimentally determined to have heat loss factors in the range of 0.94 to 0.98.

4. Determine target damage and ignition temperatures. For Thermo-Lag, an ignition temperature of 1000 DEG F is used based on guidance in the Thermo-Lag Combustibility Evaluation Methodology Plant Screening Guide.

5. Determine target damage radiant heat fluxes. For Thermo-Lag, an ignition heat flux of 2.2 BTU/s/FT2 is used based upon guidance in the Thermo-Lag Combustibilty Evaluation Methodology Plant Screen Guide.

6. Identify Heat Release Rates (HRRs) for the different categories of fixed ignition sources located within the fire zone. The FPRA manual provides HRRs for most of the standard equipment categories. In cases where HRRs are not explicitly stated, judgement is used to select an HRR. For fixed ignition sources containing oil, the HRR is calculated from the amount of oil contained in the source and the potential surface area of the oil spill.

7. Assign a location factor for each fixed ignition source in the fire zone. The location factor accounts for the higher plume temperatures found for fires near walls and in corners.

8. Calculate in-plume damage heights and radiant damage ranges for each fixed ignition source located in the fire zone. This calculation uses equations contained in the FIVE manual.

9. Determine targets for each ignition source. This step utilizes the damage heights and ranges calculated in step 8. Any piece of equipment, cable, conduit or tray within the damage heights and ranges were noted. Targets that are outside of the radiant damage range and are not located in the plume are evaluated for potential damage from the ceiling jet. Fixed ignition sources without any potential targets are excluded from further analysis other than the loss of the fixed ignition source itself and impact of forming a damaging hot gas layer.

   If a target is found to be within the ignition range of a fixed ignition source, the target is in turn treated as an ignition source and additional targets are identified. This models the propagation of a fire from a source to a series of combustible targets. Additionally, the heat content of the ignited target must be considered to determine if the formation of a damaging HGL is possible.

Modeling of transient ignition sources and combustibles is similar to fixed ignition sources with some additional steps to account for the uncertainty in location and the amount of combustibles. These additional steps are as follows:

10. Determine what transient combustibles are likely to be present or traverse the fire zone. Due to the potential for large HRRs from oil fires, special emphasis was placed on identifying oil lubricated components as well as any such equipment that was likely to be reached by traversing the fire zone under analysis. The type of container in which oil is transported is also of importance. Oil transported in 55 gallon drums or NFPA approved containers are assumed to be not exposed to potential ignition sources.

11. Select an appropriate transient fuel package based on what types of transient materials are likely to be present in the fire zone. The fuel packages and their associated HRRs are selected from Sandia National Laboratory (SNL) testing.

12. Determine target sets based on specific floor locations. Target sets that could be damaged by a fire involving the transient fuel package are identified.

Once the fire hazard tool has determined the time-temperature history for each scenario, the EPRI "Barrier Performance Tool" is then utilized to establish the exposure to the thermo-lag in each scenario equivalent to an ASTM E-119 exposure fire. Inputs to the tool are the calculated time temperature history as determined by the fire hazard tool.

This tool is based upon the premise that two different exposure histories, which would cause two identical fire barrier raceway configurations to reach the same failure point would have equal areas under their incident heat flux curves.

The "Barrier Performance Tool" therefore calculates the total heat load for the exposure history developed for each scenario by the fire hazard tool.

The duration as expressed by the "Cable Qualification Rating" is then compared with the calculated equivalent ASTM E-119 duration for each scenario to assess the calculated severity of each scenario with an ASTM E-119 exposure.

3.0 SUMMARY OF RESULTS

The results of applying the above methodology towards establishing an actual fire rating and a cable qualification rating for Thermo-Lag fire barriers are as follows:

3.1 Office "A" 480 V Switchgear Room (Fire Zone OB-FZ-6A)

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CNXA1125	2" Conduit	5	39 min.	21 min.	2-1
	2" Radial Bend Conduit	5	39 min.	21 min.	2-1
	2" Box (Condulet)	2	39 min.	21 min.	2-1
	2" Conduit (Penet.)	1	39 min.	21 min.	2-1
	12"x6"x4" Box Penet.	1	HOLD		

The 2" conduit, 2" conduit radial bend, 2" condulet and 2" penetration elements will be upgraded to provide an "actual" fire rating of one hour and will therefore meet the requirements of III.G.2.c. Materials which successfully demonstrate a 60 minute fire endurance rating for these conduits (either by themselves or in conjunction with the existing Thermo-Lag installations) will be installed. Such changes will not be submitted for NRC approval but handled under existing licensing conditions; ie. 50.59 process. The commitment is to upgrade these envelopes to an "actual" fire rating of 60 minutes.

All barriers in this fire zone currently will be upgraded to meet the requirements of Appendix R section III.G.2.c. Therefore, no exemptions will be necessary.

3.2 Office "B" 480 V Switchgear Room (Fire Zone OB-FZ-6B)

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CNCA1041	3" Conduit	1	39 min.	60 min.	2-1
	3" Box (Condulet)	1	39 min.	60 min.	2-1
	3" Conduit (Penetration)	1	HOLD		
CNCA1043	3" Conduit	1	39 min.	60 min.	2-1
	3" Box (Condulet)	1	39 min.	60 min.	2-1
	3" Box Penetration	1	HOLD		
CNPA1042	1" Conduit	2	27 min.	41 min.	2-1
	1" Box (Condulet)	1	27 min.	41 min.	2-1
	1" Box Penetration	1	HOLD		
	1" Conduit (Penetration)	1	HOLD		
NO. NUMBER	10'X5'X1' Box	1	HOLD		
DUCTWORK	From 40"X16" to 30"x18"	NA	NO RATING		

To summarize the above results, 3"conduit and 3"condulet elements meet the requirements of III.G.2.c because their "CABLE QUALIFICATION RATING" is at least one hour. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was used to compare raceway temperatures at 60 minutes to the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at 60 minutes are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a rating of 60 minutes. No additional justification is required for these barriers.

The 1" conduit, 1" condulet and 1" penetration elements will be upgraded to provide an "actual" fire rating of one hour and will therefore meet the requirements of III.G.2.c. Materials which successfully demonstrate a 60 minute fire endurance rating for these conduits (either by themselves or in conjunction with the existing Thermo-Lag installations) will be installed. Such changes will not be submitted for NRC approval but handled under existing licensing conditions; ie. 50.59 process. The commitment is to upgrade these envelopes to an "actual" fire rating of 60 minutes.

The 10'X 5'X1' box (HOLD)

Based upon existing information, a fire endurance rating cannot be established for the Thermo-Lag installed on the ductwork fire barriers. These barriers provide insulation for ductwork which is part of the ventilation system for the "A" Switchgear Room which is Fire Zone OB-FZ-6A. The insulated ductwork is routed through the "B" Switchgear Room or Fire Zone OB-FZ-6B. It was provided with the Thermo-Lag for the ductwork in the event of a fire in the "B" Switchgear Room to maintain ventilation in the "A" Switchgear Room. A "rated" configuration for these barriers is not critical to the ability of the ventilation system to maintain an adequate environment in the "A" Switchgear Room. In fact, acceptable duct internal temperatures for a "rated" barrier (250 deg F above ambient) are not desirable from a practical standpoint even though a "rated" barrier may technically meet Appendix R. GPU Nuclear does not plan on establishing a fire endurance rating for the Thermo-Lag installed on ductwork. Corrective action will consist of insuring adequate ventilation in fire zone OB-FZ-6A if a fire occurs in fire zone OB-FZ-6B. Adequate ventilation may be insured by operating procedure changes if analysis of the existing ventilation system configuration with Thermo-Lag serving as duct insulation provides an adequate basis for leaving the existing configuration as is. Preliminary results of our analysis indicates that loss of ventilation to the "A" Switchgear Room results in acceptable temperatures after one hour for equipment in this room required to operate in the event of a fire in the "B" Switchgear Room. If adequate ventilation cannot be proven analytically, corrective action may take the form of modifications to the "A" Switchgear Room ventilation system.

All electrical raceway barriers in this fire zone currently meet the requirements of Appendix R, section III.G.2.c or will be upgraded to meet the aforementioned requirements. Therefore, no exemptions will be necessary.

The Thermo-Lag installed on the ductwork in this zone does not require a fire endurance rating. Corrective action will be based upon completion of a ventilation system analysis which considers Thermo-Lag as duct insulation, not a "rated" barrier as stated previously. By insuring adequate ventilation for the "A" Switchgear Room if a fire occurs in the "B" Switchgear Room, either procedurally or by modification, GPU Nuclear will meet the requirements of Section IIIG.1.a in that "one train of systems necessary to achieve and maintain hot shutdown from either the control room or emergency control station(s) is free of fire damage". Completion of the aforementioned ventilation system analysis will identify the scope of work required to insure adequate ventilation for the "A" Switchgear Room.

3.3 Reactor Building 51' Elevation (Fire Zone RB-FZ-1D)

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CGCA1027	2" Conduit	10	39 min.	60 min.	2-1
	2" Radial Bend Conduit	8	39 min.	60 min.	2-1
	2" Box (Condulet)	2	39 min.	60 min.	2-1
	2" Conduit (Penetration)	1	39 min.	60 min.	2-1
	2" Box Penetration	1	HOLD		
CGPA3026	2" Conduit	10	39 min.	60 min.	2-1
	2" Radial Bend Conduit	8	39 min.	60 min.	2-1
	2" Box (Condulet)	2	39 min.	60 min.	2-1
	2" Conduit (Penetration)	1	39 min.	60 min.	2-1
	2" Box Penetration	1	HOLD		
CRCA1026	2" Conduit	4	39 min.	60 min.	2-1
	2" Radial Bend Conduit	4	39 min.	60 min.	2-1
	2" Conduit (Penetration)	1	39 min.	60 min.	2-1
	2" Conduit (Penetration)	1	HOLD		

To summarize the above results, 2"conduit, 2" conduit radial bends, 2"condulet and 2" penetration elements meet the requirements of III.G.2.c because their "CABLE QUALIFICATION RATING" is at least one hour. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was used to compare raceway temperatures at 60 minutes to the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at 60 minutes are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a rating of 60 minutes. No additional justification is required for these barriers.

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
62-153	2" Conduit	4	39 min.	56 min.	2-1
	2" Radial Bend Conduit	4	39 min.	56 min.	2-1
	2" Conduit (Penetration)	1	39 min.	56 min.	2-1
	2" Conduit (Penetration)	1	HOLD		
CGCR2086	1" Conduit	3	27 min.	36 min.	2-1
	1" Radial Bend Conduit	3	27 min.	36 min.	2-1
	1" Box (Condulet)	1	27 min.	36 min.	2-1
	1" Conduit (Penetration)	2	27 min.	36 min.	2-1
CGCR3021	1" Conduit	9	27 min.	41 min.	2-1
	1" Radial Bend Conduit	7	27 min.	41 min.	2-1
	1" Box (Condulet)	3	27 min.	41 min.	2-1
	1" Conduit (Penetration)	2	27 min.	41 min.	2-1

The above three envelopes (62-153, CGCR2086, CGCR3021) will be the subject of an exemption request from the requirement in Appendix R, Section III.G.2.c, for a one hour rated fire barrier in fire zone RB-FZ-1D. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was compared with the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at the duration listed are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a cable qualification rating as listed above.

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CGXA3028	1" Conduit	8	27 min.	14 min.	2-1
	1" Radial Bend Conduit	13	27 min.	14 min.	2-1
	1" Box (Condulet)	2	27 min.	14 min.	2-1
	1" Conduit (Penetration)	1	27 min.	14 min.	2-1
	1" Box Penetration	1	HOLD		

The 1" conduit, 1 inch conduit radial bends, 1 inch condulet, and 1 inch conduit penetration elements will be upgraded to provide an "actual" fire rating of one hour and will therefore meet the requirements of III.G.2.c. Materials which successfully demonstrate a 60 minute fire endurance rating for these conduits (either by themselves or in conjunction with the existing Thermo-Lag installations) will be installed. Such changes will not be submitted for NRC approval but handled under existing licensing conditions; ie. 50.59 process. The commitment is to upgrade these envelopes to an "actual" fire rating of 60 minutes.

3.4 Reactor Building 23' Elevation (Fire Zone RB-FZ-1E)

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CGPA2008	3" Conduit	2	39 min.	60 min.	2-1
	3" Box (Condulet)	3	39 min.	60 min.	2-1
	3" Conduit (Penetration)	1	39 min.	60 min.	2-1
	3" Conduit (Penetration)	1	HOLD		

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CRCA1026	2" Conduit	1	39 min.	60 min.	2-1
	2" Radial Bend Conduit	3	39 min.	60 min.	2-1
	2" Box (Condulet)	1	39 min.	60 min.	2-1
	2" Conduit (Penetration)	2	HOLD		

To summarize the above results, 2"and 3" conduit, 2" conduit radial bends and 2"and 3" condulet elements meet the requirements of III.G.2.c because their "CABLE QUALIFICATION RATING" is at least one hour. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was used to compare raceway temperatures at 60 minutes to the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at 60 minutes are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a rating of 60 minutes. No additional justification is required for these barriers.

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
62-153	2" Conduit	1	39 min.	56 min.	2-1
	2" Radial Bend Conduit	3	39 min.	56 min.	2-1
	2" Box (Condulet)	1	39 min.	56 min.	2-1
	2" Conduit (Penetration)	2	HOLD		
CGCA2010	1.5" Conduit	2	27 min.	36 min.	2-1
	1.5" Box (Condulet)	3	27 min.	36 min.	2-1
	1.5" Conduit (Penetration)	1	27 min.	36 min.	2-1
	1.5" Conduit (Penetration)	1	HOLD		
CGCR3021	1" Conduit	10	27 min.	41 min.	2-1
	1" Radial Bend Conduit	9	27 min.	41 min.	2-1
	1" Box (Condulet)	3	27 min.	41 min.	2-1
	1" Conduit (Penetration)	1	27 min.	41 min.	2-1
	Drywell Pen. Box	1	HOLD		
PEN	Drywell Pen. Box	4	HOLD		

The above envelopes (62-153, CGCA2010, CGCR3021) will be the subject of an exemption request from the requirement in Appendix R, Section III.G.2.c, for a one hour rated fire barrier in fire zone RB-FZ-1E. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was compared with the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at the duration listed are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a cable qualification rating as listed above.

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CGXR2051	1" Conduit	3	27 min.	23 min.	2-1
	1" Radial Bend Conduit	3	27 min.	23 min.	2-1
	1" Box (Condulet)	1	27 min.	23 min.	2-1
	1" Conduit (Penetration)	1	27 min.	23 min.	2-1
	Drywell Pen. Box	1	HOLD		
CRXR2050	1" Conduit	11	27 min.	23 min.	2-1
	1" Radial Bend Conduit	10	27 min.	23 min.	2-1
	1" Box (Condulet)	3	27 min.	23 min.	2-1
	1" Conduit (Penetration)	1	27 min.	23 min.	2-1
	Drywell Pen. Box Bend	1	HOLD		

The 1" conduit, 1 inch conduit radial bends, 1 inch condulet, and 1 inch conduit penetration elements will be upgraded to provide an "actual" fire rating of one hour and will therefore meet the requirements of III.G.2.c. Materials which successfully demonstrate a 60 minute fire endurance rating for these conduits (either by themselves or in conjunction with the existing Thermo-Lag installations) will be installed. Such changes will not be submitted for NRC approval but handled under existing licensing conditions; ie. 50.59 process. The commitment is to upgrade these envelopes to an "actual" fire rating of 60 minutes.

3.5 Reactor Building -19' Elevation (Fire Zone RB-FZ-1F2)

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CGPA2002	1.5" Conduit	2	27 min.	41 min.	2-1
	1.5" Radial Bend Conduit	1	27 min.	41 min.	2-1
	1.5" Box (Condulet)	2	27 min.	41 min.	2-1
	1.5" Conduit (Penetration)	1	27 min.	41 min.	2-1
	1.5" Box Penetration	1	HOLD		

The above envelope (CGPA2002) will be the subject of an exemption request from the requirement in Appendix R, Section III.G.2.c, for a one hour rated fire barrier in fire zone RB-FZ-1F2. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was compared with the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at the duration listed are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a cable qualification rating as listed above.

3.6 Turbine Building Basement, South End (FIRE ZONE TB-FZ-11D)

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
86-71	4" Conduit	11	50 min.	60 min.	2-1
	4" Radial Bend Conduit	10	50 min.	60 min.	2-1
	4" Conduit (Penetration)	2	HOLD		
	4" Penetration	1	HOLD		

To summarize the above results, 4" conduit, and 4" conduit radial bends meet the requirements of III.G.2.c because their "CABLE QUALIFICATION RATING" is at least one hour. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was used to compare raceway temperatures at 60 minutes to the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at 60 minutes are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a rating of 60 minutes. No additional justification is required for these barriers

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
14-25	3.5" Conduit	2	39 min.	56 min.	2-1
	3.5" Radial Bend Conduit	2	39 min.	56 min.	2-1
	3.5" Conduit (Penetration)	1	HOLD		
	3.5" Box Penetration	1	HOLD		
14-28	2.5" Conduit	1	39 min.	56 min.	2-1
	2.5" Radial Bend Conduit	2	39 min.	56 min.	2-1
	2.5" Conduit (Penetration)	2	HOLD		
62-93	1.5" Conduit	6	27 min.	36 min.	2-1
	1.5" Radial Bend Conduit	5	27 min.	36 min.	2-1
	1.5" Box (Condulet)	1	27min.	36 min.	2-1
	12"x12" Box	1	HOLD		
86-71	4" Box	1	50 min.	50 min.	2-2
CGCTB017	1" Conduit	11	27 min.	36 min.	2-1
	1" Radial Bend Conduit	12	27 min.	36 min.	2-1
	1" Box (Condulet)	1	27 min.	36 min.	2-1
	1" Box	1	27 min.	36 min.	2-1
	4"x4"x8" Box	1	27 min.	36 min.	2-1
	1" Conduit (Penetration)	1	HOLD		
	6"x6"x4" Junction Box	1	HOLD		
CGCTB071	1" Conduit	1	27 min.	36 min.	2-1
	1" Radial Bend Conduit	1	27 min.	36 min.	2-1
	1" Box (Condulet)	1	27 min.	36 min.	2-1
	8"x11"X2'-8" Box	1	HOLD		

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CGPTB020	1.5" Conduit	12	27 min.	36 min.	2-1
	1.5" Radial Bend Conduit	12	27 min.	36 min.	2-1
	1.5" Box (Condulet)	3	27 min.	36 min.	2-1
	1.5" Conduit (Penetration)	1	27 min.	36 min.	2-1
	1.5" Junction Box	2	HOLD		
CGPTB029	1" Conduit	9	27 min.	36 min.	2-1
	1" Radial Bend Conduit	7	27 min.	36 min.	2-1
	1" Box (Condulet)	1	27 min.	36min.	2-1
	6"x6" Junction Box	1	HOLD		
CGPTB030	1.5" Conduit	11	27 min.	36 min.	2-1
	1.5" Radial Bend Conduit	7	27 min.	36 min.	2-1
	1.5" Box (Condulet)	2	27 min.	36 min.	2-1
	12"x12" Junction Box	1	HOLD		

The above envelopes (14-25, 14-28, 62-93, 86-71, CGCTB017, CGCTB071, CGPTB020, CGPTB029 and CGPTB030) will be the subject of an exemption request from the requirement in Appendix R, Section III.G.2.c, for a one hour rated fire barrier in fire zone TB-FZ-11D. The heat transfer model which projects temperatures inside these raceways out to 60 minutes was compared with the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at the duration listed are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a cable qualification rating as listed above.

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
CGPTB020	1.5" Flex. Conduit	2	INDETERMINATE		N/A

The 1.5" flexible conduit will be upgraded to provide an "actual" fire rating of one hour and will therefore meet the requirements of III.G.2.c. GPU Nuclear is currently planning on designing and installing the upgrade for these elements to conform to Texas Utilities Scheme 11-2 for a 1-1/2" airdrop. These tests were successful in establishing a 60 minute fire endurance rating. This constitutes GPU Nuclear's current design detail for the aforementioned upgrades. If other types of upgrades which provide an "actual" fire rating of 60 minutes are identified due to more industry testing, an alternative configuration could be used. Such changes will not be submitted for NRC approval but handled under existing licensing conditions; ie. 50.59 process. The commitment is to upgrade these envelopes to an "actual" fire rating of 60 minutes.

3.7 Turbine Building, Switchgear Room, West End, Mezzanine (Fire Zone TB-FZ-11C)

ENVELOPE NO.	TYPE	NO. ELEMENTS	ACTUAL RTG.	CABLE RTG.	NEI TEST QUALIFICATION
86-71	4" Conduit	2	91 min.	102 min.	2-3
	4" Radial Bend Conduit	4	91 min.	102 min.	2-3
	4" Conduit (Penetration)	4	HOLD		

The above envelope (86-71) will be the subject of an exemption request from the requirement in Appendix R, Section III.G.2.a, for a three hour rated fire barrier in fire zone TB-FZ-11C. Request an exemption from the requirement for an area wide automatic suppression system. The temperature inside these raceways at 102 minutes, when the test was terminated, was compared with the cable insulation failure threshold temperatures for required safe shutdown circuits inside these raceways. For these raceways, the projected raceway temperatures at the duration listed are below the cable insulation failure threshold temperatures by more than 70 deg F; therefore these raceway barriers have a cable qualification rating as listed above.

4.0 REFERENCES

4.1 NRC Generic Letter 86-10, Supplement 1, Enclosure 1, "FIRE ENDURANCE TEST ACCEPTANCE CRITERIA FOR FIRE BARRIER SYSTEMS USED TO SEPARATE REDUNDANT SAFE SHUTDOWN TRAINS WITHIN THE SAME FIRE AREA", dated March 25, 1994.

4.2 10 CFR Part 50 Appendix R, "FIRE PROTECTION PROGRAM FOR NUCLEAR POWER FACILITIES OPERATING PRIOR TO JANUARY 1, 1979".

4.3 NEI Report No. 0784-00001-TR-02, Revision 1, "NEI APPLICATION GUIDE FOR EVALUATION OF THERMO-LAG 330 FIRE BARRIER SYSTEMS".

4.4 GPU Nuclear Oyster Creek Nuclear Generating Station Fire Hazards Analysis Report (FHAR) No. 990-1746, Revision 7.

4.5 NFPA 251 (ASTM E-119), "STANDARD FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS".

4.6 Sandia Test Report SAND90-0696 May, 1991 "AN INVESTIGATION OF THE EFFECTS OF THERMAL AGING ON THE FIRE DAMAGEABILITY OF ELECTRICAL CABLES".

4.7 Gilbert Commonwealth Letter G/C/TMI-1CS/16503 Sept. 15,1988, J. Brendlen to J.W.Langenbach, "TSI DERATING CHECK".

4.8 NFPA Fire Protection Handbook, Seventeenth Edition.

4.9 EPRI TR 100370, April, 1992, "FIRE INDUCED VULNERABILITY EVALUATION".

4.10 EPRI TR 104030, draft January, 1994, "FIRE RISK ANALYSIS IMPLEMENTATION GUIDE".

4.11 NUMARC, Sept 1993, "THERMO-LAG 330-1 COMBUSTIBILITY EVALUATION METHODOLOGY PLANT SCREENING GUIDE".

4.12 EPRI Project 3385-05, June 1995, "METHODS FOR EVALUATION OF CABLE WRAP FIRE BARRIER PERFORMANCE".

APPENDICES

A. USING FIVE FIRE MODELLING TO APPROXIMATE EXPOSURE TIME-HISTORY FOR THERMO-LAG CONFIGURATIONS IN OC FIRE ZONE RB-FZ-1D.

B. USING FIVE FIRE MODELLING TO APPROXIMATE EXPOSURE TIME-HISTORY FOR THERMO-LAG CONFIGURATIONS IN OC FIRE ZONE RB-FZ-1E.

C. USING FIVE FIRE MODELLING TO APPROXIMATE EXPOSURE TIME-HISTORY FOR THERMO-LAG CONFIGURATIONS IN OC FIRE ZONE RB-FZ-1F2.

D. USING FIVE FIRE MODELLING TO APPROXIMATE EXPOSURE TIME-HISTORY FOR THERMO-LAG CONFIGURATIONS IN OC FIRE ZONE TB-FZ-11D.

E. USING FIVE FIRE MODELLING TO APPROXIMATE EXPOSURE TIME-HISTORY FOR THERMO-LAG CONFIGURATIONS IN OC FIRE ZONE TB-FZ-11C.

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APPENDIX A

Using FIVE Fire Modeling to Approximate Exposure Time-History for Thermo-Lag Configurations in OC Fire Zone RB-FZ-1D

Letter Report
September 27, 1995

Prepared by:
GPUN Risk Analysis Group

Using FIVE Fire Modeling to Approximate Exposure Time-History for Thermo-Lag Configurations

1. PURPOSE

The purpose of this report is to document the detailed fire modeling performed for fire scenarios involving Thermo-Lag wrapped fire barriers, as identified during plant walkdowns of OC fire zone RB-FZ-1D. Thermo-Lag exposure time-history results were obtained for each T-L configuration determined to be impacted by a fire source/combustible.

2. APPROACH

The approach followed for modeling of fire scenarios is based on methodology detailed in the EPRI "Methods for Evaluation of Cable Wrap Fire Barrier Performance" document (Ref. 1) which was based on fire modeling techniques developed for FIVE (Ref. 2). Fire modeling was accomplished in two steps:

1. Screening walkdowns to eliminate from further consideration those fire ignition sources and potential fire scenarios that cannot develop into damaging fires.

2. Fire modeling of specific scenarios that were not screened out in the first step.

For each Thermo-Lag configuration analyzed, one or more fire scenarios (including bounding scenarios) were postulated based on the following:

a. information gathered during plant walkdowns (i.e., fixed or transient ignition source and Thermo-Lag target location, type and quantity of combustibles present in zone);
b. information obtained from reviewing applicable sections in Appendix R documents for OC (Ref. 3);
c. information obtained from reviewing OC procedure 120.5, Rev. 5, "Control of Combustibles." (Ref. 4)
d. information provided by GPUN engineers (specializing in fire protection, risk assessment, mechanical).

Thermo-Lag FIVE analyses were performed using computerized Excel spreadsheets which duplicate FIVE Worksheets 1, 2, or 3 and are linked to tables containing the same information as in FIVE Reference Tables. For each Thermo-Lag fire modeling scenario, results are presented as exposure time-temperature profiles. In all scenarios evaluated , time-dependent temperatures were derived by incrementally adding the total heat content of the fuel into the fire compartment hot gas layer.

3. FIRE MODELING ASSUMPTIONS

The following Thermo-Lag fire modeling assumptions were made:

1. Worst-case fixed fire source scenarios were modeled for each Thermo-Lag sub-

configuration. The determination of which fixed fire source might cause the worst-case Thermo-Lag fire scenario was made during the plant fire area walkdown and was based on minimum damage threshold heights and distances calculated for typical fixed fire sources (e.g., electrical cabinets, electrical motors, lube oil in pumps) found at Oyster Creek.

2. Worst-case transient fire source scenarios observed during walkdowns were also modeled. Worst-case transient fire scenarios considered were similar to the type and quantities of transient combustibles allowed by OC station procedure (Ref. 4).
3. To ensure conservative results, worst-case fire plume (or ceiling jet) scenarios and/or radiant flux scenario were first modeled. For T-L sub-configurations not in the plume or ceiling jet, hot gas layer fire scenarios were evaluated.
4. Electrical cable inside cabinets, motor control centers, switchgear and cable trays was assumed to be non-qualified (i.e., non IEEE-383 type). This assumption is conservative since electrical cable purchased and installed at Oyster Creek in the past decade was IEEE-383 type.
5. The Fire Hazard Tool developed for the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature curve as soon as the compartment hot gas layer (HGL) reaches 1000°F. When the HGL temperature reaches 1000°F, the plume (or ceiling jet) temperatures are assumed to follow that of the E-119 (see discussion in Appendix B).
6. The Thermo-Lag wrap is assumed to burn by itself (i.e., even after the initial fire source is out of fuel) unless otherwise stated. Per, the EPRI Method (Ref. 1, Appendix I-D), credit may be taken for a time lag before the Thermo-Lag ignites based on exposure temperature.
7. The maximum plume and ceiling jet temperature is assumed to be 1600°F, which corresponds to flame temperature. This assumption is valid until hot gas layer temperature exceeds 1600°F, at which point the plume temperature is assumed to be equal to hot gas layer temperature.
8. Fire Zone RB-FZ-1D specific data:
   - total area of 9,100 ft2 (Ref. 3 - Oyster Creek Fire Hazard Analysis Report, Rev. No. 8);
   - fire zone ceiling height of 24 feet (Oyster Creek General arrangement Drawings);
   - ambient temperature of 100°F.

4. FIRE MODELING RESULTS

4.1 Fire Zone RB-FZ-1D

Fire zone RB-FZ-1D is the Reactor Building 51' Elevation. There are three areas in this fire zone that contain the T-L wrap. They are designated as location Nos. 6, 7, and 8 on the general arrangement drawing shown in Appendix D.

Location No. 6

Four scenarios were evaluated for this T-L configuration. The first two scenarios model auto-ignition of non-qualified cable trays and their impact on the T-L wrapped conduits above. The third scenario evaluates a transient ignition source/combustible that was noted during the walk-downs in the area, and the last scenario models the HGL contribution due to a core spray booster pump oil fire.

Scenario #1. There are two vertical T-L wrapped conduit runs that start from Location No. 9 at Elevation 33' below and go up to elevation 51' and then curve along the wall. An I&C cable runs by the two vertical T-L conduits in this area, however, this is a qualified cable and auto-ignition is not a concern. There are, however, three very loosely-packed cable trays in this area that run about 7 ft. below The T-L wrap. This was modeled here as one fully packed cable tray self-igniting that could impact the T-L wrap. Two ft. of a 24"-wide cable tray was assumed to initially self-ignite and the T-L target was modeled "in-plume" with the fire source located against the wall. This fire is assumed to propagate horizontally along the exposed cable tray with a flame speed of 10 feet per hour (per Ref. 1, Appendix I-C).

The heat release rate considered for this scenario (before the T-L wrap is ignited) is as follows:

1. Cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); since 4 ft2 are initially burning, the HRR for this source alone is 93.6 BTU/sec; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 141 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

The total available heat (Qtot) from this cable tray fire source is:

1. Cable tray – 4,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

Results

The analysis as shown in Table 1 indicates that the "in-plume" temperatures exceed 1000°F at t=24 minutes into this scenario, so the T-L wrap will be ignited and burn. However, the HGL temperature is only 112°F. Once the cable-trays' fire ignites the T-L wrapped conduits, they will start to burn. T-L wrap HRR is assumed to be 8.8 BTU/sec-ft2 (per Ref. 5); the amount of Thermo-Lag that could be involved in this fire scenario is assumed to be 12 linear feet (6 linear feet per conduit). The total surface area is 15.7 ft2 (conduits are 4-inch in diameter with 1/2 inch thick T-L wrap); the HRR is thus 138 BTU/sec. This HRR will be considered only for calculating the HGL temperature rise. The total available heat (Qtotal) from this amount of T-L fire source is 705,600 BTUs (it assumes 58,800 BTU/linear foot, from Ref. 5). A sample model worksheet is provided in Appendix A, Figure A-1.

Table 1. Temperature-Time History for Fire Scenario 1, Location No. 6.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	94	94	0	671	100
6	141	141	50760	672	102
12	188	188	118440	795	104
18	235	235	203040	909	107
24	282	420	354240	1018	112
30	329	467	522360	1121	117
36	376	514	707400	1221	123
42	423	561	909360	1317	130
48	470	608	1128240	1411	138
54	517	655	1364040	1584	146
60	564	702	1616760	1593	155

Scenario #2. There are three T-L wrapped conduit runs along the wall in this area with two 24"-wide cable trays (1 ft. apart on top of each other) about 8 ft. directly underneath the T-L conduits. The cable trays are 6 ft. off the floor and are perpendicular to the wall. At the location where this scenario is postulated, this area communicates with a higher elevation through a large opening but there is a 3.5-4' lip on the ceiling and the T-L ends at the ceiling of this lip. Therefore, this area was modeled as a 20' by 20' room with a 24' ceiling for this scenario.

This fire scenario modeled a fixed ignition source/combustible, a 2 foot wide cable tray with non IEEE-383 cable, 6 feet off the room's floor. Since the cable is non-qualified, the cable fire can self-ignite (per Ref. 2, Reference Table 1.2, "Fire Ignition Sources and Frequencies by Applicable Plant Locations) and cable would start to burn. The fire will then propagate (almost immediately) to a second cable tray, located 1 foot above. In addition to the vertical propagation, the fire is also assumed to propagate horizontally along the exposed cable tray with a flame speed of 10 feet per hour (per Ref. 1, Appendix I-C). The targets are three 3-inch diameter conduits wrapped in 0.5 inch thick Thermo-Lag. The T-L wrapped conduits pass perpendicularly over the cable trays, 8 feet above them. Due to the close distance between the cable trays and T-L wrapped conduits, the T-L will be ignited by the cable tray fire. Once this happens, additional heat is released into this fire zone.

The heat release rates considered for this scenario are as follows (by fire source):

- first cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider

Equation 2 on FIVE manual, page 10.4-10); since 4 ft2 are initially burning, the HRR for this source alone is 93.6 BTU/sec; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 140.4 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

- second cable tray -- 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the first cable tray, the HRR for this source alone is 140.4 BTU/sec (since 6 ft2 is initially assumed to be burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 187.2 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);
- T-L wrap HRR is assumed to be 8.8 BTU/sec-ft2 (per Ref. 5); the amount of Thermo-Lag that could be involved in this fire scenario is assumed to be 7 linear feet (visual observation) for a total surface area of 7.3 ft2; the HRR is thus 64 BTU/sec; this HRR will be considered only for calculating the HGL temperature rise.

The total available heat (Qtot) from each fire source is:

- first cable tray -- 4,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];
- second cable tray -- 4,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];
- Thermo-Lag wrap -- 333,200 BTUs (it assumes 47,600 BTU/linear foot, from Ref. 5).

Results

The results are presented in Table 2 below. As indicated by the temperature-time histories in the table, the 'in-plume' temperature at the T-L targets 8 feet above the burning cable trays exceeds 1000°F at t=12 minutes, so the T-L wrap will be ignited and burn. However, the HGL temperature is only 263°F. As indicated by the temperature-time histories in Table 2, post-flashover conditions (i.e., above 1000°F HGL temperature) occur at t=36 minutes and the HGL temperatures will follow those of the ASTM E-119 from then on. Appendix B contains the basis for this assumption. A sample model worksheet is provided in Appendix A, Figure A-2.

Table 2. Temperature-Time History for Fire Scenario 2, Location No. 6.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	234	234	0	902	100
6	328	328	118080	963	161
12	422	486	293040	1212	263
18	516	580	501840	1493	408
24	610	674	744480	1600	612
30	704	768	1020960	1600	905
36	798	862	1331280	1600	1329
42	892	956	1675440	1600	1399*
48	986	1050	2053440	1600	1462*
54	1080	1144	2465280	1600	1526*
60	1174	1238	2910960	1600	1550*

* Temperatures follow those of ASTM E-119.

Scenario #3. A wooden ladder was noted stored on the floor during walkdowns of the same area described above for Scenario #2 for this fire zone. This is modeled here as a transient ignition source/combustible. There is a 24"-wide cable tray four feet above "in-plume" of this fire which will be ignited due to close proximity to the ladder fire source. It is assumed that 2 ft. of this cable tray will be initially ignited and this fire is assumed to propagate horizontally along the exposed cable tray with a flame speed of 10 feet per hour (per Ref. 1, Appendix I-C). The HGL temperatures were calculated here for the impact on the T-L in the area 14 ft. above the floor.

The heat release rates considered for this scenario are as follows (by fire source):

- wooden ladder - 12 BTU/sec- ft2 (Ref. 2, FIVE Table 2E); it is assumed that a total surface area of 10 ft2 are initially burning, the HRR for this source alone is 120 BTU/sec.
- cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); the HRR for this source is 93.6 BTU/sec (since 4 ft2 is initially assumed to be burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 140.4 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

The total available heat (Qtot) from each fire source is:

- wooden ladder – 400,000 BTUs [it assumes the ladder weighs 50 lbm x 8,000 BTU/lbm (per Ref. 6, Page E2-3)];
- cable tray – 4,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

Results

The analysis indicates that as a result of the ladder igniting, the "in-plume" temperatures at the cable tray 4 ft. above reaches 937°F at t = 6 minutes. Two feet of this cable tray is assumed to ignite at this time and propagate horizontally along the exposed cable tray. The HGL temperatures calculated for the T-L wrapped conduits 14 ft. above the floor in this area are shown in Table 3 below. As can be seen, the HGL temperatures exceed 1000°F at the end of this scenario (t = 60 minutes). This fire scenario is ended at 1 hour since the T-L modeled is assumed to be a 1-hour wrap. It should also be noted that these HGL temperatures are bounded by Scenario # 2 above. A sample model worksheet is provided in Appendix A, Figure A-3. The target temperature reflected on this worksheet is the temperature seen by the cable tray 4 feet above the ladder and The T-L wrap (14 ft above) sees the HGL temperatures in this scenario.

Table 3. Temperature-Time History for Fire Scenario 3, Location No. 6.

Time	HRR to	HRR to	QTOT	Temp.	Temp.
	Target	HGL			
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	120	120	0	100	100
6	214	214	77040	129	129
12	261	261	171000	166	166
18	308	308	281880	213	213
24	355	355	409680	272	272
30	402	402	554400	345	345
36	449	449	716040	435	435
42	496	496	894600	545	545
48	543	543	1090080	683	683
54	590	590	1302480	853	853
60	637	637	1531800	1066	1066

Scenario #4. The fixed ignition source modeled here is the core spray booster pump P-20-2A. This pump contains up to 2 gallons of lube oil (Ref. 7). Total Q available is 310080 BTU (from Ref. 6, page E2-1, assumed to be the same at OC), heat release rate 110 BTUs/sec-ft^2 (from Ref. 2, Table 2E). The potential oil spread area around the pump was estimated at 5 ft^2. The closest thermo-Lag wrap conduits run along the north wall about 20 ft. away longitudinally from the pump and at the highest elevation 4 ft. below the ceiling. Source (i.e., pump) was modeled as being 'in-center'.

Results

Thermo-Lag target is not damaged (i.e., temperature does not reach 1000 °F) by HGL contributions, see Table 4. There just isn't enough energy in 2 gallons of oil. The maximum temperature at the T-L wrap was calculated to be 105°F. A sample model worksheet is provided in Appendix A, Figure A-4.

Table 4. Temperature-Time History for Fire Scenario 4, Location No. 6.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	550	550	0	100	100
6	550	550	198000	103	103
10	550	550	330000	105	105
11	0	0	330000	105	105
20	0	0	330000	105	105
30	0	0	330000	105	105
36	0	0	330000	105	105
42	0	0	330000	105	105
48	0	0	330000	105	105
54	0	0	330000	105	105
60	0	0	330000	105	105

Location No. 7

Scenario #1. The bounding scenario for this T-L configuration run was identified as the electrical panel V50F as the fixed ignition source during walkdowns. This panel is 6 feet off the floor and this was assumed as the virtual surface of the fire. The T-L conduit runs horizontally along the wall 52 inches above this panel. The T-L wrap is approximately 3 inches in diameter, 0.5 inches thick, and was modeled "in-plume" of fire "against the wall".

Results

As shown in Table 5, the energy contribution from the panel as modeled immediately raises the "in-plume" temperature to 1600 °F at the target and is assumed to ignite the T-L wrap. The heat release rate assumed for this electrical cabinet is 400 BTUs/sec (containing non-qualified cable, Ref. 1, Appendix I-B). A fire duration of 15 minutes was assumed for this electrical cabinet. It is assumed that 2 feet of T-L wrap with a surface area of 1.6 ft^2 (3 inches diameter) begins to burn. From NEI study on Thermo-Lag 330-1 Combustibility (Ref. 5 – Thermo-Lag 330-1 Combustibility, Attachment 1 and Table 1 of Attachment 3), heat release rates and total BTU for the T-L wrap were obtained (8.8 BTU/sec-ft^2 and 47,600 BTU/linear foot, respectively). The T-L heat release rate of 14 BTU/sec was added to that of the electrical cabinet (400 BTU/sec) for HGL calculations. The virtual surface of the fire is at electrical cabinet 6 feet off the floor.

The cabinet fire is exhausted at time t=15 minutes. At this time, the T-L temperature (in plume) is 1600°F. With the T-L wrap burning, the HGL temperature is only 108°F. Ref. 1, Appendix I-D indicates that "once Thermo-Lag is ignited, there is no test data to demonstrate how and when it will stop burning after the fire source is removed. Therefore, the Hazard tool assumes that once the fire source is removed, the Thermo-Lag in the plume (or ceiling jet) could be exposed to temperatures ranging from HGL (if the Thermo-Lag stops burning completely) to peak plume temperature (if the Thermo-Lag continues to burn)". It was very conservatively assumed here that the Thermo-Lag will continue to burn at peak plume temperature for the remainder of the scenario. A sample model worksheet is provided as Appendix A, Figure A-5.

Table 5. Temperature-Time History for Fire Scenario 1, Location No. 7.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	400	400	0	1600	100
6	400	414	149040	1600	103
12	400	414	298080	1600	106
15	400	414	372600	1600	108
16	0	14	373440	1600	108
25	0	14	381000	1600	108
36	0	14	390240	1600	108
42	0	14	395280	1600	109
48	0	14	400320	1600	109
54	0	14	405360	1600	109
60	0	14	410400	1600	109

Location No. 8

Scenario #1. At this location, there is one vertical T-L conduit run that is by the equipment hatch. An open top cable tray (TGXR 2006) runs vertically right next to the T-L conduit 6 inches apart at its closest point. There are no other fixed ignition sources nearby except the RBCCW pump (P-5-2) which is more than 20 feet away.

Results

The analysis , shown in Figure A-R1, used FIVE Worksheet #3 (Ref. 2) to model this scenario. It was assumed that 2 ft^2 of 12-inch wide cable tray (TGXR 2006) will self-ignite. A heat release rate of 23.4 BTU/sec- ft^2 (Ref. 1, FIVE Table 1E, cable # 5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10) was assumed for the burning cable tray. The total HRR for this source is 47 BTU/sec. The results indicate that if the cable tray is located at 0.8 ft or less of the T-L wrap, the T-L wrap reaches a critical damage flux of 2.2 BTU/sec-ft^2 (this is the minimum ignition radiant flux for T-L, per Ref. 5, page A1-8). This analysis is extremely conservative because it uses a point source radiant heat flux model (for the 2 feet of cable tray) and it assumes 40 percent of the total heat release rate of accidental fires is radiative, with the remainder released convectively.

5. FIRE MODELING SUMMARY

Fire modeling was performed for three locations containing Thermo-Lag fire barrier in this fire zone. Fire scenarios involving fixed and transient sources were analyzed. The analysis results are presented as temperature-time histories in Tables 1 through 5. These results are used in the following section to develop Total Heat Load and then convert to equivalent ASTM E-119 exposures.

6. APPROXIMATING EXPOSURE TIME-HISTORY OF THERMO-LAG SUB-CONFIGURATIONS – THE TOTAL HEAT LOAD CONCEPT

Calculation of an exposure time-temperature profile for a specific T-L Sub-configuration is based on the methodology presented in Reference 1. The time -temperature profiles are used to develop the total heat load (Reference 1, Appendix III-A) for each fire exposure. The total heat load concept holds that the area under the incident heat flux vs. time curve, or total heat load, can be used as a measure of fire severity. Comparing the total heat load of a fire scenario exposure to the total heat load of a test exposure (ASTM E-119) allows one to predict the response of a Thermo-Lag barrier to the scenario exposure. The total heat load per unit area of fire barrier surface is equal to the area under the incident heat flux-time curve, corrected for convection effects as described in Reference 1, Appendix III-A.

6.1 Total Heat Load Results

Location No.(GA DWG, App. D)	Scenario	Description	Peak Temperature at Target (°F)	Total Heat Load Equivalent E-119 Exposure Duration (min.)
6	1	cable Tray	1593	<4[illegible]
6	2	Cable Tray	1600	>60
6	3	Wooden Ladder	1066	<18
6	4	CS Booster Pump	105	<10
7	1	Electrical Panel	1600	>60
8	1	Cable tray	Radiant Exposure	>0.8 Ft.

Appendix C contains tables with Total Heat Load values calculated for Thermo-Lag scenarios.

7. REFERENCES

1. EPRI Report "Methods for Evaluation of Cable Wrap Fire Barrier Performance", July, 1995

2. EPRI TR-100370, "Fire-Induced Vulnerability Evaluation," April 1992.

3. GPUN, "Fire Hazards Analysis Report -- OC," Doc. No. 990-1746, Rev. 8, May 24, 1995.

4. GPUN - OC Procedure No. 120.5 (Revision 5), May 20, 1993.

5. Thermo-Lag 330-1 Combustibility Study, NEI, 1994.

6. GPUN - TMI-1 Procedure No. 1035 (Revision 24), August 23, 1994.

7. Personal communication with Malcom Gonzales of GPUN, in charge of plant oil program.

Appendix A

Scenarios FIVE Worksheets

Figure A-1

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	9100
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	7.00
3	Height from Fire Source to Ceiling, H	ft	12.00
4	Ratio of Target Height/Ceiling Height		0.583
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	141
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	282
12	Plume Temperature Rise at Target	F	571
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	571
15	Temperature at Target	F	672
16	Temperature in HGL	F	102
17	Qtot to HGL	Btu	50760
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	3046
20	Calculated Enclosure Volume, V	ft3	109200
21	Calculated Qnet/V	Qnet/ft3	0.03
22	HGL Temperature Increase	F	2

Figure A-2

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	400
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	8.00
3	Height from Fire Source to Ceiling, H	ft	18.00
4	Ratio of Target Height/Ceiling Height		0.444
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	328
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	656
12	Plume Temperature Rise at Target	F	802
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	802
15	Temperature at Target	F	963
16	Temperature in HGL	F	161
17	Qtot to HGL	Btu	118080
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	7085
20	Calculated Enclosure Volume, V	ft3	7200
21	Calculated Qnet/V	Qnet/ft3	0.98
22	HGL Temperature Increase	F	61

Figure A-3

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	400
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	4.00
3	Height from Fire Source to Ceiling, H	ft	24.00
4	Ratio of Target Height/Ceiling Height		0.167
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	214
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	214
12	Plume Temperature Rise at Target	F	1207
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	1207
15	Temperature at Target	F	1336
16	Temperature in HGL	F	129
17	Qtot to HGL	Btu	77040
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	4622
20	Calculated Enclosure Volume, V	ft3	9600
21	Calculated Qnet/V	Qnet/ft3	0.48
22	HGL Temperature Increase	F	29

Figure A-4

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	9100
1	Location of Target		Hot Gas Layer
2	Height of Target above Fire Source	ft	20.00
3	Height from Fire Source to Ceiling, H	ft	24.00
4	Ratio of Target Height/Ceiling Height		0.833
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	550
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	550
12	Plume Temperature Rise at Target	F	155
13	Temp Rise Factor at Target		0.00
14	Temperature Rise at Target	F	0
15	Temperature at Target	F	103
16	Temperature in HGL	F	103
17	Qtot to HGL	Btu	198000
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	11880
20	Calculated Enclosure Volume, V	ft3	218400
21	Calculated Qnet/V	Qnet/ft3	0.05
22	HGL Temperature Increase	F	3

Figure A-5

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	9100
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	4.33
3	Height from Fire Source to Ceiling, H	ft	18.00
4	Ratio of Target Height/Ceiling Height		0.241
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	400
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	800
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	1600
15	Temperature at Target	F	1600
16	Temperature in HGL	F	103
17	Qtot to HGL	Btu	149040
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	8942
20	Calculated Enclosure Volume, V	ft3	163800
21	Calculated Qnet/V	Qnet/ft3	0.05
22	HGL Temperature Increase	F	3

Figure A-R1, scenario 1, Loc. No. 8

WORKSHEET 3: RADIANT EXPOSURE SCENARIOS

1	Critical Radiant Flux to the Target (Representative value = 1)	Btu/s/ft2	2.2	<-User Input
2	Peak Fire Intensity	Btu/s	47	<-User Input
3	Radiant Fraction of Heat Release (Representative value = 0.4)		0.4	<-User Input
4	Radiant Heat Release Rate	Btu/s	18.8	
5	Critical Radiant Flux Distance	ft	0.8	

If the exposure fire is located within this distance (indicated in Box 5) of the target, critical conditions can occur. Outside this range, critical conditions are not indicated for the scenario under consideration.

Appendix B

Basis for Following ASTM E-119 Time-Temperature Relationship When T(HGL) is 1000 °F

TRANSITION TO
ASTM E-119 TIME-HISTORY
IN THE HOT GAS LAYER

ISSUE:

The Fire Hazard Tool currently under development in the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature relationship as soon as the compartment hot gas layer reaches 1000°F.

BASIS:

- The Handbook (Ref, pg 6-75) states that "Flashover of an enclosure is likely to occur if the temperature of the upper gas layer reaches approximately 1000°F (600°C).

  The EPRI assumption of 1000°F is therefore conservative.

- As stated near the top of page 6-67 of the Handbook, the intensity of the fire will be somewhat lower when the walls and ceiling absorb significant amounts of energy rather than when act as insulation or radiation barriers.

  Since power plant compartments are typically concrete barriers which absorb significant amounts of heat, the intensity of fire will tend to be less severe than fires in compartments with insulated barriers.

- ASTM E-119 has been the accepted standard for testing fire barrier systems since the early 1900's. The standard, which was developed from actual fire tests, has been used to evaluate the fire endurance capabilities of fire barriers since it was developed. The time-temperature relationship represented by the curve represents a fully-involved fire compartment.

- According to Fred Mowrer of the University of Maryland, plume and ceiling effects disappear in a fully involved fire compartment as the plume/ceiling jet gas are no longer more buoyant than surrounding gases.

- Use of the ASTM E-119 time-temperature relationship to represent a fully involved power plant compartment fire is therefore consistent with industry practice. Assuming that that occurs when the hot gas layer reaches 1000°F is more conservative than the 1100°F noted in the Handbook.

  Reference: NFPA Fire Protection Handbook, Seventeenth Edition, Section 6/Chapter 6.

Appendix C

Total Heat Load Results

Figure C-1

Total Heat Load
Scenario 1, Loc. No. 6

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	671	1.2	0.0	0.00	0.00
6	672	1.2	0.44	0.11	0.41
12	795	1.7	0.97	0.19	1.65
18	909	2.2	1.67	0.27	3.56
24	1018	2.8	2.56	0.36	5.93
30	1121	3.6	3.71	0.45	8.64
36	1221	4.4	5.14	0.54	11.59
42	1317	5.4	6.91	0.64	14.73
48	1411	6.5	9.07	0.74	18.03
54	1584	9.2	11.90	0.85	21.49
60	1593	9.3	15.23	0.97	25.15

Figure C-2

Total Heat Load
Scenario 2, Loc. No. 6

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	902	2.1	0.0	0.00	0.00
6	963	2.5	0.83	0.13	0.41
12	1212	4.3	2.06	0.27	1.35
18	1493	7.8	4.24	0.44	3.56
24	1600	9.5	7.34	0.72	5.93
30	1600	9.5	10.75	1.29	8.64
36	1600	9.5	14.16	2.67	11.59
42	1600	9.5	17.57	4.84	14.73
48	1600	9.5	20.97	7.31	18.03
54	1600	9.5	24.38	10.10	21.49
60	1600	9.5	27.79	13.12	25.15

Figure C-3

Total Heat Load
Scenario 3, Loc. No. 6

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	100	0.4	0.0	0.00	0.00
6	129	0.3	0.12	0.12	0.41
12	166	0.4	0.23	0.23	1.65
18	213	0.3	0.35	0.35	3.56
24	272	0.5	0.49	0.49	5.93
30	345	0.5	0.66	0.66	8.64
36	435	0.6	0.87	0.87	11.59
42	545	0.9	1.14	1.14	14.73
48	683	1.3	1.52	1.52	18.03
54	853	1.9	2.10	2.10	21.49
60	1066	3.2	3.02	3.02	25.15

Figure C-4

Total Heat Load
Scenario 4, Loc. No. 6

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	100	0.4	0.0	0.00	0.00
6	103	0.2	0.11	0.11	0.41
10	105	0.2	0.16	0.16	1.24
11	105	0.2	0.18	0.18	1.52
20	105	0.2	0.30	0.30	4.57
30	105	0.2	0.44	0.44	8.93
36	105	0.2	0.53	0.53	11.88
42	105	0.2	0.61	0.61	15.02
48	105	0.2	0.70	0.70	18.32
54	105	0.2	0.78	0.78	21.77
60	105	0.2	0.87	0.87	25.44

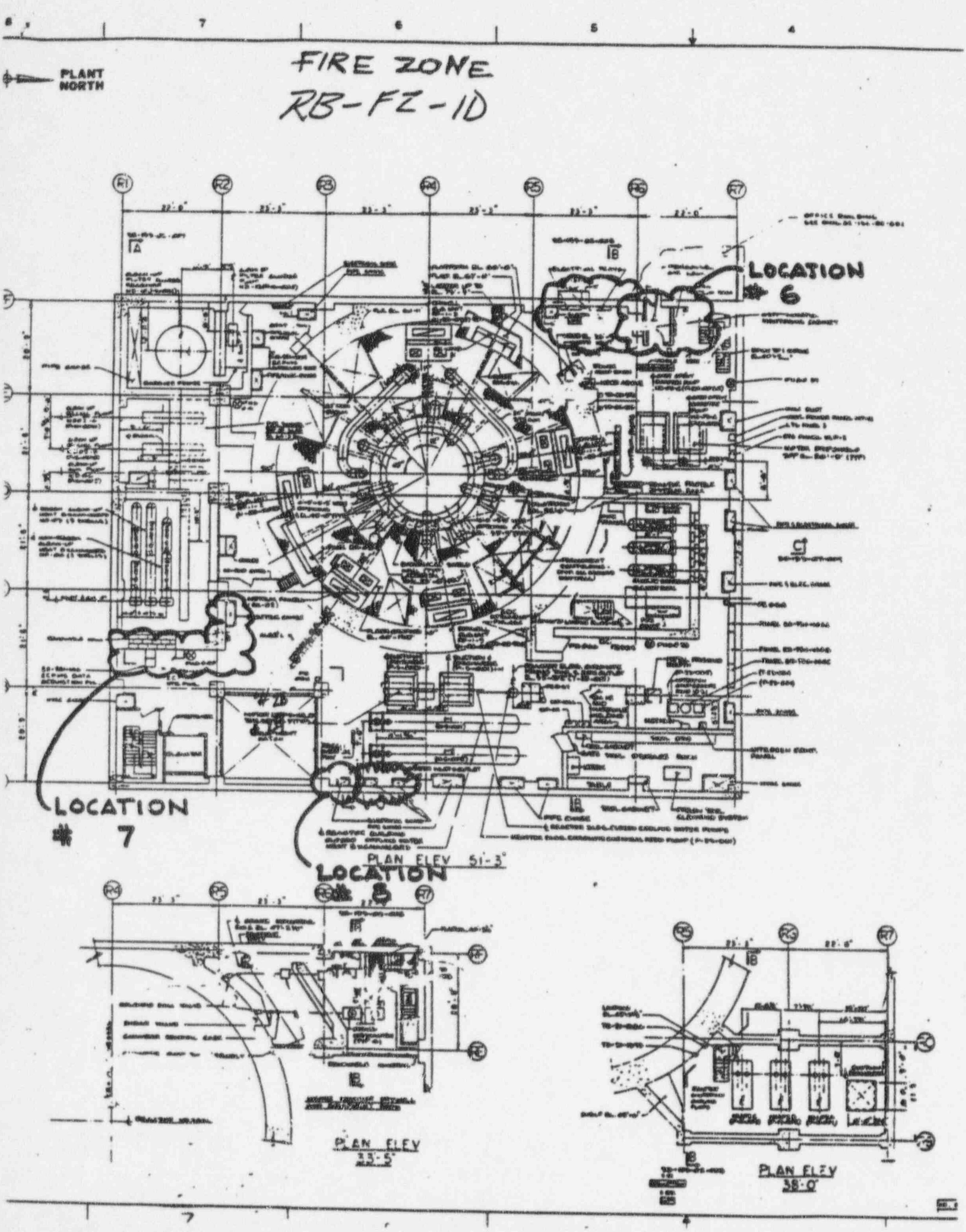
Figure C-5

Total Heat Load
Scenario 1, Loc. No.7

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	1600	9.5	0.0	0.00	0.00
6	1600	9.5	3.41	0.11	0.41
12	1600	9.5	6.82	0.19	1.65
15	1600	9.5	8.52	0.23	2.59
16	1600	9.5	9.09	0.25	2.94
25	1600	9.5	14.20	0.38	6.53
36	1600	9.5	20.46	0.54	11.73
42	1600	9.5	23.86	0.62	14.87
48	1600	9.5	27.27	0.71	18.17
54	1600	9.5	30.68	0.80	21.63
60	1600	9.5	34.09	0.88	25.29

Appendix D

General Arrangement Drawings



8
7
6
5
4
PLANT NORTH
FIRE ZONE
RB-FZ-1D
R1
R2
R3
R4
R5
R6
R7
LOCATION # 6
LOCATION # 7
LOCATION # 8
PLAN ELEV 51'-3"
PLAN ELEV 33'-5"
PLAN ELEV 38'-0"

TR 102
APPENDIX B

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Using FIVE Fire Modeling to Approximate Exposure Time-History for Thermo-Lag Configurations in OC Fire Zone RB-FZ-1E

Letter Report
September 27, 1995

Prepared by:
GPUN Risk Analysis Group
Using FIVE Fire Modeling to Approximate Exposure Time-History for Thermo-Lag Configurations

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1. PURPOSE

The purpose of this report is to document the detailed fire modeling performed for fire scenarios involving Thermo-Lag wrapped fire barriers, as identified during plant walkdowns of OC fire zone RB-FZ-1E. Thermo-Lag exposure time-history results were obtained for each T-L configuration determined to be impacted by a fire source/combustible.

2. APPROACH

The approach followed for modeling of fire scenarios is based on methodology detailed in the EPRI "Methods for Evaluation of Cable Wrap Fire Barrier Performance" document (Ref. 1) which was based on fire modeling techniques developed for FIVE (Ref. 2). Fire modeling was accomplished in two steps:

1. Screening walkdowns to eliminate from further consideration those fire ignition sources and potential fire scenarios that cannot develop into damaging fires.
2. Fire modeling of specific scenarios that were not screened out in the first step.

For each Thermo-Lag configuration analyzed, one or more fire scenarios (including bounding scenarios) were postulated based on the following:

a. information gathered during plant walkdowns (i.e., fixed or transient ignition source and Thermo-Lag target location, type and quantity of combustibles present in zone);
b. information obtained from reviewing applicable sections in Appendix R documents for OC (Ref. 3);
c. information obtained from reviewing OC procedure 120.5, Rev. 5, "Control of Combustibles." (Ref. 4)
d. information provided by GPUN engineers (specializing in fire protection, risk assessment, mechanical).

Thermo-Lag FIVE analyses were performed using computerized Excel spreadsheets which duplicate FIVE Worksheets 1, 2, or 3 and are linked to tables containing the same information as in FIVE Reference Tables. For each Thermo-Lag fire modeling scenario, results are presented as exposure time-temperature profiles. In all scenarios evaluated , time-dependent temperatures were derived by incrementally adding the total heat content of the fuel into the fire compartment hot gas layer.

3. FIRE MODELING ASSUMPTIONS

The following Thermo-Lag fire modeling assumptions were made:

1. Worst-case fixed fire source scenarios were modeled for each Thermo-Lag sub-configuration. The determination of which fixed fire source might cause the worst-case Thermo-Lag fire scenario was made during the plant fire area walkdown and

was based on minimum damage threshold heights and distances calculated for typical fixed fire sources (e.g., electrical cabinets, electrical motors, lube oil in pumps) found at Oyster Creek.

2. Worst-case transient fire source scenarios observed during walkdowns were also modeled. Worst-case transient fire scenarios considered were similar to the type and quantities of transient combustibles allowed by OC station procedure (Ref. 4).
3. To ensure conservative results, worst-case fire plume (or ceiling jet) scenarios and/or radiant flux scenario were first modeled. For T-L sub-configurations not in the plume or ceiling jet, hot gas layer fire scenarios were evaluated.
4. Electrical cable inside cabinets, motor control centers, switchgear and cable trays was assumed to be non-qualified (i.e., non IEEE-383 type). This assumption is conservative since electrical cable purchased and installed at Oyster Creek in the past decade was IEEE-383 type.
5. The Fire Hazard Tool developed for the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature curve as soon as the compartment hot gas layer (HGL) reaches 1000°F. When the HGL temperature reaches 1000°F, the plume (or ceiling jet) temperatures are assumed to follow that of the E-119 (see discussion in Appendix B).
6. The Thermo-Lag wrap is assumed to burn by itself (i.e., even after the initial fire source is out of fuel) unless otherwise stated. Per, the EPRI Method (Ref. 1, Appendix I-D), credit may be taken for a time lag before the Thermo-Lag ignites based on exposure temperature.
7. The maximum plume and ceiling jet temperature is assumed to be 1600°F, which corresponds to flame temperature. This assumption is valid until hot gas layer temperature exceeds 1600°F, at which point the plume temperature is assumed to be equal to hot gas layer temperature.
8. Fire Zone RB-FZ-1E specific data:
   - total area of 12,140 ft2 (Ref. 3 - Oyster Creek Fire Hazard Analysis Report, Rev. No. 8);
   - fire zone ceiling height of 25 feet (Oyster Creek General arrangement Drawings);
   - ambient temperature of 100°F.

4. FIRE MODELING RESULTS

4.1 Fire Zone RB-FZ-1E

Fire zone RB-FZ-1E is the Reactor Building 23' Elevation. Fire modeling was performed for three areas on Elevation 23'-6" and two areas on Elevation 33'-5" in this fire zone that contain the T-L wrap. They are designated as location Nos. 10, 11, 12, 9, and 15 on the general arrangement drawings shown in Appendix D.

Location No. 10

Two scenarios were modeled for this T-L configuration. There are two vertical runs of T-L wrapped conduits about 4 ft. long at elevation 12 ft. above the floor at this location. One conduit is 11/2" with 1/2" thick T-L wrap and the other is 3" with 1/2" thick T-L wrap. The first scenario models a transient ignition source/combustible and the other evaluates the impact of scenario #1 for location #11 on the T-L configuration here.

Scenario #1. This fire scenario modeled a transient ignition source/combustible, a 5 gallon container containing lube oil. Per Oyster Creek Procedure "Control of Combustibles," Procedure No. 120.5, Rev. 4 (Ref. 4), combustible liquids could be transported throughout the plant in an approved closed metal container (but not necessarily a safety-can). For this fire scenario, it was postulated that 1 quart of lube oil is spilled out of a can on the floor and is not cleaned up. The oil is later ignited by a welder working nearby or another transient ignition source and begins to burn. The oil fire could potentially impact a T-L wrap 12. feet above.

The heat release rate for the lube oil is 110 Btu/s-ft^{-2} (from Ref. 2, Table 2E). The oil could spread unconfined over an area of 13.5 ft^{-2} (54 ft.^{2}/gal from Ref. 2, Table 3E). The heat release rate assumed for this fire scenario is 1,485 Btu/s (110 Btu/s-ft^{-2} x 13.5 ft^{-2}). The heat content of one quart of oil is (17,111 Btu/lb. * 60 lb./1 ft^{-3}. * 1 ft.^{3}/30 quarts) 34,222 Btu (from Ref. 2, Table 2E). The oil fire duration will be less than one minute, but one minute will be used for conservatism. The virtual surface of the fire is at the floor level. The location factor for this source is one.

Results

The short oil fire does not cause an exposure "in-plume" temperature high enough to ignite the Thermo-Lag. The fire is of a short duration, with very slight hot gas layer effects. A sample model worksheet is provided as Appendix A, Figure A-1.

Table 1. Temperature-Time History for Fire Scenario 1, Location No. 10.

Time (min.)	HRR to Target (Btu/s)	HRR to HGL (Btu/s)	QTOT (Btu)	Temp. Target - (F)	Temp. HGL - (F)
0	1485	1485	0	804	100
1	1485	1485	89100	805	101
2	0	0	89100	101	101
10	0	0	89100	101	101
15	0	0	89100	101	101
25	0	0	89100	101	101
30	0	0	89100	101	101
35	0	0	89100	101	101
40	0	0	89100	101	101
50	0	0	89100	101	101
60	0	0	89100	101	101

Scenario #2. This scenario evaluates the impact of HGL produced by the self ignition of stack of four cable trays described in scenario #1 for location #11 on the T-L wrap in this location # 10.

Results

This fire zone is pretty open and location nos. 10 and 11 freely communicate with each other, therefore, the HGL temperatures calculated for scenario #1 for location #11 is also assumed to apply here. It should be noted that the bottom cable tray, the auto-ignition source/combustible for that scenario, is at 12 ft. below the ceiling and the T-L wrap here is at about 9 ft. below the ceiling (top of the T-L wrapped conduits), therefore, the target is in the HGL region of scenario #1 for location #11. The results are presented in Table 2.

Table 2. Temperature-Time History for Fire Scenario 2, Location No. 10.

Time (min.)	HRR to Target (Btu/s)	HRR to HGL (Btu/s)	QTOT (Btu)	Temp. Target - (F)	Temp. HGL - (F)
0	1047	1047	0	100	100
6	1234	1234	444240	111	111
12	1421	1421	955800	124	124
18	1608	1608	1534680	138	138
24	1795	1795	2180880	155	155
30	1982	1982	2894400	174	174
36	2169	2169	3675240	196	196
42	2356	2356	4523400	221	221
48	2543	2543	5438880	248	248
54	2730	2730	6421680	279	279
60	2917	2917	7471800	313	313

Location No. 11

Three scenarios were modeled for this T-L configuration. Three T-L wrapped 1"-conduits in this area run along the ceiling (CGCR3021, CGPR3019, & CNXR2050, see B&R Drawing Nos. 1303 & 1317). There are four 24"-wide cable trays stacked on top of each other that run directly underneath this T-L configuration. In the north view, there is a 24"-wide cable tray that runs about 4-inches apart from the T-L wrapped penetration box on the drywell at about 8 ft. below the ceiling. This was found to be the most limiting case from all the four T-L wrapped penetration boxes in this area (Penetration Nos. 8, 9, 18, & 19). There is also a core spray booster pump on the floor at this elevation that is 15 ft. away longitudinally from the T-L wrapped conduits on the ceiling.

Scenario #1. The fixed ignition source considered here, is the self-ignition of stack of four cable trays (Nos. 23, 25, 24, & 26). They are stacked one on top of each other about 1 ft. apart with the closest one (cable tray # 23) being about 9 ft. directly below the T-L wrap conduit runs on the ceiling. All the cable trays are 24 inches wide and cable trays # 24 and # 26 (the bottom two trays) have light loads.

This scenario models self-ignition of 2 ft. of cable tray # 26 initially which will then ignite 4 ft. of cable tray # 24, 6 ft. of cable tray # 25, and 8 ft of cable tray # 23. It is conservatively assumed that all the cable trays ignition occur instantaneously for calculation simplification. In addition to the vertical propagation, the fire is also assumed to propagate horizontally along the exposed cable tray with a flame speed of 10 feet per hour (per Ref. 1 , Appendix I-C). The total amount of cable tray available for this fire scenario is 10 feet per tray (for the first hour of fire scenario). The T-L target was assumed "in-plume" with the fire ignition source modeled as "in-center".

The heat release rates considered for this scenario before the T-L wrap is ignited are as follow (by fire source):

1. first cable tray (# 26) – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); since 4 ft2 are initially burning, the HRR for this source alone is 93.6 BTU/sec; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 140.4 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

2. second cable tray (# 24) – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the first cable tray, the HRR for this source alone is 187 BTU/sec (since 8 ft2 are initially burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 234 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

3. third cable tray (# 25) – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the second cable tray, the HRR for this source alone is 281 BTU/sec (since 12 ft2 are initially burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 328 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

4. forth cable tray (# 23) – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the second cable tray, the HRR for this source alone is 374 BTU/sec (since 16 ft2 are initially burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 421 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

The total available heat (Qtot) from each fire source is:

1. first cable tray (# 26) –2,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 20 lbm/linear foot (engineering judgment for 50% filled, 24 inch wide cable tray)];

2. second cable tray (# 24) –2,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 20 lbm/linear foot (engineering judgment for 50% filled, 24 inch wide cable tray)];

3. third cable tray (# 25) –4,000,000 BTUs [itassumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

4. forth cable tray (# 23) –4,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 10 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

Once the cable-trays' fire ignites the T-L wrapped conduits, they will start to burn. T-L wrap HRR is assumed to be 8.8 BTU/sec-ft2 (per Ref. 5); the amount of Thermo-Lag that could be initially involved in this fire scenario is assumed to be 24 linear feet (8 linear feet per conduit run that is directly above cable tray # 23). The total surface area is 12.6 ft2 (conduits are 1-inch in diameter with 1/2 inch thick T-L wrap); the HRR is thus 111 BTU/sec. The impact of horizontal propagation of cable tray fire on the T-L wrap conduits is ignored here due to insignificant heat contribution from the T-L wrap as compared to the cable trays. The total available heat (Qtotal) from this amount of T-L fire source is 571,200 BTUs (it assumes 23,800 BTU/linear foot, from Ref. 5).

Results

The results are presented in Table 3 below. As indicated by the temperature-time histories in the table, the `in-plume' temperature at the T-L targets 9 feet above the burning cable trays reaches 1000°F immediately, so the T-L wrap will be ignited and burn. However, the HGL temperature is only 313°F after one hour into this scenario. A sample model worksheet is provided in Appendix A, Figure A-2.

Table 3. Temperature-Time History for Fire Scenario 1, Location No. 11.

Time (min.)	HRR to Target (Btu/s)	HRR to HGL (Btu/s)	QTOT (Btu)	Temp. Target - (F)	Temp. HGL - (F)
0	936	1047	0	1043	100
6	1123	1234	444240	1054	111
12	1310	1421	955800	1169	124
18	1497	1608	1534680	1281	138
24	1684	1795	2180880	1391	155
30	1871	1982	2894400	1500	174
36	2058	2169	3675240	1600	196
42	2245	2356	4523400	1600	221
48	2432	2543	5438880	1600	248
54	2619	2730	6421680	1600	279
60	2806	2917	7471800	1600	313

Scenario #2. This scenario evaluates the radiant exposure from self-ignition of the 24"-wide cable tray running about 4 inches apart from the T-L wrapped penetration box on the drywell.

Results

The analysis , shown in Appendix A, Figure A-R1, uses FIVE Worksheet #3 (Ref. 2). It was assumed that 2 ft of 24-inch wide cable tray will self-ignite. A heat release rate of 23.4 BTU/sec- ft^2 (per Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10) was assumed for the burning cable tray. The total HRR for this source is 93.6 BTU/sec. The results indicate that if the cable tray is located at 1.2 ft or less of the T-L wrap, the T-L wrap reaches a critical damage flux of 2.2 BTU/sec-ft^2 (this is the minimum ignition radiant flux for T-L, per Ref. 5, page A1-8). This analysis is extremely conservative because it uses a point source radiant heat flux model (for the 2 feet of cable tray) and it assumes 40 percent of the total heat release rate of accidental fires is radiative, with the remainder released convectively.

Scenario #3. The fixed ignition source modeled here is the core spray booster pump P-20-2B. This pump contains up to 2 gallons of lube oil (Ref. 7). Total Q available is 310080 BTU, (from Ref. 6, page E2-1, assumed to be the same at OC), heat release rate 110 BTUs/sec-ft^2 (from Ref. 2, Table 2E). The potential oil spread area around the pump was estimated at 4 ft^2 during the plant walkdown. The Thermo-Lag wrap conduits are located on the ceiling 15 feet away longitudinally from the pump and in the "Ceiling Jet" sublayer. Source (i.e., pump) was modeled as being 'in-center'. Ambient temperature assumed was 100 °F.

Results

Thermo-Lag target is not damaged (i.e., temperature does not reach 1000 °F) by Ceiling Jet effects or Ceiling Jet/HGL contribution.There just isn't enough energy in 2 gallons of oil. The maximum temperature at the T-L wrap was calculated to be 135°F. Temperature-time histories are shown in Table 4. A sample model worksheet is provided in Appendix A, Figure A-3.

Table 4. Temperature-Time History for Fire Scenario 3, Location No. 11.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	440	440	0	131	100
5	440	440	132000	132	102
10	440	440	264000	134	103
12	440	440	316800	135	104
13	0	0	316800	104	104
15	0	0	316800	104	104
20	0	0	316800	104	104
30	0	0	316800	104	104
40	0	0	316800	104	104
50	0	0	316800	104	104
60	0	0	316800	104	104

Location No. 12

There is a 1-inch T-L wrapped conduit (CNXR2051) and associated T-L wrapped penetration box (penetration 57) in this area (see B&R drawing Nos. E1303 & E1317). About five feet of a half full 24"- cable tray runs directly underneath the penetration box, vertically on the drywell, placing the box right in the plume of such cable fire. Auto-ignition of this cable was modeled as one scenario for this area. Also, this area is very open and freely communicates with other areas in this fire zone, therefore, the HGL temperatures calculated for scenario #1 for location #11 is also applicable here. Finally, a transient ignition source/combustible was considered for this location to be placed on the floor against the drywell underneath the T-L wrapped conduit.

Scenario #1. This scenario models auto-ignition of 5 ft. of a half full 24"-wide cable tray against the wall directly underneath the T-L wrapped penetration box. The penetration box was estimated to be 17 ft. above the floor. A heat release rate of 23.4 BTU/sec-ft^2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); was used for this cable tray. Since 5 ft^2 are initially assumed to be burning for the "in-plume" calculations, the HRR for this source is 117 BTU/sec. at the beginning of the scenario. The total available heat from this source is 4,000,000 BTUs [it assumes 10,000 BTU/lbm of cable tray (per Ref. 6, page E2-1) x 20 linear feet x 20 lbm/linear foot (engineering judgment for 50% filled, 24 inch wide cable tray)]. The target was assumed "in-plume" for this scenario.

Results

The analysis as shown in Table 5 below indicate that the "in-plume" energy contribution is able to immediately ignite the T-L wrap and the temperatures reach 1600°F at the target. Once the cable-tray's fire ignites the T-L wrapped penetration box, it will start to burn. T-L wrap HRR is assumed to be 8.8 BTU/sec-ft2 with a heat load of 36,750 BTU/ft2 for 1/2" thick T-L wrap (per Ref. 5). The total surface area of the T-L wrap that would be in the plume of such fire is approximated at 2.5 ft2. The HRR is thus 22 BTU/sec., and the T-L wrap should last for 70 minutes (for a total heat load of 91875 BTUs). The "HGL" temperatures were calculated for this scenario considering that the HRR for the burning cable tray increases with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 140.4 BTU/s, which includes the HRR from 1 ft2 of additional cable tray). A sample model worksheet is provided as Appendix A, Figure A-4.

Table 5. Temperature-Time History for Fire Scenario 1, Location No. 12.

Time	HRR to	HRR to	QTOT	Temp.	Temp.
	Target	HGL			
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	117	139	0	1600	100
6	117	162	58320	1600	102
12	117	185	125280	1600	105
18	117	209	200520	1600	107
24	117	233	284400	1600	110
30	117	256	376560	1600	114
36	117	279	477000	1600	118
42	117	303	586080	1600	122
48	117	326	703440	1600	126
54	117	350	829440	1600	131
60	117	373	963720	1600	136

Scenario #2. This scenario evaluates the impact of HGL produced by self ignition of stack of four cable trays described in scenario #1 for location #11 on the T-L wrap in this location # 12.

Results

This fire zone is pretty open and location nos. 11 and 12 freely communicate with each other, therefore, the HGL temperatures calculated for scenario #1 for location #11 is also assumed to apply here. It should be noted that the bottom cable tray, the auto-ignition source/combustible for that scenario, is at 12 ft. below the ceiling and the T-L wrap here is at about 8 ft. below the ceiling, therefore, the target is in the HGL region of scenario #1 for location #11. The results are presented in Table 6 below.

Table 6. Temperature-Time History for Fire Scenario 2, Location No. 12.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	1047	1047	0	100	100
6	1234	1234	444240	111	111
12	1421	1421	955800	124	124
18	1608	1608	1534680	138	138
24	1795	1795	2180880	155	155
30	1982	1982	2894400	174	174
36	2169	2169	3675240	196	196
42	2356	2356	4523400	221	221
48	2543	2543	5438880	248	248
54	2730	2730	6421680	279	279
60	2917	2917	7471800	313	313

Scenario #3. The ignition source/combustible considered in this scenario is maintenance refuse being left in a plastic container on the floor against the drywell, placing the T-L wrap directly "in-plume" above. It was assumed that 50 lbm of maintenance trash (rags, paper, etc.) were left in the plastic container, for a total Q available of 800,000 BTUs (400,000 BTUs for the trash, and 400,000 BTUs for the plastic can, Ref. 6, page E2-1). The heat release rate is 138 BTUs/s (Ref. 1, Appendix I-E).

Results

As shown in Table 7, the "in-plume" temperatures (including the HGL energy contribution) for the T-L wrap target do not exceed 284°F by the time this scenario for the transient fuel source is ended. Therefore, the T-L wrap is not damaged. A sample model worksheet is provided in Appendix A, Figure A-5.

Table 7. Temperature-Time History for Fire Scenario 3, Location No. 12.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	138	138	0	277	100
6	138	138	49680	278	101
12	138	138	99360	279	101
18	138	138	149040	279	102
24	138	138	198720	280	103
30	138	138	248400	281	103
36	138	138	298080	281	104
42	138	138	347760	282	105
48	138	138	397440	282	105
54	138	138	447120	283	106
60	138	138	496800	284	107

Location No. 9

There are two vertical T-L wrapped conduits by the stairwell at this location. During the walkdowns, no fixed combustibles were noted within a 15'-radius. Possibility of HGL entrapment was also discarded during walkdowns. There is an extension cord within 2-3 ft. of these T-L conduit runs but its impact is deemed insignificant. There are no pumps nearby and it is very unlikely that any combustibles will be stored in this area. No scenarios were developed for this location.

Location No. 15

This area "the TIP room" was not accessible during the walkdowns due to high radiation. The information gathered here was obtained from Plant personnel and drawings. There are two T-L wrapped penetrations at this location (Penetration Nos. 44 & 54, see drawing no. B&R E1317). The dimensions for this room were estimated at 20 3/4 ft. by 20 ft. by 15 ft. height (from general arrangement drawings). Since there are no maintenance activities being done in this area (High Radiation area) during power operation, only one transient ignition source was modeled for this room.

Scenario #1. A wooden ladder was noted stored in this area from the pictures obtained prior to the application of the thermo-lag fire barrier for this location (pictures from Susan Hopson from OC PLant Rad. Engineering). This is modeled here as a transient ignition source/combustible. The heat release rate considered for this source (wooden ladder) is 12 BTU/sec- ft2 (Ref. 2, FIVE Table 2E); it is assumed that a total surface area of 10 ft2 is burning, the total HRR for this source is, therefore, 120 BTU/sec. The total available heat (Qtot) is 400,000 BTUs [it assumes the ladder weighs 50 lbm x 8,000 BTU/lbm (per Ref. 6, Page E2-3)]. The ignition source was modeled conservatively "against the wall". The T-L wrapped penetrations were assumed "in-plume" located about half-way below the ceiling at 7.5 ft. above the fire source.

Results

The analysis as shown Table 8 indicates that as a result of the ladder igniting, the "in-plume" temperatures in the room reach 863°F at one hour into the scenario. Therefore, the T-L wrap is not damaged. A sample model worksheet is provided in Appendix A, Figure A-6.

Table 8. Temperature-Time History for Fire Scenario 1, Location No. 15.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	120	120	0	557	100
6	120	120	43200	582	125
12	120	120	86400	608	151
18	120	120	129600	635	178
24	120	120	172800	664	207
30	120	120	216000	693	236
36	120	120	259200	724	267
42	120	120	302400	757	300
48	120	120	345600	791	334
54	120	120	388800	826	369
60	120	120	432000	863	406

5. FIRE MODELING SUMMARY

Fire modeling was performed for three locations containing Thermo-lag wrap in Oyster Creek fire zone RB-FZ-1E. The analysis results are presented as temperature-time history profiles in Tables 1 through 8. These results are used in the following section to develop Total Heat Load and then convert to equivalent ASTM E-119 exposures.

6. APPROXIMATING EXPOSURE TIME-HISTORY OF THERMO-LAG SUB-CONFIGURATIONS – THE TOTAL HEAT LOAD CONCEPT

Calculation of an exposure time-temperature profile for a specific T-L Sub-configuration is based on the methodology presented in Reference 1. The time -temperature profiles are used to develop the total heat load (Reference 1, Appendix III-A) for each fire exposure. The total heat load concept holds that the area under the incident heat flux vs. time curve, or total heat load, can be used as a measure of fire severity. Comparing the total heat load of a fire scenario exposure to the total heat load of a test exposure (ASTM E-119) allows one to predict the response of a Thermo-Lag barrier to the scenario exposure. The total heat load per unit area of fire barrier surface is equal to the area under the incident heat flux-time curve, corrected for convection effects as described in Reference 1, Appendix III-A.

6.1 Total Heat Load Results

Location No.(GA DWG, App. D)	Scenario	Description	Peak Temperature at Target (°F)	Total Heat Load Equivalent E-119 Exposure Duration (min.)
10	1	Oil Transient	805	<10
10	2	Cable Tray	313	<12
11	1	Cable tray	1600	>60
11	2	Cable Tray	Radiant Exposure	> 1.2 Ft.
11	3	CS Booster Pump	135	<10
12	1	Cable Tray	1600	>60
12	2	Cable Tray	313	<12
12	3	Maintenance Refuse	284	<18
9	None			
15	1	Wooden Ladder	863	<24

Appendix C contains tables with Total Heat Load values calculated for Thermo-Lag scenarios.

7. REFERENCES

1. EPRI Report "Methods for Evaluation of Cable Wrap Fire Barrier Performance", July, 1995

2. EPRI TR-100370, "Fire-Induced Vulnerability Evaluation," April 1992.

3. GPUN, "Fire Hazards Analysis Report -- OC," Doc. No. 990-1746, Rev. 8, May 24, 1995.

4. GPUN - OC Procedure No. 120.5 (Revision 5), May 20, 1993.

5. Thermo-Lag 330-1 Combustibility Study, NEI, 1994.

6. GPUN - TMI-1 Procedure No. 1035 (Revision 24), August 23, 1994.

7. Personal communication with Malcom Gonzales of GPUN, in charge of plant oil program.

Appendix A

Sample Scenario Worksheets

Figure A-1

Temperature calculation at time		min	1
Maximum ambient temperature		F	100
Floor Area		ft2	12140
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	12.00
3	Height from Fire Source to Ceiling, H	ft	25.00
4	Ratio of Target Height/Ceiling Height		0.480
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	1485
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	1485
12	Plume Temperature Rise at Target	F	704
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	704
15	Temperature at Target	F	805
16	Temperature in HGL	F	101
17	Qtot to HGL	Btu	89100
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	5346
20	Calculated Enclosure Volume, V	ft3	303500
21	Calculated Qnet/V	Qnet/ft3	0.02
22	HGL Temperature Increase	F	1

Figure A-2

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	12140
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	9.00
3	Height from Fire Source to Ceiling, H	ft	12.00
4	Ratio of Target Height/Ceiling Height		0.750
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	1123
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	1123
12	Plume Temperature Rise at Target	F	943
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	943
15	Temperature at Target	F	1054
16	Temperature in HGL	F	111
17	Qtot to HGL	Btu	444240
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	26654
20	Calculated Enclosure Volume, V	ft3	145680
21	Calculated Qnet/V	Qnet/ft3	0.18
22	HGL Temperature Increase	F	11

Figure A-R1, Scenario 2, Loc. No. 11

WORKSHEET 3: RADIANT EXPOSURE SCENARIOS				
1	Critical Radiant Flux to the Target (Representative value = 1)	Btu/s/ft2	2.2	<-User Input
2	Peak Fire Intensity	Btu/s	94	<-User Input
3	Radiant Fraction of Heat Release (Representative value = 0.4)		0.4	<-User Input
4	Radiant Heat Release Rate	Btu/s	37.6	
5	Critical Radiant Flux Distance	ft	1.2	

If the exposure fire is located within this distance (indicated in Box 5) of the target, critical conditions can occur. Outside this range, critical conditions are not indicated for the scenario under consideration.

Figure A-3

Temperature calculation at time		min	5
Maximum ambient temperature		F	100
Floor Area		ft2	12140
1	Location of Target		Ceiling Jet
2	Height of Target above Fire Source	ft	25.00
3	Height from Fire Source to Ceiling, H	ft	25.00
4	Ratio of Target Height/Ceiling Height		1.000
5	Longitudinal Distance from Fire Source to Target, L	ft	15
6	Longitudinal Distance to Height Ratio, L/H		0.60
7	Enclosure Width, W	ft	25
8	Height to Width Ratio, H/W		1.00
9	Peak Fire Intensity	Btu/s	440
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	440
12	Plume Temperature Rise at Target	F	92
13	Temp Rise Factor at Target		0.34
14	Temperature Rise at Target	F	31
15	Temperature at Target	F	132
16	Temperature in HGL	F	102
17	Qtot to HGL	Btu	132000
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	7920
20	Calculated Enclosure Volume, V	ft3	303500
21	Calculated Qnet/V	Qnet/ft3	0.03
22	HGL Temperature Increase	F	2

Figure A-4

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	12140
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	0.10
3	Height from Fire Source to Ceiling, H	ft	8.00
4	Ratio of Target Height/Ceiling Height		0.013
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	117
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	234
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	1600
15	Temperature at Target	F	1600
16	Temperature in HGL	F	102
17	Qtot to HGL	Btu	58320
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	3499
20	Calculated Enclosure Volume, V	ft3	97120
21	Calculated Qnet/V	Qnet/ft3	0.04
22	HGL Temperature Increase	F	2

Figure A-5

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	12140
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	14.00
3	Height from Fire Source to Ceiling, H	ft	22.00
4	Ratio of Target Height/Ceiling Height		0.636
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	138
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	276
12	Plume Temperature Rise at Target	F	177
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	177
15	Temperature at Target	F	278
16	Temperature in HGL	F	101
17	Qtot to HGL	Btu	49680
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	2981
20	Calculated Enclosure Volume, V	ft3	267080
21	Calculated Qnet/V	Qnet/ft3	0.01
22	HGL Temperature Increase	F	1

Figure A-6

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	415
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	7.50
3	Height from Fire Source to Ceiling, H	ft	15.00
4	Ratio of Target Height/Ceiling Height		0.500
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	120
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	240
12	Plume Temperature Rise at Target	F	457
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	457
15	Temperature at Target	F	582
16	Temperature in HGL	F	125
17	Qtot to HGL	Btu	43200
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	2592
20	Calculated Enclosure Volume, V	ft3	6225
21	Calculated Qnet/V	Qnet/ft3	0.42
22	HGL Temperature Increase	F	25

Appendix B

Basis for Following ASTM E-119 Time-Temperature Relationship When T(HGL) is 1000 °F

TRANSITION TO
ASTM E-119 TIME-HISTORY
IN THE HOT GAS LAYER

ISSUE:

The Fire Hazard Tool currently under development in the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature relationship as soon as the compartment hot gas layer reaches 1000°F.

BASIS:

The Handbook (Ref., pg. 6-75) states that "Flashover of an enclosure is likely to occur if the temperature of the upper gas layer reaches approximately 1000°F (600°C).

The EPRI assumption of 1000°F is therefore conservative.

As stated near the top of page 6-67 of the Handbook, the intensity of the fire will be somewhat lower when the walls and ceiling absorb significant amounts of energy rather than when act as insulation or radiation barriers.

Since power plant compartments are typically concrete barriers which absorb significant amounts of heat, the intensity of fire will tend to be less severe than fires in compartments with insulated barriers.

ASTM E-119 has been the accepted standard for testing fire barrier systems since the early 1900's. The standard, which was developed from actual fire tests, has been used to evaluate the fire endurance capabilities of fire barriers since it was developed. The time-temperature relationship represented by the curve represents a fully-involved fire compartment.

According to Fred Mowrer of the University of Maryland, plume and ceiling effects disappear in a fully involved fire compartment as the plume/ceiling jet gas are no longer more buoyant than surrounding gases.

Use of the ASTM E-119 time-temperature relationship to represent a fully involved power plant compartment fire is therefore consistent with industry practice. Assuming that that occurs when the hot gas layer reaches 1000°F is more conservative than the 1100°F noted in the Handbook.

Reference: NFPA Fire Protection Handbook, Seventeenth Edition, Section 6/Chapter 6.

Appendix C

Total Heat Load Results

Figure C-1

Total Heat Load
Scenario 1, Loc. No. 10

Time	Temperature	Inc Heat Flux	Target Total Heat Load	Hot Gas Layer Total Heat Load	ASTM E-119 Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	804	1.6	0.0	0.00	0.00
1	805	1.7	0.10	0.02	0.00
2	101	0.2	0.16	0.03	0.02
10	101	0.2	0.26	0.14	1.23
15	101	0.2	0.33	0.21	2.80
20	101	0.2	0.40	0.28	4.66
25	101	0.2	0.47	0.35	6.75
30	101	0.2	0.54	0.41	9.04
40	101	0.2	0.67	0.55	14.10
50	101	0.2	0.81	0.69	19.73
60	101	0.2	0.95	0.82	25.84

Figure C-2

Total Heat Load

Scenario 1, Loc. No. 11

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	1043	3.0	0.0	0.00	0.00
6	1054	3.1	1.10	0.11	0.41
12	1169	4.0	2.37	0.20	1.65
18	1281	5.1	4.01	0.30	3.56
24	1391	6.4	6.07	0.41	5.93
30	1500	7.9	8.63	0.54	8.64
36	1600	9.5	11.76	0.68	11.59
42	1600	9.5	15.17	0.82	14.73
48	1600	9.5	18.57	0.95	18.03
54	1600	9.5	21.98	1.11	21.49
60	1600	9.5	25.39	1.27	25.15

Figure C-3

Total Heat Load
Scenario 3,Loc. No. 11

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	131	0.3	0.0	0.00	0.00
5	132	0.3	0.08	0.09	0.34
10	134	0.3	0.17	0.16	1.37
12	135	0.3	0.20	0.19	1.93
13	104	0.2	0.22	0.20	2.21
15	104	0.2	0.25	0.23	2.84
20	104	0.2	0.32	0.30	4.71
30	104	0.2	0.46	0.44	9.07
40	104	0.2	0.60	0.58	14.13
50	104	0.2	0.73	0.71	19.76
60	104	0.2	0.87	0.85	25.87

Figure C-4

Total Heat Load
Scenario 1, Loc. No. 12

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	1600	9.5	0.0	0.00	0.00
6	1600	9.5	3.41	0.11	0.41
12	1600	9.5	6.82	0.19	1.65
18	1600	9.5	10.23	0.28	3.56
24	1600	9.5	13.64	0.36	5.93
30	1600	9.5	17.05	0.45	8.64
36	1600	9.5	20.46	0.54	11.59
42	1600	9.5	23.86	0.63	14.73
48	1600	9.5	27.27	0.73	18.03
54	1600	9.5	30.68	0.83	21.49
60	1600	9.5	34.09	0.93	25.15

Figure C-5

Total Heat Load
Scenario 3, Loc. No. 12

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	277	0.5	0.0	0.00	0.00
6	278	0.5	0.17	0.11	0.41
12	279	0.5	0.34	0.19	1.65
18	279	0.5	0.51	0.27	3.56
24	280	0.5	0.68	0.35	5.93
30	281	0.5	0.85	0.44	8.64
36	281	0.5	1.02	0.52	11.59
42	282	0.5	1.19	0.60	14.73
48	282	0.5	1.37	0.69	18.03
54	283	0.5	1.54	0.77	21.49
60	284	0.5	1.71	0.86	25.15

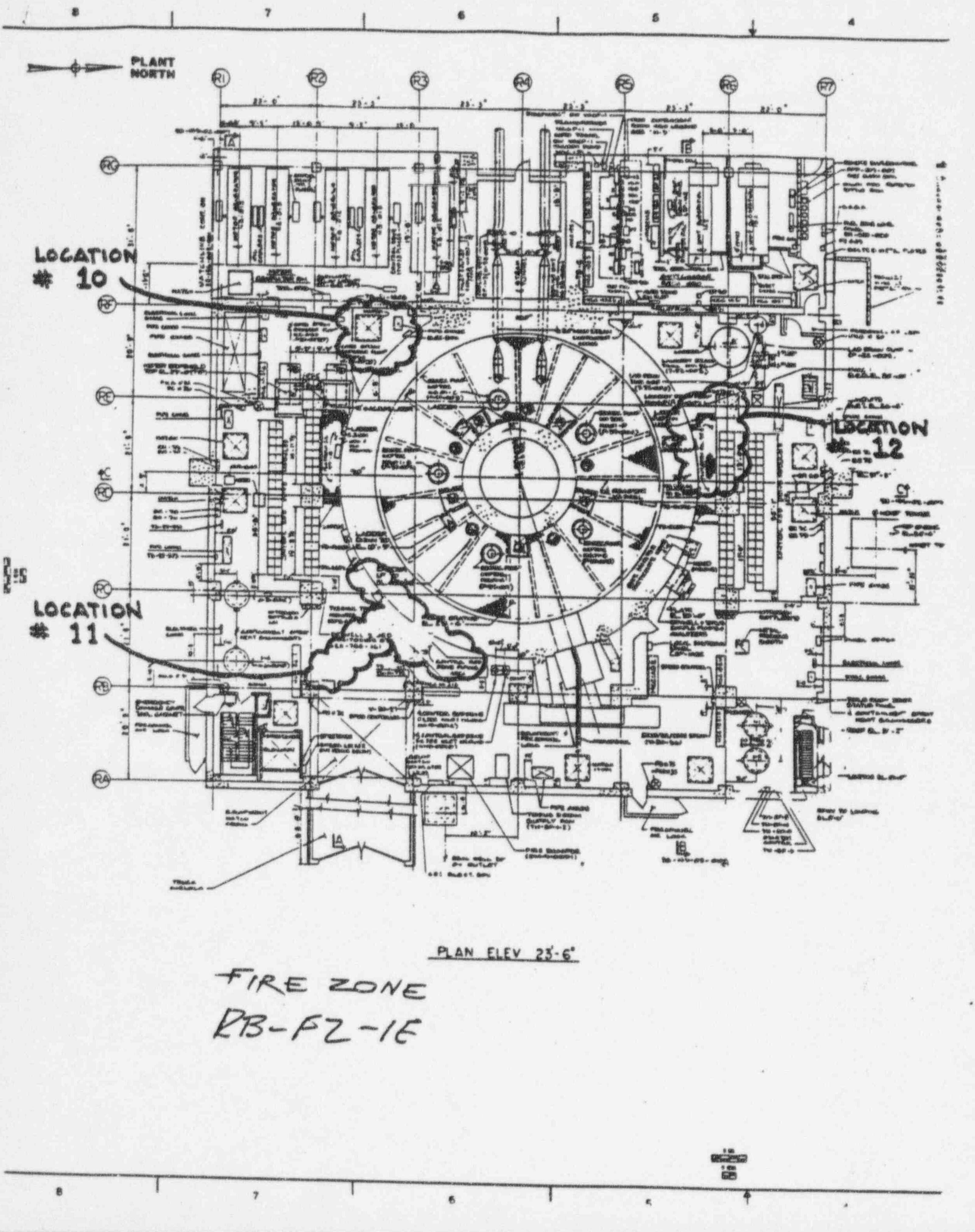
Figure C-6

Total Heat Load
Scenario 1, Loc. No. 15

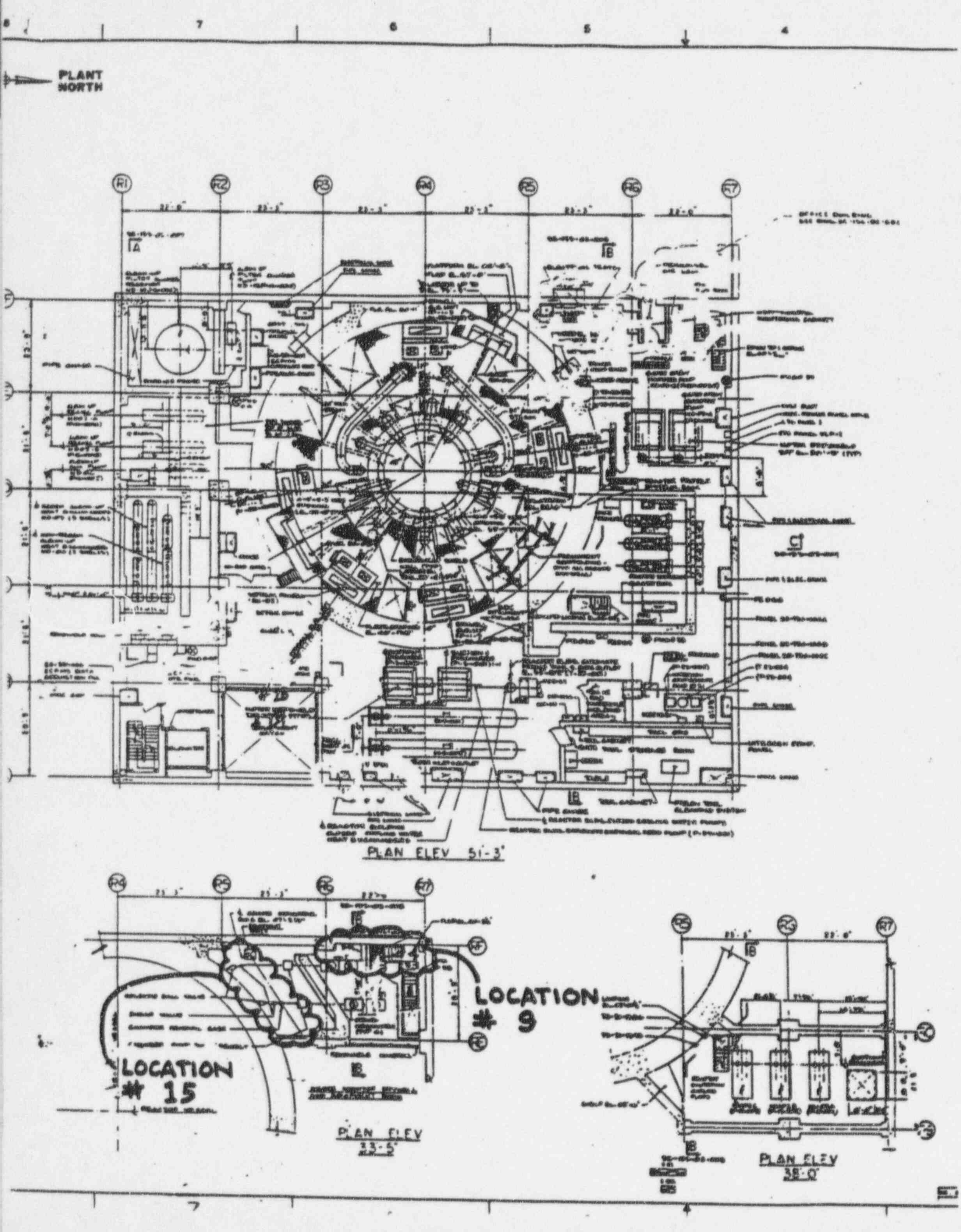
			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	557	0.9	0.0	0.00	0.00
6	582	1.0	0.34	0.11	0.41
12	608	1.0	0.70	0.22	1.65
18	635	1.1	1.07	0.35	3.56
24	664	1.2	1.48	0.47	5.93
30	693	1.3	1.93	0.59	8.64
36	724	1.4	2.42	0.74	11.59
42	757	1.5	2.93	0.92	14.73
48	791	1.7	3.51	1.10	18.03
54	826	1.8	4.13	1.29	21.49
60	863	2.0	4.80	1.49	25.15

Appendix D

General Arrangement Drawings



PLANT NORTH
LOCATION # 10
LOCATION # 11
LOCATION # 12
PLAN ELEV 23'-6"
FIRE ZONE
RB-FZ-1E



PLANT NORTH
PLAN ELEV 51'-3"
LOCATION # 9
LOCATION # 15
PLAN ELEV 23'-5"
PLAN ELEV 38'-0"

TR 102
APPENDIX C

Using FIVE Fire Modeling to Approximate Exposure Time-History for Thermo-Lag Configurations in OC Fire Zone RB-FZ-1F2

Letter Report
September 26, 1995

Prepared by:
GPUN Risk Analysis Group

1. PURPOSE

The purpose of this report is to document the detailed fire modeling performed for fire scenarios involving Thermo-Lag wrapped cable conduits as identified during plant walkdowns of OC fire zone RB-FZ-1F2. Thermo-Lag exposure time-history results were obtained for each T-L configuration determined to be impacted by a fire source/combustible.

2. APPROACH

The approach followed for modeling of fire scenarios is based on methodology detailed in the EPRI "Methods for Evaluation of Cable Wrap Fire Barrier Performance" document (Ref. 1) which was based on fire modeling techniques developed for FIVE (Ref. 2). Fire modeling was accomplished in two steps:

1. Screening walkdowns to eliminate from further consideration those fire ignition sources and potential fire scenarios that cannot develop into damaging fires.

2. Fire modeling of specific scenarios that were not screened out in the first step.

For each Thermo-Lag configuration analyzed, one or more fire scenarios (including bounding scenarios) were postulated based on the following:

a. information gathered during plant walkdowns (i.e., fixed or transient ignition source and Thermo-Lag target location, type and quantity of combustibles present in zone);
b. information obtained from reviewing applicable sections in Appendix R documents for OC (Ref. 3);
c. information obtained from reviewing OC procedure 120.5, Rev. 5, "Control of Combustibles." (Ref. 4)
d. information provided by GPUN engineers (specializing in fire protection, risk assessment, mechanical).

Thermo-Lag FIVE analyses were performed using computerized Excel spreadsheets which duplicate FIVE Worksheets 1, 2, or 3 and are linked to tables containing the same information as in FIVE Reference Tables. For each Thermo-Lag fire modeling scenario, results are presented as exposure time-temperature profiles. In all scenarios evaluated , time-dependent temperatures were derived by incrementally adding the total heat content of the fuel into the fire compartment hot gas layer.

3. FIRE MODELING ASSUMPTIONS

The following Thermo-Lag fire modeling assumptions were made:

1. Worst-case fixed fire source scenarios were modeled for each Thermo-Lag sub-configuration. The determination of which fixed fire source might cause the worst-

was based on minimum damage threshold heights and distances calculated for typical fixed fire sources (e.g., electrical cabinets, electrical motors, lube oil in pumps) found at Oyster Creek.

2. Worst-case transient fire source scenarios observed during walkdowns were also modeled. Worst-case transient fire scenarios considered were similar to the type and quantities of transient combustibles allowed by OC station procedure (Ref. 4).
3. To ensure conservative results, worst-case fire plume (or ceiling jet) scenarios and/or radiant flux scenario were first modeled. For T-L sub-configurations not in the plume or ceiling jet, hot gas layer fire scenarios were evaluated.
4. Electrical cable inside cabinets, motor control centers, switchgear and cable trays was assumed to be non-qualified (i.e., non IEEE-383 type). This assumption is conservative since electrical cable purchased and installed at Oyster Creek in the past decade was IEEE-383 type.
5. The Fire Hazard Tool developed for the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature curve as soon as the compartment hot gas layer (HGL) reaches 1000°F. When the HGL temperature reaches 1000°F, the plume (or ceiling jet) temperatures are assumed to follow that of the E-119 (see discussion in Appendix B).
6. The Thermo-Lag wrap is assumed to burn by itself (i.e., even after the initial fire source is out of fuel) unless otherwise stated. Per, the EPRI Method (Ref. 1, Appendix I-D), credit may be taken for a time lag before the Thermo-Lag ignites based on exposure temperature.
7. The maximum plume and ceiling jet temperature is assumed to be 1600°F, which corresponds to flame temperature. This assumption is valid until hot gas layer temperature exceeds 1600°F, at which point the plume temperature is assumed to be equal to hot gas layer temperature.

4. FIRE MODELING RESULTS

4.1 Fire Zone RB-FZ-1F2

Fire zone RB-FZ-1F2 is the Reactor Building South-West Corner Room at Elevation -19'6". This fire zone houses two core spray pumps, the reactor building equipment drain tank and, the reactor building equipment drain pump. The T-L wrap conduit run in this fire zone starts at Elevation 2 ft. (about 21 ft. off the floor) and runs along the west wall and then curves and exits through the ceiling. The general location of the T-L wrap in this fire zone is shown as location # 2 on the general arrangement drawing shown in Appendix D. This area was not accessible during the walkdowns due to high radiation and the information used here was obtained from previously taken pictures, drawings, and communication with plant fire protection personnel.

Scenario No. 1

The fixed fire ignition source considered here is the Reactor Building Equipment Drain Pump (P-22-001). This pump contains up to 2.5 gallons of lube oil in the motor and the gearbox (Ref. 6) and sits at -6' Elevation (General Arrangement Drawings). This source was chosen because it is more bounding than the core spray pumps. Each of core spray pumps contain up to 2 gallons of oil (Ref. 6) and they are at Elevation -19 ft. The total Q available for this source is 387,600 BTU (Ref. 5, Page E2-1, assumed to be the same at OC), heat release rate 110 BTUs/sec-ft^2 (from Ref. 2, Table 2E). The potential oil spread area around the pump was estimated at 5 ft^2 The Thermo-Lag wrap is located 8 ft above the fire source at its closest proximity and is outside of fire plume. The floor area for this fire zone is 560 ft^2 (Ref. 3). The ceiling height is 40 ft. (general arrangement drawings). Ambient temperature assumed was 100 °F.

Results

The time temperature profile scenario calculated by the model are presented in Table 1. The model results indicate that hot gas layer effects in the zone due to this postulated fire cause the temperature to rise to approximately 194°F. A sample model worksheet is provided in Appendix A, Figure A-1.

Table 1. Temperature-Time History for Fire Scenario 1.

Time (min.)	HRR to Target (Btu/s)	HRR to HGL (Btu/s)	QTOT (Btu)	Temp. Target - (F)	Temp. HGL - (F)
0	550	550	0	100	100
5	550	550	165000	138	138
10	550	550	330000	179	179
11.7	550	550	386100	194	194
12	0	0	386100	194	194
15	0	0	386100	194	194
20	0	0	386100	194	194
30	0	0	386100	194	194
40	0	0	386100	194	194
50	0	0	386100	194	194
60	0	0	386100	194	194

Scenario No. 2

This fire scenario modeled a transient ignition source/combustible, a 5 gallon container containing lube oil. Per Oyster Creek Procedure "Control of Combustibles," Procedure No. 120.5, Rev. 4 (Ref. 4), combustible liquids could be transported throughout the plant in an approved closed metal container (but not necessarily a safety-can). For this fire scenario, it was postulated that 1 quart of lube oil is spilled out of a can on the floor and is not cleaned up. The oil is later ignited by a welder working nearby or another transient ignition source and begins to burn. The oil fire could potentially impact a T-L wrap 20 feet above the floor.

The heat release rate for the lube oil is 110 Btu/s-ft^{-2} (from Ref. 2, Table 2E). The oil could spread unconfined over an area of 13.5 ft^{-2} (54 ft.^{2}/gal from Ref. 2, Table 3E). The heat release rate assumed for this fire scenario is 1,485 Btu/s (110 Btu/s-ft^{-2} x 13.5 ft^{-2}). The heat content of one quart of oil is (17,111 Btu/lb. * 60 lb./1 ft^{-3}. * 1 ft.^{3}/30 quarts) 34,222 Btu (from Ref. 2, Table 2E). The oil fire duration will be less than one minute, but one minute will be used for conservatism. The virtual surface of the fire is at the floor level. The location factor for this source is one.

Results

The short oil fire does not cause an exposure temperature high enough to ignite the Thermo-Lag. The fire is of a short duration, with very slight hot gas layer effects. A sample model worksheet is provided as Appendix A, Figure A-2.

Table 2. Temperature-Time History for Fire Scenario 2.

Time (min.)	HRR to Target (Btu/s)	HRR to HGL (Btu/s)	QTOT (Btu)	Temp. Target - (F)	Temp. HGL - (F)
0	1485	1485	0	400	100
1	1485	1485	89100	414	114
2	0	0	89100	114	114
10	0	0	89100	114	114
15	0	0	89100	114	114
25	0	0	89100	114	114
30	0	0	89100	114	114
35	0	0	89100	114	114
40	0	0	89100	114	114
50	0	0	89100	114	114
60	0	0	89100	114	114

5. FIRE MODELING SUMMARY

Fire modeling was performed for one fixed and one transient fire Source-Thermo-lag wrap configuration in Oyster Creek Fire Zone RB-FZ-1F2. The analysis results are presented as time- temperature profiles. These results are used in the following section to develop total heat load and then convert to equivalent ASTM E-119 exposures.

6. APPROXIMATING EXPOSURE TIME-HISTORY OF THERMO-LAG SUB-CONFIGURATIONS – THE TOTAL HEAT LOAD CONCEPT

Calculation of an exposure time-temperature profile for a specific T-L Sub-configuration is based on the methodology presented in Reference 1. The time -temperature profiles are used to develop the total heat load (Reference 1, Appendix III-A) for each fire exposure. The total heat load concept holds that the area under the incident heat flux vs. time curve, or total heat load, can be used as a measure of fire severity. Comparing the total heat load of a fire scenario exposure to the total heat load of a test exposure (ASTM E-119) allows one to predict the response of a Thermo-Lag barrier to the scenario exposure. The total heat load per unit area of fire barrier surface is equal to the area under the incident heat flux-time curve, corrected for convection effects as described in Reference 1, Appendix III-A.

6.1 Total Heat Load Results

Location No.(GA DWG, App. D)	Scenario	Description	Peak Temperature at Target (°F)	Total Heat Load Equivalent E-119 Exposure Duration (min.)
2	1	Oil fire at RBED Pump (P-22-001)	194	<12
2	2	Oil Transient	414	<10

Appendix C contains tables with Total Heat Load values calculated for Thermo-Lag scenarios 1, and 2.

7. REFERENCES

1. EPRI Report "Methods for Evaluation of Cable Wrap Fire Barrier Performance", July, 1995

2. EPRI TR-100370, "Fire-Induced Vulnerability Evaluation," April 1992.

3. GPUN, "Fire Hazards Analysis Report – OC," Doc. No. 990-1746, Rev. 8, May 24, 1995.

4. GPUN - OC Procedure No. 120.5 (Revision 5), May 20, 1993.

5. GPUN - TMI-1 Procedure No. 1035 (Revision 24), August 23, 1994.

6. Personal communication with Malcolm Gonzales of GPUN, in charge of plant oil program.

Appendix A

Sample Scenario Worksheets

Figure A-1

Temperature calculation at time		min	5
Maximum ambient temperature		F	100
Floor Area		ft2	560
1	Location of Target		Hot Gas Layer
2	Height of Target above Fire Source	ft	8.00
3	Height from Fire Source to Ceiling, H	ft	28.00
4	Ratio of Target Height/Ceiling Height		0.286
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	550
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	550
12	Plume Temperature Rise at Target	F	713
13	Temp Rise Factor at Target		0.00
14	Temperature Rise at Target	F	0
15	**Temperature at Target**	F	**138**
16	**Temperature in HGL**	F	**138**
17	Qtot to HGL	Btu	165000
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	9900
20	Calculated Enclosure Volume, V	ft3	15680
21	Calculated Qnet/V	Qnet/ft3	0.63
22	HGL Temperature Increase	F	38

Figure A-2

Temperature calculation at time		min	1
Maximum ambient temperature		F	100
Floor Area		ft2	560
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	20.00
3	Height from Fire Source to Ceiling, H	ft	40.00
4	Ratio of Target Height/Ceiling Height		0.500
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	1485
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	1485
12	Plume Temperature Rise at Target	F	300
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	300
15	**Temperature at Target**	F	**414**
16	**Temperature in HGL**	F	**114**
17	Qtot to HGL	Btu	89100
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	5346
20	Calculated Enclosure Volume, V	ft3	22400
21	Calculated Qnet/V	Qnet/ft3	0.24
22	HGL Temperature Increase	F	14

Appendix B

Basis for Following ASTM E-119 Time-Temperature Relationship When T(HGL) is 1000 °F

TRANSITION TO
ASTM E-119 TIME-HISTORY
IN THE HOT GAS LAYER

ISSUE:

The Fire Hazard Tool currently under development in the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature relationship as soon as the compartment hot gas layer reaches 1000°F.

BASIS:

The Handbook (Ref., pg. 6-75) states that "Flashover of an enclosure is likely to occur if the temperature of the upper gas layer reaches approximately 1000°F (600°C).

The EPRI assumption of 1000°F is therefore conservative.

As stated near the top of page 6-67 of the Handbook, the intensity of the fire will be somewhat lower when the walls and ceiling absorb significant amounts of energy rather than when act as insulation or radiation barriers.

Since power plant compartments are typically concrete barriers which absorb significant amounts of heat, the intensity of fire will tend to be less severe than fires in compartments with insulated barriers.

ASTM E-119 has been the accepted standard for testing fire barrier systems since the early 1900's. The standard, which was developed from actual fire tests, has been used to evaluate the fire endurance capabilities of fire barriers since it was developed. The time-temperature relationship represented by the curve represents a fully-involved fire compartment.

According to Fred Mowrer of the University of Maryland, plume and ceiling effects disappear in a fully involved fire compartment as the plume/ceiling jet gas are no longer more buoyant than surrounding gases.

Use of the ASTM E-119 time-temperature relationship to represent a fully involved power plant compartment fire is therefore consistent with industry practice. Assuming that that occurs when the hot gas layer reaches 1000°F is more conservative than the 1100°F noted in the Handbook.

Reference: NFPA Fire Protection Handbook, Seventeenth Edition, Section 6/Chapter 6.

Appendix C

Total Heat Load Results

Figure C-1

Total Heat Load
Scenario 1

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	100	0.4	0.0	0.00	0.00
5	138	0.3	0.10	0.10	0.34
10	179	0.4	0.20	0.20	1.37
11.7	194	0.4	0.24	0.24	1.85
12	194	0.4	0.25	0.25	1.93
15	194	0.4	0.32	0.32	2.88
20	194	0.4	0.45	0.45	4.74
30	194	0.4	0.70	0.70	9.11
40	194	0.4	0.95	0.95	14.17
50	194	0.4	1.20	1.20	19.80
60	194	0.4	1.45	1.45	25.91

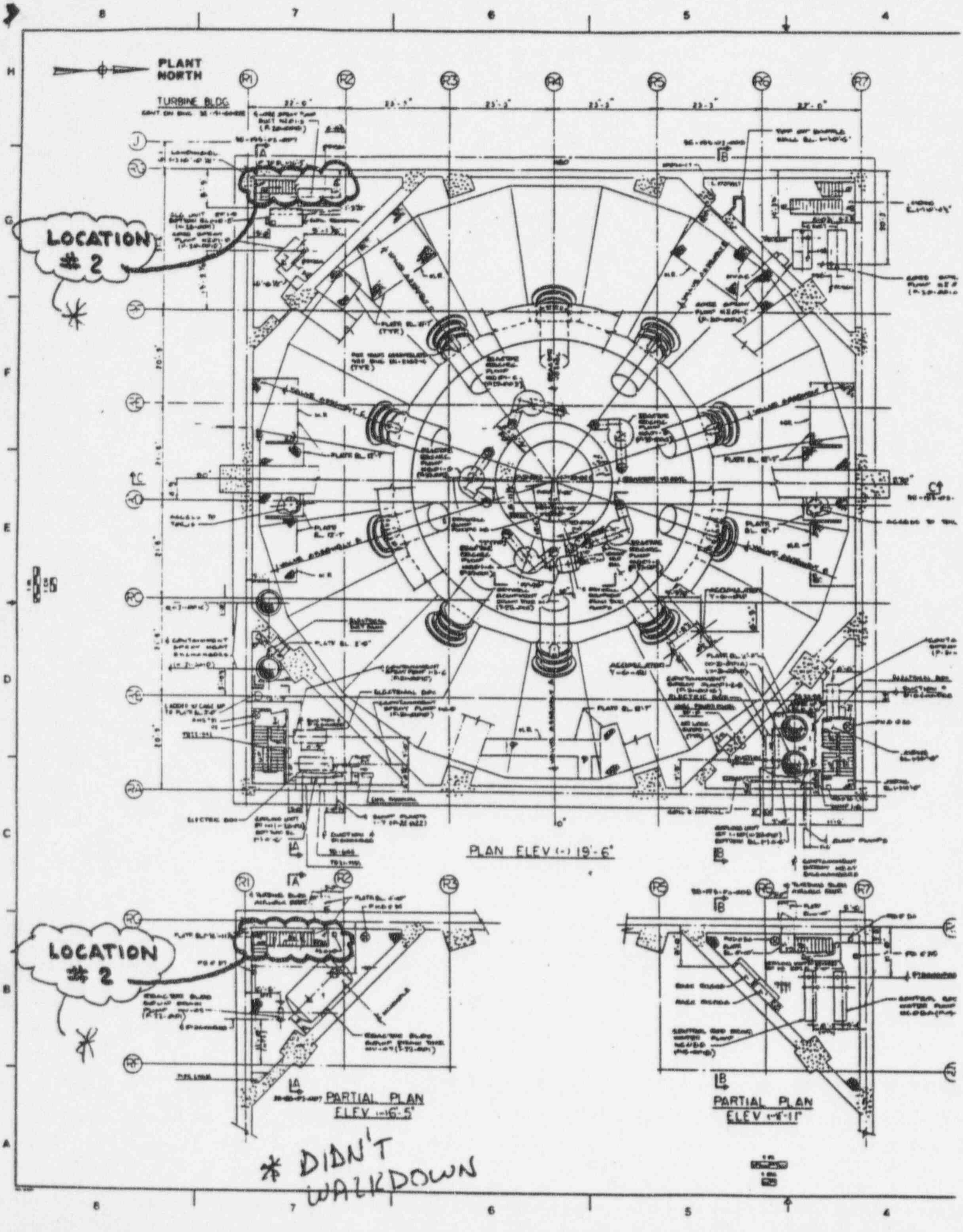
Figure C-2

Total Heat Load
Scenario 2

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	400	0.7	0.0	0.00	0.00
1	414	0.6	0.04	0.02	0.00
2	114	0.2	0.06	0.03	0.02
10	114	0.2	0.18	0.15	1.23
15	114	0.2	0.26	0.23	2.80
20	114	0.2	0.33	0.30	4.66
25	114	0.2	0.41	0.38	6.75
30	114	0.2	0.48	0.45	9.04
40	114	0.2	0.63	0.60	14.10
50	114	0.2	0.78	0.75	19.73
60	114	0.2	0.93	0.90	25.84

Appendix D

General Arrangement Drawings



PLANT NORTH
TURBINE BLDG
LOCATION #2
PLAN ELEV (-) 19'-6"
LOCATION #2
PARTIAL PLAN ELEV (-)16'-5"
PARTIAL PLAN
* DIDN'T WALKDOWN

TR 102

APPENDIX D

Evaluation of Thermo-Lag Cable Wrap Fire Barriers in Oyster Creek Fire Zone TB-FZ-11D

Report No. 01-0082-05-2965-700-1

July 21, 1995

Prepared by:
Science Applications International Corporation, Inc.

1. PURPOSE

The purpose of this report is to document the detailed fire modeling performed for fire scenarios involving Thermo-Lag wrapped cable conduits, as identified during plant walkdowns of the Oyster Creek Turbine Building Basement Floor, South End, Fire Zone TB-FZ-11D. This fire zone includes two separate Thermo-Lag (T-L) conduit configurations (based on plant walkdown notes of October 27, 1994 and Oyster Creek plant drawings of Appendix R Raceway-Turbine Building Basement, Ref. 1). Fire exposure time-temperature profile results were obtained for each of these two T-L configurations, as analyzed in seven fire modeling scenarios involving fixed and transient fire sources.

2. APPROACH

The approach followed for modeling of fire scenarios is based on methodology detailed in the EPRI "Methods for Evaluation of Cable Wrap Fire Barrier Performance" document (Ref. 2). which was based on fire modeling techniques developed for FIVE (Ref. 3). Fire modeling was accomplished in two steps:

1. Screening walkdowns to eliminate from further consideration those fire ignition sources and potential fire scenarios that can't develop into damaging fires.
2. Fire modeling of specific scenarios that were not screened out in the first step.

For each of the two Thermo-Lag configuration analyzed, one or more fire scenarios (including bounding scenarios) were postulated based on the following:

a. information gathered during plant walkdowns (i.e., fixed or transient ignition source and Thermo-Lag target location, type and quantity of combustibles present in zone);
b. information obtained from reviewing applicable sections in Appendix R documents for Oyster Creek Unit (Ref. 4);
c. information obtained from reviewing Oyster Creek procedure 120.5, Rev. 5, "Control of Combustibles" (Ref. 6)
d. information provided by GPUN engineers (specializing in fire protection, risk assessment, mechanical).

Thermo-Lag FIVE analyses were performed using computerized Excel spreadsheets which duplicate FIVE Worksheets 1, 2, or 3 and are linked to tables containing the same information as in FIVE Reference Tables. For each Thermo-Lag fire modeling scenario, results are presented as exposure time-temperature profiles. In all evaluated scenarios, time-dependent temperatures were derived by incrementally adding the total heat content of the fuel into the fire compartment hot gas layer.

3. FIRE MODELING ASSUMPTIONS

The following Thermo-Lag fire modeling assumptions were made:

1. Worst-case fixed fire source scenarios were modeled for each Thermo-Lag sub-configuration. The determination of which fixed fire source might cause the worst-case Thermo-Lag fire scenario was made during the plant fire area walkdown and was based on minimum damage threshold heights and distances calculated for typical fixed fire sources (e.g., electrical cabinets, electrical motors, lube oil in pumps) found at Oyster Creek.
2. Worst-case transient fire source scenarios observed during walkdowns were also modeled. Worst-case transient fire scenarios considered were identical to the types and quantities of transient combustibles identified specifically for TB-FZ-11D in walkdown.
3. To ensure conservative results, worst-case fire plume (or ceiling jet) scenarios and/or radiant flux scenario were first modeled. For T-L sub-configurations not in the plume or ceiling jet, hot gas layer fire scenarios were evaluated.
4. Electrical cable inside cabinets, motor control centers, switchgear and cable trays was assumed to be non-qualified (i.e., non IEEE-383 type). This assumption is conservative since electrical cable purchased and installed at Oyster Creek in the past decade was IEEE-383 type.
5. The Fire Hazard Tool developed for the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature curve as soon as the compartment hot gas layer (HGL) reaches 1000°F. When the HGL temperature reaches 1000°F, the plume (or ceiling jet) temperatures are assumed to follow that of the E-119 (see discussion in Appendix B).
6. The Thermo-Lag wrap is assumed to burn by itself (i.e., even after the initial fire source is out of fuel) unless otherwise stated. Per, the EPRI Method (Ref. 2, Appendix I-D), credit may be taken for a time lag before the Thermo-Lag ignites based on exposure temperature.
7. The maximum plume and ceiling jet temperature is assumed to be 1600°F, which corresponds to flame temperature. This assumption is valid until hot gas layer temperature exceeds 1600°F, at which point the plume temperature is assumed to be equal to hot gas layer temperature.

8. Fire Zone TB-FZ-11D specific data:
    - total area of 9,668 ft^2 (Ref. 4 - Oyster Creek Fire Hazard Analysis Report, Rev. No. 5);
    - fire zone ceiling height of 20 feet (General Arrangement dwg.);
    - ambient temperature of 100°F.

4. FIRE MODELING RESULTS

4.1 Thermo-Lag Configuration 1, Scenario 1

The ignition source/combustible considered in this scenario is a Protective Clothing (PC) storage bin (a transient combustible) observed during the plant walkdown. It is assumed that the PC bin (3 ft tall) contains 50 lb. of PC's and the plastic container itself, for a total heat content (Q) of 800,000 Btu (from Ref. 5, page E2-1). The heat content assumes 400,000 Btus for the plastic container and 400,000 Btus (8000 Btu/lb. * 50 lb.) for the PCs. A heat release rate of 285 Btu/s was chosen for this fire source based on test data (Ref. 2 App. I-E NBS-Lee, clothing). The test report indicates that there were 10 lb. of clothing used for this test and that the heat release rate was 57 Btu/s. The heat release rate is assumed to increase in proportion to the mass of the PCs. This increase is conservative, because heat release rates are normally more dependent on surface area than on combustible mass. At this heat release rate, the PC bin source will burn for 47 minutes (800,000 Btu/285 Btu/s). The targets in this scenario are two Thermo-Lag wrapped conduits, CGCTB019 and CGPTB020, each 1.5 inch in diameter, (Ref. 1). The Thermo-Lag wrap is assumed to be 0.5 inch thick, with a 6 inch combined total diameter. The targets are located 5 feet above the room floor and 3.5 feet offset from the source/combustible (i.e., in the hot gas layer). However, one T-L wrapped support is located directly in the plume of the fire and is assumed to ignite and burn for the entire scenario. The heat release rate for the T-L wrap is 8.8 $Btu/s/ft.^2$ (Ref. 2, Appendix I-D). The T-L heat release rate of 41.5 Btu/s was added to that of PC bin fire source (285 Btu/s) for the hot gas layer calculations. The virtual surface of the fire is 3 feet above floor level. The fire source is not against the room wall, so the location factor is one.

Results

The time temperature profile scenario calculated by the model are presented in Table 1. The time-temperature profile shows that the temperature at the target will be at flame temperature for the entire scenario. The target in this case is the Thermo-Lag wrapped support, not the protected conduits themselves. The conduit exposure is expected to be only hot gas layer because it is outside of the plume region. The model results indicate that hot gas layer effects in the zone due to this postulated fire are negligible. A sample model worksheet is provided as Appendix A, Figure A-1. The time-temperature profile for this scenario is shown in Table 1.

Table 1. Temperature-Time History for Fire Scenario Modeled in Configuration 1, Scenario 1.

Time	HRR to Target	HRR to HGL	QTOT	Temperature	Temperature
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	285	327	0	1600	100
5	285	327	98100	1600	102
10	285	327	196200	1600	104
15	285	327	294300	1600	106
20	285	327	392400	1600	108
25	285	327	490500	1600	111
30	285	327	588600	1600	113
40	285	327	784800	1600	117
47	285	327	922140	1600	120
48	0	42	924660	1600	120
60	0	42	954900	1600	121

4.2 Thermo-Lag Configuration 1, Scenario 2

Scenario two postulates a fire in a 3' wide electrical cabinet on the wall, 4 feet off the ground. The location factor for the fire is two. The target for the scenario is an unwrapped 12" cable tray 7 feet directly above the panel, 11 feet off the ground. A second 24" cable tray is located 1 foot above the first cable tray. In addition to the vertical propagation, the fire is also assumed to propagate horizontally along the exposed cable tray with a flame spread rate of 10 feet per hour. The T-L of concern for this scenario is configuration 1 which are 6 feet offset from the cable trays and three feet below the ceiling. They will see only hot gas layer exposure.

The heat release rates used for this scenario are as follows:

1. electrical panel with non qualified cable -- 400 Btu/s (Ref. 3); this HRR is applicable to scenario time t=0 to 15 minutes;
2. first cable tray -- 23.4 Btu/s- $ft.^2$ (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); since 3 $ft.^2$ (3 linear feet, 1 foot wide) are initially burning, the HRR for this source alone is 70 Btu/s. An additional 23.4 Btu/s are added every 6 minutes to account for fire propagation;
3. second cable tray -- 23.4 Btu/s- $ft.^2$ (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); 10 ft^2 (5 linear feet, 2 feet wide) are burning, therefore the HRR for this second cable tray is 234 Btu/s, and additional 47 Btu/s are added every 6 minutes to account for fire propagation.

The total available heat (Q_{tot}) from each fire source is:

1. electrical panel – 360,000 Btus (assumes that the panel contains enough fuel to sustain a 15 minute fire);
2. first cable tray – 2,400,000 Btus [assumes 10,000 Btu/lb. of cable tray (per Ref. 5, page E2-1) x 10 linear feet x 24 lb./linear foot (engineering judgment for 100% filled, 12 inch wide cable tray)]. The fuel will last for the full one hour duration of the fire;
3. second cable tray – 4,000,000 Btus [assumes 10,000 Btu/lb. of cable tray (per Ref. 5, page E2-1) x 10 linear feet x 40 lb./linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)]. The fuel will last for the full one hour duration of the fire.

Results

The results are presented in Table 2. The model results indicate that hot gas layer effects in the zone due to this postulated fire cause the temperature to rise to approximately 322°F. A sample model worksheet is provided in Appendix A, Figure A-2.

Table 2. Temperature-Time History for Fire Scenario Modeled in Configuration 1, Scenario 2.

Time	HRR to Target	HRR to HGL	QTOT	Temperature	Temperature
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	704	704	0	100	100
5	774	774	232260	111	111
10	844	844	485580	123	123
15	915	915	759960	136	136
16	985	985	819048	138	138
25	1055	1055	1388748	167	167
30	1125	1125	1726308	184	184
35	1195	1195	2084928	203	203
40	1266	1266	2464608	224	224
50	1336	1336	3266088	270	270
60	1406	1406	4109688	322	322

4.3 Thermo-Lag Configuration 1, Scenario 3

This fire scenario modeled a fire in an oil-filled transformer near 460V unit sub-station 1-A-1. The transformer contains 190 gallons of mineral oil (from the plant walkdown). Each gallon of oil is equivalent to 125,656 Btus (from Ref. 3, Table 2E), for a total of about 23.9 million Btus for the entire volume of oil in the transformer. The heat release rate for the transformer oil is 135 Btu/s-ft^2 (from Ref. 2, Table 2E). The oil could spread outside the transformer over an area of 98.5 ft^2 (measured during the plant walkdown). The heat release rate assumed for this fire scenario is 13,300 Btus/s (135 Btu/s-ft^2 x 98.5 ft^2). The fire duration is then (23,9M Btu/13,300 But/s) 30 minutes. The nearest T-L target is 1 foot off the room ceiling and 15 feet offset from the edge of the postulated target is 1 foot off the room ceiling and 15 feet offset from the edge of the postulated transformer oil pool fire. The T-L target in this scenario is configuration 1. It consists of two conduits, CGCTB019 and CGPTB020, each 1.5 inch in diameter, wrapped in Thermo-Lag (Ref. 1), with a 6 inch combined total diameter. They are in the ceiling jet region of the fire. When the exposure temperature at the targets reaches 1000°F, the Thermo-Lag is assumed to ignite. A twenty foot length of Thermo-Lag with a surface area of (20' * 0.5'π) 31.4 ft.^{2} is assumed to start burning with a heat release rate of (8.8 Btu/s/ft.^{2} * 31.4 ft.^{2}) 276 Btu/s, which contributes to the hot gas layer. Because the Thermo-Lag is burning when the oil fire goes out, the exposure at the Thermo-Lag is conservatively assumed to remain the same for the remaining fire duration.

Results

The time temperature profile for this model shows that the temperature at the target will reach approximately 1278°F due to a fire of this nature. This temperature is above the ignition temperature of Thermo-Lag. The model results indicate that hot gas layer effects in the zone due to this postulated fire will not reach flashover in the zone. A sample model worksheet is provided in Appendix A, Figure A-3.

Table 3. Temperature-Time History for Fire Scenario Modeled in Configuration 1, Scenario 3.

Time	HRR to Target	HRR to HGL	QTOT	Temperature	Temperature
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	13300	13300	0	613	100
5	13300	13300	3990000	690	177
10	13300	13300	7980000	778	266
15	13300	13300	11970000	879	366
20	13300	13300	15960000	993	480
22	13300	13576	17589120	1044	532
30	13300	13576	24105600	1278	765
31	0	276	24122160	1278	766
40	0	276	24271200	1278	772
50	0	276	24436800	1278	779
60	0	276	24602400	1278	785

4.4 Thermo-Lag Configuration 2, Scenario 1

This fire scenario models a fixed ignition source/combustible. The source is a 2 foot wide cable tray with non IEEE-383 cable, 16 feet off the room's floor. Since the cable is non-qualified, the cable fire can self-ignite (per Ref. 2, Appendix I-A) and start to burn. The fire will then propagate immediately to a second cable tray, located 1 foot above it. In addition to the vertical propagation, the fire is also assumed to propagate horizontally along the exposed cable tray with a flame spread rate of 10 feet per hour (Ref. 2 Appendix I-C). The total amount of cable tray assumed to be available for this fire scenario is 10 feet for a 1 hour fire duration. The cable trays are only about 50% filled (visual observation during plant walkdown). The targets are two 2-inch diameter conduits wrapped in 0.5 inch thick Thermo-Lag. The T-L wrapped conduits pass perpendicularly over the cable trays, 3 feet above them. Due to the close distance between the cable trays and T-L wrapped conduits, the T-L will be ignited by the cable tray fire (assumed conservatively to happen at time t=0 minutes).

The heat release rates considered for this scenario are as follows (by fire source):

1. first cable tray -- 23.4 Btu/s-ft.^{2} (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); since 4 ft^2 (2 linear ft.) are assumed to be initially burning, the HRR for this source alone is 94 Btu/s; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 140 Btu/s, which includes the HRR from 2 ft^2 of additional cable tray);
2. second cable tray -- 23.4 Btu/s-ft.^{2} (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); the HRR for this source alone is 187 Btu/s since 8 ft^2 (4 linear ft.) are assumed initially burning; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 234 Btu/s, which includes the HRR from 2 ft.^{2} of additional cable tray);
3. T-L wrap HRR is assumed to be 8.8 Btu/s-ft.^{2} (per Ref. 2 Appendix I-D); the amount of Thermo-Lag that could be involved in this fire scenario is assumed to be 10 linear feet (visual observation) with a circumference of (2 * .25' * π) 1.6 ft. for a total surface area of 16 ft^2; the HRR is thus 141 Btu/s; this HRR will be considered only for calculating the HGL temperature rise.

The total available heat (Q_{tot}) from each fire source is:

1. first cable tray -- 2,000,000 Btus [assumes 10,000 Btu/lb. of cable tray (per Ref. 5, page E2-1) x 10 linear feet x 20 lb./linear foot (engineering judgment for 50% filled, 24 inch wide cable tray)]; This source has enough combustible material to burn for one hour.
2. second cable tray -- 2,000,000 Btus [assumes 10,000 Btu/lb. of cable tray (per Ref. 5, page E2-1) x 10 linear feet x 20 lb./linear foot (engineering judgment for 50% filled, 24 inch wide cable tray)]; This source has enough combustible material to burn for one hour.
3. Thermo-Lag wrap -- 588,000 Btus (assumes 58,800 Btu/linear foot, from Ref. 7).

Results

The time temperature profile shows that the temperature at the target reaches flame temperature immediately, and remains at that temperature for the remainder of the fire (1 hour). This temperature is above the ignition temperature of Thermo-Lag. The model results indicate that hot gas layer temperature will reach 702°F after an hour. A sample model worksheet is provided in Appendix A, Figure A-4.

Table 4. Temperature-Time History for Fire Scenario Modeled in Configuration 2, Scenario 1.

Time	HRR to Target	HRR to HGL	QTOT	Temperature	Temperature
(min)	(BTU/s)	(BTU/s)	(BTU)	Target - (F)	HGL - (F)
0	281	422	0	1600	100
6	375	516	185616	1600	123
12	468	609	404928	1600	151
18	562	703	657936	1600	186
24	655	796	944640	1600	227
30	749	890	1265040	1600	276
36	843	984	1619136	1600	335
42	936	1077	2006928	1600	405
48	1030	1171	2428416	1600	487
54	1123	1264	2883600	1600	586
60	1217	1358	3372480	1600	702

4.5 Thermo-Lag Configuration 2, Scenario 2

This fire scenario fixed ignition source/combustible is a 2 foot wide electrical cabinet with exposed vertical cable igniting a 24 inch wide cable tray, 14 feet above the room's floor. The scenario postulates that the fire propagates horizontally along the cable tray at a rate of 10 feet per hour (since cable is not IEEE-383 qualified), but away from the nearest Thermo-Lag targets. The nearest T-L targets are located approximately 5 feet offset from the cable tray and at about the same height (i.e., 14 feet off floor). They are below the ceiling jet and will experience hot gas layer exposure only. The Thermo-Lag targets considered in this scenario are configuration 2.

The heat release rates considered for this scenario are as follows (by fire source):

1. electrical panel with non qualified cable -- 400 Btu/s (Ref. 3); this HRR is applicable to scenario time t=0-15 minutes;
2. cable tray -- 23.4 Btu/s- ft^2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); since 4 ft^2 are initially burning, the HRR for this source alone is 94 Btu/s; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 140 Btu/s, which includes the HRR from 2 ft^2 of additional cable tray).

The total available heat (Q_{tot}) from each of the two fire sources is:

1. electrical panel -- 360,000 Btus (it assumes that the panel contains enough fuel to sustain a 15 minute fire);
2. cable tray -- 2,000,000 Btus [it assumes 10,000 Btu/lb. of cable tray (per Ref. 5, page E2-1) x 10 linear feet x 20 lb./linear foot (engineering judgment for 50% filled, 24 inch wide cable tray)]. This is enough combustible material for one hour.

Results

The results are presented in Table 5. The time temperature history shows that the temperature at the target will not increase appreciably, reaching only 202°F. A sample model worksheet is provided as Appendix A, Figure A-5.

Table 5. Temperature-Time History Fire Scenario Modeled in Configuration 2, Scenario 2.

Time	HRR to Target	HRR to HGL	QTOT	Temperature	Temperature
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	494	494	0	100	100
6	540	540	194544	112	112
12	587	587	405936	125	125
18	234	234	490176	131	131
24	281	281	591264	137	137
30	328	328	709200	145	145
36	374	374	843984	154	154
42	421	421	995616	164	164
48	468	468	1164096	175	175
54	515	515	1349424	188	188
60	562	562	1551600	202	202

4.6 Thermo-Lag Configuration 2, Scenario 3

This fire scenario modeled a fixed ignition source/combustible, a 6 inch wide cable tray with non IEEE-383 cable, 18 feet off the room's floor. Since the cable is non-qualified, the cable fire can self-ignite (per Ref. 2, Appendix I-A) and start to burn. The fire will then propagate horizontally along the exposed cable tray with a flame spread rate of 10 feet per hour (per Ref. 11). The total amount of cable tray assumed to be available for this fire scenario is 10 feet (for a 1 hour fire duration). The cable tray is only about 25% filled (visual observation during plant walkdown). The targets are two 2-inch diameter conduits wrapped in 0.5 inch thick Thermo-Lag. The T-L wrapped conduits are routed in the same direction as the cable tray, 8 inches above it. Due to the close distance between the cable tray and T-L wrapped conduits, the T-L will be ignited by the cable tray fire (assumed conservatively to happen at time t=0 minutes). Once this happens, additional heat is released into this Turbine Building Basement fire zone.

The heat release rates considered for this scenario are as follows (by fire source):

1. cable tray – 23.4 Btu/s- ft^2 (Ref. 3, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10). Two linear feet of the 6" wide tray is assumed to burn, so a heat release rate of 23 Btu/s is used. This HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 35 Btu/s, which includes the HRR from 0.5 ft^2 of additional cable tray);
2. T-L wrap HRR is 8.8 Btu/s-ft^2 (per Ref. 2, Appendix I-D). The amount of Thermo-Lag assumed to burn is that portion of the Thermo-Lag directly above the burning cable tray. The circumference of the Thermo-Lag wrapped conduit is 1.6 feet, hence, the HRR for the Thermo-Lag is 1.6 ft. * 1 ft. * 8.8 Btu/s/ft.2 = 14 Btu/linear foot. Two feet will be burning initially plus an additional foot every 6 minutes. This HRR will be considered only for calculating the HGL temperature rise

The total available heat (Q_{tot}) from each fire source is:

1. first cable tray -- 270,000 Btus [assumes 10,000 Btu/lb. of cable tray (per Ref. 5, page E2-1) x 12 linear feet x 3 lb./linear foot (engineering judgment for 25% filled, 6-inch wide cable tray) * 70% combustion];

2. Thermo-Lag wrap – 706,000 Btus (assumes 58,800 Btu/linear foot * 12 feet, from Ref. 7).

Results

Table 6. Temperature-Time History Fire Scenario Modeled in Configuration 2, Scenario 3.

Time	HRR to Target	HRR to HGL	QTOT	Temperature	Temperature
(min)	(BTU/s)	(BTU/s)	(BTU)	Target - (F)	HGL - (F)
0	23	52	0	1600	100
5	35	77	23202	1600	104
10	47	103	54138	1600	110
15	59	129	92808	1600	117
16	70	155	102089	1600	119
25	82	180	199537	1600	137
30	94	206	261409	1600	150
35	105	232	331015	1600	164
40	117	258	408355	1600	179
50	129	284	578503	1600	216
60	140	309	764119	1600	258

The results are presented in Table 6. The T-L wrapped target is at flame temperature for the entire scenario duration. The hot gas layer will reach approximately 234°F. A sample model worksheet is provided as Appendix A, Figure A-6.

4.7 Thermo-Lag Configuration 2, Scenario 4

This fire scenario modeled a transient ignition source/combustible, a 5 gallon container containing lube oil. Per Oyster Creek Procedure "Control of Combustibles," Procedure No. 120.5, Rev. 4 (Ref. 6), combustible liquids could be transported throughout the plant in an approved closed metal container (but not necessarily a safety-can). For this fire scenario, it was postulated that 1 quart of lube oil is spilled out of a can on the floor and is not cleaned up. The oil is later ignited by a welder working nearby or another transient ignition source and begins to burn. The oil fire could potentially impact a T-L wrap 14. feet above the ground.

The heat release rate for the lube oil is 110 Btu/s-ft^2 (from Ref. 3, Table 2E). The oil could spread unconfined over an area of 13.5 ft^2 (54 ft.^{2}/gal from Ref. 3, Table 3E). The heat release rate assumed for this fire scenario is 1,485 Btu/s (110 Btu/s-ft^2 x 13.5 ft^2). The heat content of one quart of oil is (17,111 Btu/lb. * 60 lb./1 ft^3. * 1 ft.^{3}/30 quarts) 34,222 Btu (from Ref. 3, Table 2E). The oil fire duration will be less than one minute, but one minute will be used for conservatism. The virtual surface of the fire is at the floor level. The location factor for this source is one.

Results

The short oil fire does not cause an exposure temperature high enough to ignite the Thermo-Lag. The fire is of a short duration, with almost no hot gas layer effects. A sample model worksheet is provided as Appendix A, Figure A-7.

Table 7. Temperature-Time History for Fire Scenario Modeled in Configuration 2, Scenario 4.

Time	HRR to Target	HRR to HGL	QTOT	Temperature	Temperature
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	1485	1485	0	964	100
1	1485	1485	89100	965	102
2	0	0	89100	102	102
10	0	0	89100	102	102
15	0	0	89100	102	102
25	0	0	89100	102	102
30	0	0	89100	102	102
35	0	0	89100	102	102
40	0	0	89100	102	102
50	0	0	89100	102	102
60	0	0	89100	102	102

5. FIRE MODELING SUMMARY

Seven scenarios were modeled for the two T-L configurations in Oyster Creek Fire Zone TB-FZ-11D.. The analysis results are presented as time- temperature profiles. These results are used in the following section to develop total heat load and then convert to equivalent ASTM E-119 exposures.

6. APPROXIMATING EXPOSURE TIME-HISTORY OF THERMO-LAG SUB-CONFIGURATIONS -- THE TOTAL HEAT LOAD CONCEPT

Calculation of an exposure time-temperature profile for a specific T-L Sub-configuration is based on a the methodology presented in Reference 2. The time - temperature profiles are used to develop the total heat load (Reference 2, Appendix III-A) for each fire exposure. The total heat load concept holds that the area under the incident heat flux vs. time curve, or total heat load, can be used as a measure of fire severity. Comparing the total heat load of a fire scenario exposure to the total heat load of a test exposure (ASTM E-119) allows one to predict the response of a Thermo-Lag barrier to the scenario exposure. The total heat load per unit area of fire barrier surface is equal to the area under the incident heat flux-time curve, corrected for convection effects as described in Reference 2, Appendix III-A.

6.1 Total Heat Load Results

Raceway configuration	Scenario	Description	Peak Temperature at Target (°F)	Total Heat Load Equivalent E-119 Exposure Duration (min.)
1	1	Protective Clothing	1600	>60
1	2	Electrical Cabinet and Cable Tray	322	10
1	3	Transformer	1278	40
2	1	Cable Tray	1600	>60
2	2	Electrical Cabinet and Cable Tray	202	10
2	3	Cable Tray	1600	>60
2	4	Oil transient	965	10

Appendix C contains tables with Total Heat Load values calculated for Thermo-Lag sub-configurations 1, and 2.

7. REFERENCES

1. Oyster Creek Plant Drawing of Turbine Building Basement.

2. EPRI Report "Methods for Evaluation of Cable Wrap Fire Barrier Performance", July, 1995

3. EPRI TR-100370, "Fire-Induced Vulnerability Evaluation," April 1992.

4. GPUN, "Fire Hazard Analysis Report – Oyster Creek," Doc. Non. 990-1746 Rev. 8.

5. GPUN - TMI-1 Procedure No. 1035 (Revision 24), August 23, 1994.

6. GPUN- Oyster Creek Procedure No. 120.5, Rev. 5, "Control Of Combustibles," May 10, 1993.

7. Thermo-Lag 330-1 Combustibility Study, NEI, 1994.

8. "Methods for Evaluating Cable Wrap Fire Barrier Performance," EPRI draft report developed under the Tailored Collaboration Project, October 1994.

9. EPRI TR-100443, "Methods of Quantitative Fire Hazard Analysis," EPRI final report, May 1992.

10. EPRI NP-7332, "Design Guide for Fire Protection of Grouped Electrical Cables," EPRI Final Report, May 1991.

Appendix A

Sample Scenario Worksheets

Temperature calculation at time		min	5
Maximum ambient temperature		F	100
Floor Area		ft2	9668
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	2.00
3	Height from Fire Source to Ceiling, H	ft	17.00
4	Ratio of Target Height/Ceiling Height		0.118
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	285
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	285
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	1600
15	**Temperature at Target**	F	**1600**
16	**Temperature in HGL**	F	**102**
17	Qtot to HGL	Btu	98100
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	5886
20	Calculated Enclosure Volume, V	ft3	164356
21	Calculated Qnet/V	Qnet/ft3	0.04
22	HGL Temperature Increase	F	2

Temperature calculation at time		min	5
Maximum ambient temperature		F	100
Floor Area		ft2	9668
1	Location of Target		Hot Gas Layer
2	Height of Target above Fire Source	ft	5.00
3	Height from Fire Source to Ceiling, H	ft	8.00
4	Ratio of Target Height/Ceiling Height		0.625
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	774
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	1548
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		0.00
14	Temperature Rise at Target	F	0
15	**Temperature at Target**	F	**111**
16	**Temperature in HGL**	F	**111**
17	Qtot to HGL	Btu	232260
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	13936
20	Calculated Enclosure Volume, V	ft3	77344
21	Calculated Qnet/V	Qnet/ft3	0.18
22	HGL Temperature Increase	F	11

Temperature calculation at time		min	5
Maximum ambient temperature		F	100
Floor Area		ft2	9668
1	Location of Target		Ceiling Jet
2	Height of Target above Fire Source	ft	19.00
3	Height from Fire Source to Ceiling, H	ft	20.00
4	Ratio of Target Height/Ceiling Height		0.950
5	Longitudinal Distance from Fire Source to Target, L	ft	15
6	Longitudinal Distance to Height Ratio, L/H		0.75
7	Enclosure Width, W	ft	112
8	Height to Width Ratio, H/W		0.18
9	Peak Fire Intensity	Btu/s	13300
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	13300
12	Plume Temperature Rise at Target	F	1411
13	Temp Rise Factor at Target		0.36
14	Temperature Rise at Target	F	513
15	**Temperature at Target**	F	**690**
16	**Temperature in HGL**	F	**177**
17	Qtot to HGL	Btu	3990000
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	239400
20	Calculated Enclosure Volume, V	ft3	193360
21	Calculated Qnet/V	Qnet/ft3	1.24
22	HGL Temperature Increase	F	77

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	9668
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	2.90
3	Height from Fire Source to Ceiling, H	ft	3.00
4	Ratio of Target Height/Ceiling Height		0.967
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	375
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	375
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	1600
15	**Temperature at Target**	F	**1600**
16	**Temperature in HGL**	F	**123**
17	Qtot to HGL	Btu	185616
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	11137
20	Calculated Enclosure Volume, V	ft3	29004
21	Calculated Qnet/V	Qnet/ft3	0.38
22	HGL Temperature Increase	F	23

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	9668
1	Location of Target		Hot Gas Layer
2	Height of Target above Fire Source	ft	0.00
3	Height from Fire Source to Ceiling, H	ft	6.00
4	Ratio of Target Height/Ceiling Height		0.000
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	540
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	540
12	Plume Temperature Rise at Target	F	0
13	Temp Rise Factor at Target		0.00
14	Temperature Rise at Target	F	0
15	**Temperature at Target**	F	**112**
16	**Temperature in HGL**	F	**112**
17	Qtot to HGL	Btu	194544
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	11673
20	Calculated Enclosure Volume, V	ft3	58008
21	Calculated Qnet/V	Qnet/ft3	0.20
22	HGL Temperature Increase	F	12

Temperature Calculation at time		min	5
Maximum ambient temperature		F	100
Floor Area		ft2	9668
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	0.66
3	Height from Fire Source to Ceiling, H	ft	2.00
4	Ratio of Target Height/Ceiling Height		0.330
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	35
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	35
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	1600
15	**Temperature at Target**	F	**1600**
16	**Temperature in HGL**	F	**104**
17	Qtot to HGL	Btu	23202
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	1392
20	Calculated Enclosure Volume, V	ft3	19336
21	Calculated Qnet/V	Qnet/ft3	0.07
22	HGL Temperature Increase	F	4

Temperature Calculation at time		min	1
Maximum ambient temperature		F	100
Floor Area		ft2	9668
1	Location of Target		Plume
2	Height of Target above Fire Source	ft	14.00
3	Height from Fire Source to Ceiling, H	ft	20.00
4	Ratio of Target Height/Ceiling Height		0.700
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	1485
10	Fire Location Factor		2
11	Effective Fire Intensity	Btu/s	2970
12	Plume Temperature Rise at Target	F	864
13	Temp Rise Factor at Target		1.00
14	Temperature Rise at Target	F	864
15	**Temperature at Target**	F	**965**
16	**Temperature in HGL**	F	**102**
17	Qtot to HGL	Btu	89100
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	5346
20	Calculated Enclosure Volume, V	ft3	193360
21	Calculated Qnet/V	Qnet/ft3	0.03
22	HGL Temperature Increase	F	2

Appendix B

Basis for Following ASTM E-119 Time-Temperature Relationship When T(HGL) is 1000 °F

TRANSITION TO ASTM E-119 TIME-HISTORY IN THE HOT GAS LAYER

ISSUE:

The Fire Hazard Tool currently under development in the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature relationship as soon as the compartment hot gas layer reaches 1000°F.

BASIS:

- The Handbook (Ref., pg. 6-75) states that "Flashover of an enclosure is likely to occur if the temperature of the upper gas layer reaches approximately 1000°F (600°C).

  The EPRI assumption of 1000°F is therefore conservative.

- As stated near the top of page 6-67 of the Handbook, the intensity of the fire will be somewhat lower when the walls and ceiling absorb significant amounts of energy rather than when act as insulation or radiation barriers.

  Since power plant compartments are typically concrete barriers which absorb significant amounts of heat, the intensity of fire will tend to be less severe than fires in compartments with insulated barriers.

- ASTM E-119 has been the accepted standard for testing fire barrier systems since the early 1900's. The standard, which was developed from actual fire tests, has been used to evaluate the fire endurance capabilities of fire barriers since it was developed. The time-temperature relationship represented by the curve represents a fully-involved fire compartment.

- According to Fred Mowrer of the University of Maryland, plume and ceiling effects disappear in a fully involved fire compartment as the plume/ceiling jet gas are no longer more buoyant than surrounding gases.

- Use of the ASTM E-119 time-temperature relationship to represent a fully involved power plant compartment fire is therefore consistent with industry practice. Assuming that that occurs when the hot gas layer reaches 1000°F is more conservative than the 1100°F noted in the Handbook.

Reference: NFPA Fire Protection Handbook, Seventeenth Edition, Section 6/Chapter 6.

Appendix C

Total Heat Load Results

Total Heat Load
Scenario 1 Subconfig. 1

Time (min)	Temperature (F)	Inc Heat Flux (Btu/s-sf)	Target Total Heat Load (1000Btu/sf)	Hot Gas Layer Total Heat Load (1000Btu/sf)	ASTM E-119 Total Heat Load (1000Btu/sf)
0	1600	9.5	0.0	0.00	0.00
5	1600	9.5	2.84	0.09	0.34
10	1600	9.5	5.68	0.16	1.37
15	1600	9.5	8.52	0.23	2.94
20	1600	9.5	11.36	0.30	4.81
25	1600	9.5	14.20	0.37	6.90
30	1600	9.5	17.05	0.45	9.19
40	1600	9.5	22.73	0.60	14.25
47	1600	9.5	26.71	0.70	18.10
48	1600	9.5	27.27	0.72	18.66
60	1600	9.5	34.09	0.91	25.84

Total Heat Load
Scenario 2 Subconfig. 1

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	100	0.4	0.0	0.00	0.00
5	111	0.2	0.09	0.09	0.34
10	123	0.3	0.17	0.17	1.37
15	136	0.3	0.25	0.25	2.94
16	138	0.3	0.27	0.27	3.30
25	167	0.4	0.44	0.44	6.88
30	184	0.4	0.55	0.55	9.17
35	203	0.3	0.66	0.66	11.62
40	224	0.3	0.76	0.76	14.24
50	270	0.5	1.00	1.00	19.87
60	322	0.5	1.27	1.27	25.97

Total Heat Load

Scenario 3 Subconfig. 1

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	613	1.0	0.0	0.00	0.00
5	690	1.3	0.35	0.11	0.34
10	778	1.6	0.79	0.23	1.37
15	879	2.1	1.34	0.38	2.94
20	993	2.7	2.06	0.58	4.81
22	1044	3.0	2.41	0.68	5.60
30	1278	5.1	4.34	1.25	9.10
31	1278	5.1	4.64	1.34	9.57
40	1278	5.1	7.38	2.19	14.13
50	1278	5.1	10.41	3.15	19.76
60	1278	5.1	13.44	4.14	25.87

Total Heat Load
Scenario 1 Subconfig. 2

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	1600	9.5	0.0	0.00	0.00
6	1600	9.5	3.41	0.11	0.48
12	1600	9.5	6.82	0.22	1.87
18	1600	9.5	10.23	0.35	3.92
24	1600	9.5	13.64	0.48	6.34
30	1600	9.5	17.05	0.63	9.05
36	1600	9.5	20.46	0.80	12.02
42	1600	9.5	23.86	0.99	15.21
48	1600	9.5	27.27	1.23	18.58
54	1600	9.5	30.68	1.55	22.14
60	1600	9.5	34.09	1.96	25.86

Total Heat Load

Scenario 2 Subconfig. 2

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	100	0.4	0.0	0.00	0.00
6	112	0.2	0.11	0.11	0.48
12	125	0.3	0.20	0.20	1.87
18	131	0.3	0.30	0.30	3.92
24	137	0.3	0.40	0.40	6.34
30	145	0.3	0.51	0.51	9.05
36	154	0.3	0.62	0.62	12.02
42	164	0.3	0.74	0.74	15.21
48	175	0.4	0.87	0.87	18.58
54	188	0.4	1.01	1.01	22.14
60	202	0.3	1.14	1.14	25.86

Total Heat Load
Scenario 3 Subconfig. 2

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	1600	9.5	0.0	0.00	0.00
5	1600	9.5	2.84	0.09	0.34
10	1600	9.5	5.68	0.16	1.37
15	1600	9.5	8.52	0.24	2.94
16	1600	9.5	9.09	0.25	3.30
25	1600	9.5	14.20	0.40	6.88
30	1600	9.5	17.05	0.49	9.17
35	1600	9.5	19.89	0.59	11.62
40	1600	9.5	22.73	0.70	14.24
50	1600	9.5	28.41	0.91	19.87
60	1600	9.5	34.09	1.14	25.97

Total Heat Load
Scenario 4 Subconfig. 2

Time (min)	Temperature (F)	Inc Heat Flux (Btu/s-sf)	Target Total Heat Load (1000Btu/sf)	Hot Gas Layer Total Heat Load (1000Btu/sf)	ASTM E-119 Total Heat Load (1000Btu/sf)
0	964	2.5	0.0	0.00	0.00
1	965	2.5	0.15	0.02	0.00
2	102	0.2	0.23	0.03	0.02
10	102	0.2	0.34	0.14	1.23
15	102	0.2	0.41	0.21	2.80
25	102	0.2	0.55	0.35	6.73
30	102	0.2	0.62	0.42	9.02
35	102	0.2	0.69	0.48	11.47
40	102	0.2	0.76	0.55	14.09
50	102	0.2	0.89	0.69	19.72
60	102	0.2	1.03	0.83	25.83

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APPENDIX E

Using FIVE Fire Modeling to Approximate Exposure Time-History for Thermo-Lag Configurations in OC Fire Zone TB-FZ-11C

Letter Report
September 26, 1995

Prepared by:
GPUN Risk Analysis Group
Using FIVE Fire Modeling to Approximate Exposure Time-History for Thermo-Lag Configurations

1. PURPOSE

The purpose of this report is to document the detailed fire modeling performed for fire scenarios involving Thermo-Lag wrapped conduit and armored cable wrapped in Thermo-Lag, as identified during plant walkdowns of OC fire zone TB-FZ-11C. Thermo-Lag exposure time-history results were obtained for each T-L configuration determined to be impacted by a fire source/combustible.

2. APPROACH

The approach followed for modeling of fire scenarios is based on methodology detailed in the EPRI "Methods for Evaluation of Cable Wrap Fire Barrier Performance" document (Ref. 1) which was based on fire modeling techniques developed for FIVE (Ref. 2). Fire modeling was accomplished in two steps:

1. Screening walkdowns to eliminate from further consideration those fire ignition sources and potential fire scenarios that cannot develop into damaging fires.

2. Fire modeling of specific scenarios that were not screened out in the first step.

For each Thermo-Lag configuration analyzed, one or more fire scenarios (including bounding scenarios) were postulated based on the following:

a. information gathered during plant walkdowns (i.e., fixed or transient ignition source and Thermo-Lag target location, type and quantity of combustibles present in zone);
b. information obtained from reviewing applicable sections in Appendix R documents for OC (Ref. 3);
c. information obtained from reviewing OC procedure 120.5, Rev. 5, "Control of Combustibles." (Ref. 4)
d. information provided by GPUN engineers (specializing in fire protection, risk assessment, mechanical).

Thermo-Lag FIVE analyses were performed using computerized Excel spreadsheets which duplicate FIVE Worksheets 1, 2, or 3 and are linked to tables containing the same information as in FIVE Reference Tables. For each Thermo-Lag fire modeling scenario, results are presented as exposure time-temperature profiles. In all scenarios evaluated , time-dependent temperatures were derived by incrementally adding the total heat content of the fuel into the fire compartment hot gas layer.

3. FIRE MODELING ASSUMPTIONS

The following Thermo-Lag fire modeling assumptions were made:

1. Worst-case fixed fire source scenarios were modeled for each Thermo-Lag sub-configuration. The determination of which fixed fire source might cause the worst-

case Thermo-Lag fire scenario was made during the plant fire area walkdown and was based on minimum damage threshold heights and distances calculated for typical fixed fire sources (e.g., electrical cabinets, electrical motors, lube oil in pumps) found at Oyster Creek.

2. Due to the location of the T-L wrap in this fire zone (on top of switchgears 1C & 1D), no transient combustible scenarios were noted during walkdowns or postulated as plausible.
3. To ensure conservative results, worst-case fire plume (or ceiling jet) scenarios and/or radiant flux scenario were first modeled. For T-L sub-configurations not in the plume or ceiling jet, hot gas layer fire scenarios were evaluated.
4. Electrical cable inside cabinets, motor control centers, switchgear and cable trays was assumed to be non-qualified (i.e., non IEEE-383 type). This assumption is conservative since electrical cable purchased and installed at Oyster Creek in the past decade was IEEE-383 type.
5. The Fire Hazard Tool developed for the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature curve as soon as the compartment hot gas layer (HGL) reaches 1000°F. When the HGL temperature reaches 1000°F, the plume (or ceiling jet) temperatures are assumed to follow that of the E-119 (see discussion in Appendix B).
6. The Thermo-Lag wrap is assumed to burn by itself (i.e., even after the initial fire source is out of fuel) unless otherwise stated. Per, the EPRI Method (Ref. 1, Appendix I-D), credit may be taken for a time lag before the Thermo-Lag ignites based on exposure temperature.
7. The maximum plume and ceiling jet temperature is assumed to be 1600°F, which corresponds to flame temperature. This assumption is valid until hot gas layer temperature exceeds 1600°F, at which point the plume temperature is assumed to be equal to hot gas layer temperature.

4. FIRE MODELING RESULTS

4.1 Fire Zone TB-FZ-11C

Fire zone TB-FZ-11C is the Turbine Building Switchgear Room, West End of the Mezzanine Level. There is only one area in this fire zone that contains the 3-hr rated fire barrier T-L wrap conduit. This T-L wrap conduit sits on top of switchgears 1C & 1D and it is designated as location No. 13 on the general arrangement drawing shown in Appendix D.

This fire zone has unprotected openings through the floor to fire zone TB-FZ-11D and through the walls except the north wall. The north wall adjoins the fire areas TB-FA-3A and TB-FA-3B which contain safety related 4160V switchgears 1C & 1D and are separated from this zone by 3-hour fire rated roll-up doors. Also, Fire area TB-FA-26, Battery Room, is enveloped with three hour fire resistive rated barriers within this zone.

Due to the location of the T-L wrap in this fire zone (on top of switchgears 1C & 1D), no transient combustible scenarios were noted during walkdowns or postulated as plausible. Based on fire modeling experience for other fire zones, even a quart of oil spill later ignited lasts less than one minute (see Fire Zone RB-FZ-1E, Location No. 10, Scenario # 1). Ref. 5, Attachment 3, Table 13 indicates that even at maximum plume temperature of 1600°F, it takes about one minute for the Thermo-lag to reach the ignition temperature. Therefore, this transient combustible scenario will be insignificant. However, two fixed ignition sources were modeled for this zone. It should also be noted that even though, there is hydrogen seal oil in this fire zone, it is only in piping that passes through the zone.

Scenario 1

This fire scenario models non-safety related switchgear 1B self-igniting. The T-L wrap is not in the plume of such fire and would only see the hot gas layer region. However, there are three 24-inch wide cable trays stacked on top of each other 1 ft. apart in the plume of such fire (directly over the back vents of the switchgear 1B, about 4 ft. above, and run parallel to the west wall along the back of the switchgear). It is assumed that 20 ft of the first cable tray immediately above the switchgear 1B ignites (being in the plume of the switchgear fire). This subsequently leads to ignition of 22 ft. and 24 ft. of the other cable trays above. The time required for these sequential fires to occur is conservatively ignored here. In addition to the vertical propagation, the fire is also assumed to propagate horizontally along the exposed cable tray with a flame speed of 10 feet per hour (per Ref. 2, Appendix I-C). The total amount of cable tray assumed to be available for this fire scenario is 50 feet per tray (for 3 hour fire duration).

The heat release rates considered for this scenario are as follows (by fire source):

1. electrical panel (switchgear 1B) with nonqualified cable – 400 BTU/sec (Ref.1); this HRR is applicable to scenario time t=0-15 minutes;

2. first cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); since 40 ft2 are initially burning, the HRR for this source alone is 936 BTU/sec; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 983 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

3. second cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the first cable tray, the HRR for this source alone is 1030 BTU/sec (since 44 ft2 are initially burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 1076 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

4. third cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the second cable tray, the HRR for this source alone is 1123 BTU/sec (since 48 ft2 are initially burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 1170 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

The total available heat (Qtot) from each fire source is:

1. electrical panel --360,000 BTUs (it assumes that the panel contains enough fuel to sustain a 15 minute fire);

2. first cable tray --20,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 50 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

3. second cable tray --20,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 50 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

4. third cable tray --20,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 50 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

The floor area for this fire zone is 2,666 square feet (Ref. 3) with a height of about 20 feet (General Arrangement Drawings). It should be noted that this zone contains fire areas TB-FA-3A, TB-FA-3B, and TB-FA-26. The floor areas for TB-FA-3A and TB-FA-3B combined is estimated at about 1000 square feet and the floor area for TB-FA-26 is about 250 square feet. The height for these fire areas were estimated at about 10 feet.

Results

The time temperature profile scenario calculated by the model are presented in Table 1. The model results indicate that hot gas layer effects in the zone due to this postulated fire cause the temperature to exceed 1000°F at time = 19 minutes. It should be noted that these HGL temperatures in this compartment are expected to be very conservative due to the number and size of the openings that exist in this fire zone and the tortuous path that the hot gas needs to take to reach the T-L wrap conduit area vs. other direct openings out of this fire zone.

Past the 1000°F HGL temperature, it is assumed that a fire compartment temperature will follow the ASTM E-119 time-temperature relationship (Ref. 1). Appendix B contains the basis for this assumption. A sample model worksheet is provided in Appendix A, Figure A-1.

Table 1. Temperature-Time History for Fire Scenario 1.

Time (min.)	HRR to Target (Btu/s)	HRR to HGL (Btu/s)	QTOT (Btu)	Temp. Target - (F)	Temp. HGL - (F)
0	3489	3489	0	100	100
6	3629	3629	1306440	302	302
12	3769	3769	2663280	589	589
18	3509	3509	3926520	953	953
19	3532	3532	4138440	1025	1025
25				1300*	1300*
60				1638*	1638*
90				1750*	1750*
120				1835*	1835*
150				1862*	1862*
180				1900*	1900*

* Temperatures follow those of ASTM E-119.

Scenario 2

All the cable trays in this fire zone are at a higher elevation than the T-L wrapped conduit. However, this scenario models self-ignition of one of these cable trays and evaluates the time-temperature profile in the room for the case when/if the HGL temperature reaches 1000°F and it becomes a fully involved fire.

The most bounding configuration for this scenario was found to be three cable trays stacked on top of each other, 1 ft. apart, and about 4 ft behind and 2 ft. above the T-L wrap conduit. The cable trays are 24 inches wide. It is assumed that 2 ft. of the bottom cable tray self-ignites and this ignites 4 ft. of cable tray in the middle, and consequently, 6 ft. of cable tray on top. It is conservatively assumed that all the cable trays ignition occur instantaneously for calculation simplification. In addition to the vertical propagation, the fire is also assumed to propagate horizontally along the exposed cable tray with a flame speed of 10 feet per hour (per Ref. 2, Appendix I-C). The total amount of cable tray assumed to be available for this fire scenario is 30 feet per tray (for 3 hour fire duration).

The heat release rates considered for this scenario are as follows (by fire source):

1. first cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); since 4 ft2 are initially burning, the HRR for this source alone is 93.6 BTU/sec; this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 140.4 BTU/s, which

includes the HRR from 2 ft2 of additional cable tray);

2. second cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the first cable tray, the HRR for this source alone is 187 BTU/sec (since 8 ft2 are initially burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 234 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

3. third cable tray – 23.4 BTU/sec- ft2 (Ref. 2, FIVE Table 1E, cable #5 adjusted to consider Equation 2 on FIVE manual, page 10.4-10); just as with the second cable tray, the HRR for this source alone is 281 BTU/sec (since 12 ft2 are initially burning); this HRR will increase with time, as fire propagates horizontally along the tray (i.e., 6 minutes into the fire, the HRR for this source will be 328 BTU/s, which includes the HRR from 2 ft2 of additional cable tray);

The total available heat (Qtot) from each fire source is:

1. first cable tray --12,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 30 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];
2. second cable tray --12,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 30 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];
3. third cable tray --12,000,000 BTUs [it assumes 10,000 BTU/lbm of cable insulation (per Ref. 6, page E2-1) x 30 linear feet x 40 lbm/linear foot (engineering judgment for 100% filled, 24 inch wide cable tray)];

Results

The time temperature profile scenario calculated by the model are presented in Table 2. The model results indicate that hot gas layer effects in the zone due to this postulated fire cause the temperature to exceed 1000°F at time = 34 minutes. It should be noted that these HGL temperatures in this compartment are expected to be very conservative due to the number and size of the openings that exist in this fire zone.

Past the 1000°F HGL temperature, it is assumed that a fire compartment temperature will follow the ASTM E-119 time-temperature relationship (Ref. 1). Appendix B contains the basis for this assumption. A sample model worksheet is provided in Appendix A, Figure A-2.

Table 2. Temperature-Time History for Fire Scenario 2.

Time	HRR to Target	HRR to HGL	QTOT	Temp.	Temp.
(min.)	(Btu/s)	(Btu/s)	(Btu)	Target - (F)	HGL - (F)
0	562	562	0	100	100
6	702	702	252720	171	171
12	842	842	555840	268	268
18	982	982	909360	400	400
24	1122	1122	1313280	580	580
30	1262	1262	1767600	828	828
34	1356	1356	2093040	1042	1042
60				1550*	1550*
90				1704*	1704*
150				1850*	1850*
180				1888*	1888*

* Temperatures follow those of ASTM E-119.

5. FIRE MODELING SUMMARY

Fire modeling was performed for two fixed fire Source-Thermo-lag wrap configurations in Oyster Creek Fire Zone TB-FZ-11C. The analysis results are presented as time- temperature profiles. These results are used in the following section to develop total heat load and then convert to equivalent ASTM E-119 exposures.

6. APPROXIMATING EXPOSURE TIME-HISTORY OF THERMO-LAG SUB-CONFIGURATIONS – THE TOTAL HEAT LOAD CONCEPT

Calculation of an exposure time-temperature profile for a specific T-L Sub-configuration is based on the methodology presented in Reference 1. The time -temperature profiles are used to develop the total heat load (Reference 1, Appendix III-A) for each fire exposure. The total heat load concept holds that the area under the incident heat flux vs. time curve, or total heat load, can be used as a measure of fire severity. Comparing the total heat load of a fire scenario exposure to the total heat load of a test exposure (ASTM E-119) allows one to predict the response of a Thermo-Lag barrier to the scenario exposure. The total heat load per unit area of fire barrier surface is equal to the area under the incident heat flux-time curve, corrected for convection effects as described in Reference 1, Appendix III-A.

6.1 Total Heat Load Results

Location No.(GA DWG, App. D)	Scenario	Description	Peak Temperature at Target (°F)	Total Heat Load Equivalent E-119 Exposure Duration (min.)
13	1	Switchgear 1B and Cable Tray	1900	>150 , <180
13	2	Cable Tray	1888	>150 , <180

Appendix C contains tables with Total Heat Load values calculated for Thermo-Lag scenarios 1, and 2.

7. REFERENCES

1. EPRI Report "Methods for Evaluation of Cable Wrap Fire Barrier Performance", July, 1995

2. EPRI TR-100370, "Fire-Induced Vulnerability Evaluation," April 1992.

3. GPUN, "Fire Hazards Analysis Report – OC," Doc. No. 990-1746, Rev. 8, May 24, 1995.

4. GPUN - OC Procedure No. 120.5 (Revision 5), May 20, 1993.

5. Thermo-Lag 330-1 Combustibility Study, NEI, 1994.

6. GPUN - TMI-1 Procedure No. 1035 (Revision 24), August 23, 1994.

Appendix A

Sample Scenario Worksheets

Figure A-1

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	2666
1	Location of Target		Hot Gas Layer
2	Height of Target above Fire Source	ft	2.00
3	Height from Fire Source to Ceiling, H	ft	10.00
4	Ratio of Target Height/Ceiling Height		0.200
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	3629
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	3629
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		0.00
14	Temperature Rise at Target	F	0
15	**Temperature at Target**	F	**302**
16	**Temperature in HGL**	F	**302**
17	Qtot to HGL	Btu	1306440
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	78386
20	Calculated Enclosure Volume, V	ft3	26660
21	Calculated Qnet/V	Qnet/ft3	2.94
22	HGL Temperature Increase	F	202

Figure A-2

Temperature calculation at time		min	6
Maximum ambient temperature		F	100
Floor Area		ft2	2666
1	Location of Target		Hot Gas Layer
2	Height of Target above Fire Source	ft	0.10
3	Height from Fire Source to Ceiling, H	ft	5.00
4	Ratio of Target Height/Ceiling Height		0.020
5	Longitudinal Distance from Fire Source to Target, L	ft	NA
6	Longitudinal Distance to Height Ratio, L/H		NA
7	Enclosure Width, W	ft	NA
8	Height to Width Ratio, H/W		NA
9	Peak Fire Intensity	Btu/s	702
10	Fire Location Factor		1
11	Effective Fire Intensity	Btu/s	702
12	Plume Temperature Rise at Target	F	1600
13	Temp Rise Factor at Target		0.00
14	Temperature Rise at Target	F	0
15	Temperature at Target	F	171
16	Temperature in HGL	F	171
17	Qtot to HGL	Btu	252720
18	Estimated Heat Loss Fraction		0.94
19	Calculated Qnet	Btu	15163
20	Calculated Enclosure Volume, V	ft3	13330
21	Calculated Qnet/V	Qnet/ft3	1.14
22	HGL Temperature Increase	F	71

Appendix B

Basis for Following ASTM E-119 Time-Temperature Relationship When T(HGL) is 1000 °F

TRANSITION TO
ASTM E-119 TIME-HISTORY
IN THE HOT GAS LAYER

ISSUE:

The Fire Hazard Tool currently under development in the EPRI Cable Wrap Fire Barrier Tailored Collaboration assumes that the fire compartment temperature will follow the ASTM E-119 time-temperature relationship as soon as the compartment hot gas layer reaches 1000°F.

BASIS:

The Handbook (Ref., pg. 6-75) states that "Flashover of an enclosure is likely to occur if the temperature of the upper gas layer reaches approximately 1000°F (600°C).

The EPRI assumption of 1000°F is therefore conservative.

As stated near the top of page 6-67 of the Handbook, the intensity of the fire will be somewhat lower when the walls and ceiling absorb significant amounts of energy rather than when act as insulation or radiation barriers.

Since power plant compartments are typically concrete barriers which absorb significant amounts of heat, the intensity of fire will tend to be less severe than fires in compartments with insulated barriers.

ASTM E-119 has been the accepted standard for testing fire barrier systems since the early 1900's. The standard, which was developed from actual fire tests, has been used to evaluate the fire endurance capabilities of fire barriers since it was developed. The time-temperature relationship represented by the curve represents a fully-involved fire compartment.

According to Fred Mowrer of the University of Maryland, plume and ceiling effects disappear in a fully involved fire compartment as the plume/ceiling jet gas are no longer more buoyant than surrounding gases.

Use of the ASTM E-119 time-temperature relationship to represent a fully involved power plant compartment fire is therefore consistent with industry practice. Assuming that that occurs when the hot gas layer reaches 1000°F is more conservative than the 1100°F noted in the Handbook.

Reference: NFPA Fire Protection Handbook, Seventeenth Edition, Section 6/Chapter 6.

Appendix C

Total Heat Load Results

Figure C-1

Total Heat Load
Scenario 1

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	100	0.4	0.0	0.00	0.00
6	302	0.4	0.14	0.14	0.41
12	589	1.0	0.40	0.40	1.65
18	953	2.4	1.02	1.02	3.56
19	1025	2.9	1.18	1.18	3.92
25	1300	5.3	2.65	2.65	6.31
60	1638	10.1	18.81	18.81	25.06
90	1750	12.3	38.93	38.93	45.76
120	1835	14.2	62.74	62.74	69.38
150	1862	14.8	88.85	88.85	95.02
180	1900	15.8	116.46	116.46	122.34

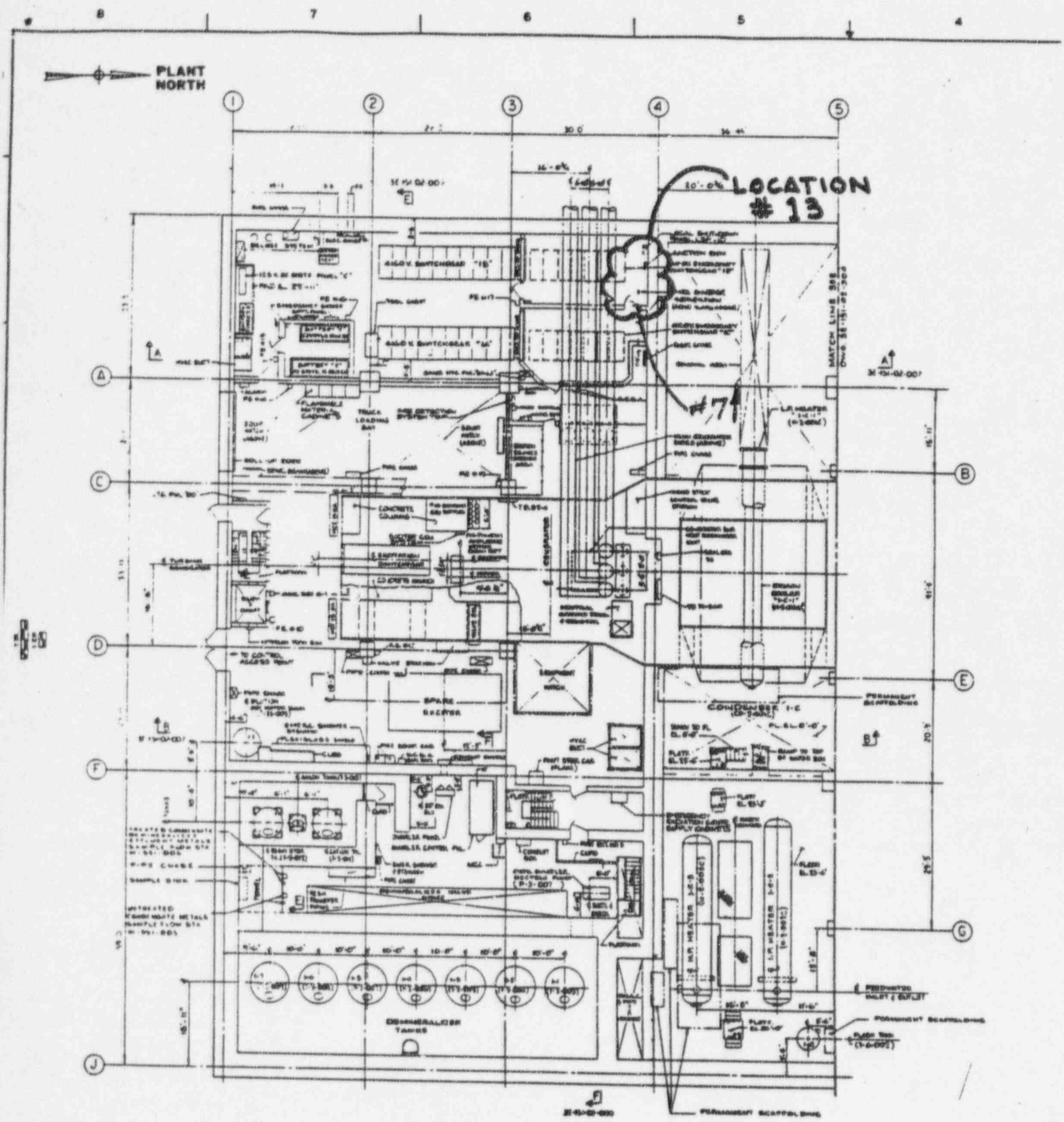
Figure C-2

Total Heat Load
Scenario 2

			Target	Hot Gas Layer	ASTM E-119
Time	Temperature	Inc Heat Flux	Total Heat Load	Total Heat Load	Total Heat Load
(min)	(F)	(Btu/s-sf)	(1000Btu/sf)	(1000Btu/sf)	(1000Btu/sf)
0	100	0.4	0.0	0.00	0.00
6	171	0.4	0.13	0.13	0.41
12	268	0.4	0.28	0.28	1.65
18	400	0.7	0.47	0.47	3.56
24	580	1.0	0.77	0.77	5.93
30	828	1.8	1.27	1.27	8.64
34	1042	3.0	1.84	1.84	10.54
60	1550	8.6	10.87	10.87	24.95
90	1704	11.3	28.76	28.76	45.65
150	1850	14.5	75.25	75.25	94.54
180	1888	15.5	102.30	102.30	121.87

Appendix D

General Arrangement Drawings



PLAN@ EL 23'-6"

TB-FZ-11C - TB MEZZANINE

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