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AUTH.NAME AUTHOR AFFILIATION
KUNDALKAR,R.S. Florida Power & Light Co.
RECIP.NAME RECIPIENT AFFILIATION
Document Control Branch (Document Control Desk)

See Reports

SUBJECT: Resquests for exemption fire rating of racing of raceway fire barriers in open turbine building.Exemption request provided as an attachment to letter.

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TITLE: OR/Licensing Submittal: Fire Protection - App R - GL-88-12

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JUL 31 1997

L-97-181
10 CFR §50.12
10 CFR §50.48
10 CFR Part 50 Appendix R

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

Subject: Turkey Point Units 3 and 4
Docket Nos. 50-250 and 50-251
Request for Exemption -
Fire Rating of Raceway Fire Barriers
in the Open Turbine Building

The purpose of this letter is to request, in accordance with the provisions of Title 10 Code of Federal Regulations section 50.12 (10 CFR §50.12), an exemption from certain requirements of 10 CFR Part 50 Appendix R, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," for Turkey Point Units 3 and 4. The exemption request is provided as an attachment to this letter.

Specifically, Florida Power & Light Company (FPL) requests an exemption from the requirements of 10 CFR Part 50 Appendix R subsection III.G.2.a for raceway fire barriers in the Open Turbine Building at Turkey Point. This exemption and supporting justification, if granted, replaces existing exemptions in outdoor fire zones outside for the Open Turbine Building at Turkey Point Units 3 and 4. A request for exemption for outdoor fire zones excluding the Open Turbine Building was submitted by FPL letter L-96-318, dated December 12, 1996.

To our knowledge, other than at Turkey Point Plant, there has been little or no use of Thermo-Lag 330-1 outdoor fire barrier configurations within the industry. These outdoor areas are not subject to fire damage from stratified gases or ceiling jet layers such as can occur from a fire in an indoor area. Turkey Point Plant has approximately 17,000 feet of Thermo-Lag protected raceways in outdoor areas. This exemption request addresses an estimated 30% of this total.

The requested exemption satisfies the requirements of 10 CFR §50.12 in that it is authorized by law, will not present an undue risk to the public health and safety, is consistent with the common defense and security, and involves special circumstances.

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FPL plans to perform, at its own risk, the engineering to achieve implementation of this exemption in parallel with NRC review and approval. Accordingly, FPL requests that this proposed exemption be given priority review by NRC staff and that the exemption be approved by December 31, 1997.

FPL will submit an implementation plan for the Open Turbine Building within 120 days of NRC approval of this exemption request.

Very truly yours,

R. S. Kundalkar
Vice President
Nuclear Engineering

OIH

Attachment

cc: L. A. Reyes, Regional Administrator, Region II, USNRC
T. P. Johnson, Senior Resident Inspector, USNRC, Turkey Point

CATEGORY 1

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JUL 31 1997

L-97-181
10 CFR §50.12
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A006/1

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FPL will submit an implementation plan for the Open Turbine Building within 120 days of NRC approval of this exemption request.

Very truly yours,

R. S. Kundalkar
Vice President
Nuclear Engineering

OIH

Attachment

cc: L. A. Reyes, Regional Administrator, Region II, USNRC
T. P. Johnson, Senior Resident Inspector, USNRC, Turkey Point

EXEMPTION REQUEST

FOR THE TURKEY POINT UNITS 3 AND 4

OPEN TURBINE BUILDING

Cover Page

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I. Introduction

The purpose of this submittal is to request, in accordance with the provisions of Title 10 Code of Federal Regulations section 50.12 (10 CFR §50.12), "Specific exemptions", an exemption for Outdoor Fire Zones for the Open Turbine Building at Turkey Point Units 3 and 4 from provisions of subsection III.G.2.a of Appendix R to 10 CFR Part 50. Appendix R sets forth certain fire protection features pertinent to satisfying Criterion 3 of Appendix A to Part 50. The subsection of Appendix R referenced above addresses specific requirements for the protection of safe shutdown capability against fire.

Under 10 CFR §50.12 the NRC may, "...upon application by any interested person . . . grant exemptions from the requirements of . . . regulations . . . ." As applied to the Commission's fire protection regulations by the U.S. Court of Appeals for the D.C. Circuit in Connecticut Light and Power v. NRC, 673 F.2d 525 (D.C. Cir.), *cert. denied*, 459 U.S. 835 (1982), section 50.12 provides, in effect, an alternative means of complying with certain provisions of Appendix R, including subsection III.G.2.a.

This exemption request supersedes and deletes previously granted exemptions for outdoor fire zones for the Open Turbine Building, at Turkey Point Units 3 and 4, as delineated herein.

II. Discussion

A. Background

Pursuant to 10 CFR §50.48(a), each operating nuclear power plant must have a plan to satisfy Criterion 3, "Fire Protection," of Appendix A to 10 CFR Part 50. Under the terms of 10 CFR §50.48(b), "Appendix R . . . establishes fire protection features required to satisfy Criterion 3 of Appendix A . . . with respect to certain generic issues . . . ." In particular, subsections III.G.2.a, b and c of Appendix R address fire protection features for assuring safe shutdown capability. Specifically, subsection III.G.2.a allows the separation of cables and equipment and associated non-safety circuits of redundant trains of certain shutdown systems by a three-hour fire barrier as an acceptable means of protection; subsection III.G.2.b allows for the separation of cables and equipment and associated non-safety circuits of redundant trains of certain shutdown systems by 20 feet of separation, with fire detectors, fire suppression and no intervening combustibles; and subsection III.G.2.c allows the enclosure of cable and equipment and associated non-safety circuits in a one-hour fire barrier, with fire detectors and an automatic fire suppression system, as an acceptable alternative.

The standards applied by the NRC in decreasing importance to grant an exemption from regulatory requirements are set forth in 10 CFR §50.12. The standards are that:

> (a) The Commission may, upon application by an interested person or upon its own initiative, grant exemptions from the requirements of the regulations of this part, which are -
>
> (1) Authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security.
>
> (2) The Commission will not consider granting an exemption unless special circumstances are present. . . .

Application of this exemption procedure within the context of the Commission's fire protection regulations was considered by the Court of Appeals for the D.C. Circuit in the Connecticut Light case. So applied, the court found that 10 CFR §50.12 provides, in effect, an alternative means of complying with certain fire protection requirements, including the options specified in subsections III.G.2.a and c for the protection of safe shutdown capability. Connecticut Light, 673 F.2d at 528-34. In the words of the court, "if the company can prove that another method works as well as one of the three stipulated by the NRC [in subsections III.G.2.a, b, and c], in light of the identified fire hazards at its plant, it may continue to employ that method." Connecticut Light, 673 F.2d at 534. As detailed below, Florida Power and Light Company (FPL) requests an exemption from the application of certain requirements of subsection III.G.2.a for the reasons stated in the specified bases.

This exemption request contains four substantive sections. Section I is an introduction. In Section II, FPL sets forth background on the regulatory requirements applicable to the proposed exemption, as summary of the requested exemption, and the standards that apply to NRC's review of the proposal. Section III contains a summary of the technical bases for the requested exemption. Section IV provides a detailed description of the fire zones at issue and the essential equipment, combustible loads, and fire protection features in each fire zone. Section V evaluates several issues raised by NRC in previous exchanges of correspondence relating to the previously requested outdoor exemptions, and provides a basis for resolution of those issues.

B. Requested Exemption

Subsection III.G.2.a of Appendix R to 10 CFR Part 50 requires that cable and equipment and associated non-safety circuits of a redundant train of certain shutdown apparatus in the same fire area be separated by a fire barrier having a 3-hour rating. FPL requests an exemption for Outdoor Fire Zones for the Open Turbine Building permitting the use of the following in lieu of subsection III.G.2.a requirements:

1) Separation of cables and equipment and associated non-safety circuits of redundant trains within the Open Turbine Building between column lines A and E by a fire barrier having a 1-hour rating. Automatic fixed water spray fire suppression systems are provided for the major combustible sources and turbine lube oil equipment, and automatic wet pipe sprinklers are provided for area coverage including turbine lube oil distribution piping locations as shown on Figures 1 and 2. However, no fire detection is provided for this area.

2) Separation of cables and equipment and associated non-safety circuits of redundant trains within the Open Turbine Building and adjoining areas between column lines E and J_c by a fire barrier having a 25-minute rating. Automatic wet pipe sprinkler coverage is provided between column lines E and J as shown on Figures 1 and 2. However, no fire detection is provided for the area between column lines E and J_c.

3) Separation of cables and equipment and associated non-safety circuits of redundant trains within the Open Turbine Building and adjoining areas between column lines E and J_c by a horizontal distance of more than 20 feet with no significant intervening combustibles. Automatic wet pipe sprinkler coverage is provided between column lines E and J as shown on Figures 1 and 2. However, no fire detection is provided for the area between column lines E and J_c.

C. Fire Zones Associated with the Exemption

The fire zones within the scope of the exemption request are listed below with respect to the exemption sections to which they apply:

II.B.1 Fire Zones 66, 69, 78 West of column line 'E', 80 between column lines 'A' and 'E', 82, 83 West of column line 'E', 85 between column lines 'A' and 'E', 87, 91, 92, 105 West of column line 'E', and 117 West of column line 'E'.

II.B.2 Fire Zones 78 East of column line 'E', 79 West of column line J_c, 80 East of column line 'E', 83 East of column line 'E', 84 West of column line J_c, 85 East of column line 'E', 88, 89 West of column line J_c, 105 East of column line 'E', 117 East of column line 'E'.

II.B.3 Fire Zones 78 East of column line 'E', 79 West of column line J_c, 80 East of column line 'E', 83 East of column line 'E', 84 West of column line J_c, 85 East of column line 'E', 88, 89 West of column line J_c, 105 East of column line 'E', 117 East of column line 'E'.

D. Exemption Fire Zone Descriptions

Fire Zone	Description
66	Unit 4 Steam Generator Feed Pump Area
69	Unit 3 Steam Generator Feed Pump Area
78 (partial)	Unit 4 Instrument Air Equipment Area
79 (partial)	Area West of Unit 4 Containment
80 (partial)	Unit 4 Main Condenser Area
82	Unit 4 Auxiliary Transformer Area
83	Unit 3 Instrument Air Equipment Area
84 (partial)	Unit 3 and 4 Auxiliary Feedwater Pump Area
85 (partial)	Unit 3 Main Condenser Area
87	Unit 3 Auxiliary Transformer Area
88 (partial)	Unit 3 Switchgear/Emergencey Diesel Generator Vestibule
89 (partial)	Unit 3 Condensate Storage Tank Area
91	Unit 4 Condensate Pump Area
92	Unit 3 Condensate Pump Area
105	Units 3 and 4 Turbine Building Mezzanine Deck
117	Units 3 and 4 Turbine Deck

A detailed description of the combustible loading, installed essential equipment and fire detection and suppression features for the fire zones included in the exemption request is provided in Section IV.

E. **Bases for Requested Exemption**

The requested exemption is consistent with the requirements of 10 CFR 50.12 and should be granted. First, in accordance with subsection 50.12(a)(1), it is clear from the discussion herein that the exemption sought by FPL for Turkey Point is authorized by law, will not present an undue risk to the public health and safety, and is consistent with the common defense and security.

(1) Authorized by Law. As discussed above, exemptions from Appendix R are expressly authorized by law. This authority is confirmed by past Commission practice since the promulgation of Appendix R, under which the Commission has granted numerous exemptions from Appendix R requirements. In its Staff Requirements Memorandum dated June 27, 1994, "Options for Resolving the Thermo-Lag Fire Barrier Issues," the Commission reaffirmed this practice as specifically applied to exemptions involving the use of Thermo-Lag as a fire barrier. In that letter, the Staff stated that the Commission would consider specific exemptions from certain technical requirements of Appendix R, "provided the licensee submits a technical basis that demonstrates the in-plant condition provides an adequate level of fire safety." Therefore, by law, the Commission is authorized to grant exemptions from Appendix R.

(2) No Undue Risk. The proposed exemptions from Appendix R requirements pose no undue risk to the public health and safety because an adequate level of fire protection is maintained. As demonstrated in the discussion below, the existing fire barriers at Turkey Point, together with fire protection measures, administrative controls, and the unique outdoor nature of the areas in question, satisfy the underlying intent of the rule, which is to assure that plant shutdown can be accomplished in the event of a fire. As such, adequate protection of the public health and safety is provided.

(3) Consistent with the Common Defense and Security. Common defense and security issues are not implicated by the proposed exemption because no safeguards issues or equipment are affected by the request.

Second, consistent with the requirements of subsection 50.12(a)(2), special circumstances are present. In particular, as discussed below, special circumstances exist within the terms of subsections 50.12(a)(2)(ii) and (iii).

Subsection 50.12(a)(2)(ii) -- Application of the regulation in the particular circumstances either would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule;

The purpose of the NRC's fire protection regulations is to assure that a fire in a nuclear power plant will not disable the capability to safely shut down the plant. The particular aspects of the regulations pertinent here concern the protection of components associated with achieving and maintaining safe shutdown conditions. As discussed above in this request, the granting of the exemption is consistent with preserving safe shutdown capability by assuring, through appropriate use of fire barrier material, that shutdown capability will, in fact, be maintained. Therefore, the underlying intent of the rule will be met. Thus, application of the regulation in the particular circumstances is not necessary to achieve the underlying purpose of the rule.

Subsection 50.12(a)(2)(iii) -- Compliance would result in undue hardship or other costs that are significantly in excess of those contemplated when the regulation was adopted, or that are significantly in excess of those incurred by others similarly situated;

The costs of regulatory compliance contemplated when Appendix R was adopted were limited to those related to the installation of fire barrier material to meet specific Appendix R requirements. At that time, the Commission did not contemplate additional expenses that reactor licensees might incur to replace degraded barrier material that was once reasonably relied upon by the NRC and its licensees as qualified. FPL has spent more than four million dollars on outdoor fire barriers at Turkey Point in order to satisfy the originally contemplated Appendix R barrier material requirements in the areas covered by this exemption request. FPL estimates that an additional expenditure approaching three million dollars would be necessary to upgrade Thermo-Lag barriers to meet the literal requirements of Appendix R. Thus, strict compliance by FPL with the Commission's fire protection regulations would result in costs significantly in excess of those originally contemplated.

III. Engineering Assessment

The scope and technical justification for the exemption request for outdoor fire zones for the Open Turbine Building is presented in this section. A more detailed description of the fire zones and associated essential equipment, combustible loads and fire protection features is presented in Section IV. Section V reflects responses to previous NRC requests for additional information, edited for consistency with this exemption request, and describes analyses specifically prepared to support this exemption request.

Technical justification for granting the exemption request is based on characteristics of Open Turbine Building outdoor areas, types and quantities of in situ combustible materials, control of transient combustible materials, proposed modifications to augment fire protection and suppression features, and providing adequate protection to ensure that, in the event of a fire, at least one train of safe shutdown equipment and components is available. If the rating of the fire barrier

assembly is less than the applicable 1-hour or 25-minutes and is not justified by fire hazards assessments, then the barrier does not meet the requirements of the exemption request and modifications will be performed.

Special Characteristics of Open Turbine Building Outdoor Areas

The outdoor areas for the Open Turbine Building addressed in this exemption request possess special features which reduce the effect of fires. The turbine deck is open to the sky and the intermediate (Mezzanine) and grade levels have open sides. As such, ceiling jet layers (in the case of the turbine deck) and stratified hot gases are not the concern as with enclosed areas. The fire energy is not localized by physical boundaries and dissipates quickly with the large heat sink. Major in situ combustibles in the Open Turbine Building, such as transformers and hydrogen seal oil units, are contained and have automatic suppression systems. Although the load center and switchgear rooms are located within the Open Turbine Building perimeter, these rooms are separated from the rest of the building by 3-hour rated fire barriers and are not within the scope of this exemption request.

Combustible Loading

A description of the in situ combustible load, fire control and fire protection features for each Open Turbine Building outdoor fire zone is provided in Sections IV.B and V.D herein. The turbine deck, in addition to being wide open, also has very low combustible loads. The hydrogen supply line passes along the west side of the Open Turbine Building. The hydrogen source is located remotely from the Open Turbine Building and is isolated from the Unit 3 and 4 generators during power operation. Other in situ combustible sources include turbine lube oil in guarded piping and lube oil in the condensate pump, feedwater pump and heater drain pump locations. The zones transitioning between the containments and turbine building are also open and combustible loads consist mainly of pumps, valves and raceways.

Throughout most of the Open Turbine Building cable trays are sparsely populated and located in horizontal, vertical and askew runs, at grade elevation, up walls and in free space. The cable in trays was either coated with Flammastic 71A or 77 (and certain of these cable coatings are maintained, as provided in UFSAR Appendix 9.6A, paragraph 2.4.D.3.f) or is qualified to IEEE-383, 1974 standards. Except for the open vestibule areas east of the switchgear rooms, the fuel load is so low and spread out that the fuel contribution from the cable and raceway protection is not considered significant.

The small quantity of lubricating oil in pumps is considered to be insignificant as an in situ combustible hazard because the oil is contained in reservoirs encased within the pumps. The relatively massive steel casings would mitigate the propagation of flame from a credible exposure fire to the oil in the reservoirs, and would provide protection

equivalent to containers required by NFPA 30, consistent with Generic Letter 86-10, Supplement 1 guidance.

The above paragraphs describe typical in situ combustible loading that can be characterized as negligible. The only area regarded as having a significant combustible loading is the area subject to the postulated low-pressure turbine and/or generator lube oil leak as a result of bearing seal gross failure. Modifications are proposed to accommodate this scenario.

Transient Combustible Control Program

The Turkey Point Combustible Control Program does not allow storage of combustibles in outdoor areas within or near the Open Turbine Building that contain safety related equipment or cables. Procedures require that flammable liquids be attended at all times and a special permit is required for quantities greater than 5 gallons. Hence, transient combustible controls assure that a worst case transient fire caused by a spill would be far below a hazard level that could challenge protected raceways and components. There are very few transient combustibles in the plant at any one time, and those few have sufficient controls. Therefore, the potential accumulation of transient combustibles would not challenge the fire-resistive capability of fire barriers. Additionally, the fire brigade response time for drills and actual outdoor fires is less than 15 minutes after detection, which is well below fire barrier fire endurance capabilities (see Sections V.E and V.J).

IV. Fire Zone Evaluations

This section provides an overview of the existing outdoor fire zone configurations for the Open Turbine Building, combustible loading, installed essential equipment and fire detection and fire suppression features. While most of this information is provided in Appendix 9.6A of the UFSAR, some additional information is also presented in the following table to facilitate NRC review.

SUMMARY OF EXISTING OPEN TURBINE BUILDING FIRE ZONE FACILITIES

FIRE ZONE	COMBUSTIBLE. LOAD (BTU)	SOURCE OF IN SITU COMBUSTIBLE	AVAILABLE FIRE PROTECTION FEATURES	ESSENTIAL EQUIPMENT	SEPARATION
66	Negligible	Cable, < 100 gal. Lube Oil in each of 2 SGF Pumps	Wet pipe sprinkler system Extinguishers, Hose Station and Hydrant	Steam Generator Feedwater Pumps	Spurious Action ONLY Concern (1)
69	Negligible	Cable, <100 gal. Lube Oil in each of 2 SGF Pumps	Wet pipe sprinkler system Extinguishers and Hose Station	Steam Generator Feedwater Pumps	Spurious Action ONLY Concern (1)
78	1.5×10^8	Cable, 1000 gal. in Lube Oil Conditioner	Fixed water spray over lube oil filter and pump system Wet pipe sprinkler coverage over turbine lube oil piping Extinguishers, Hose Station and Hydrant	Heater Drain Pumps	Spurious Action ONLY Concern (1)
79	Negligible	Cable, Guard House and Access Control Enclosures Trays located 13' above grade	Extinguishers and Hose Stations	None	(1)
80	Negligible	Cable, Guarded Turbine Lube Oil Piping	Wet pipe sprinkler coverage beneath lube oil piping and Condenser pit Extinguishers, Hose Station and Hydrant	None	(1)
82	8.74×10^8	Cable, 5824 gal. in Auxiliary Transformer and Hydrogen Seal Oil Equipment, Generator Hydrogen Piping	Fixed water spray suppression with thermal detection which annunciates in the Control Room Extinguishers, Hose Station and Hydrant	None	(1)
83	1.5×10^8	Cable, 1000 gal. in Lube Oil Conditioner, Generator Hydrogen Piping	Fixed water spray over lube oil filter and pump system Wet pipe sprinkler coverage over turbine lube oil piping Extinguishers, Hose Station and Hydrant	Heater Drain Pumps	Spurious Action ONLY Concern (1)

FIRE ZONE	COMBUSTIBLE. LOAD (BTU)	SOURCE OF IN SITU COMBUSTIBLE	AVAILABLE FIRE PROTECTION FEATURES	ESSENTIAL EQUIPMENT	SEPARATION
84	Negligible	~24.5 gal. Lube Oil and Grease in each of 3 AFW pumps	Extinguishers and Hose Station	Turbine-Driven AFW Pumps	>50' to Standby Steam Generator Feed Pumps (1)
85	Negligible	Cable, Guarded Turbine Lube Oil Piping	Wet pipe sprinkler coverage beneath lube oil piping and Condenser pit Extinguishers, Hose Station and Hydrant	None	(1)
87	8.74×10^8	Cable, 5824 gal. in Auxiliary Transformer and Hydrogen Seal Oil Equipment, Generator Hydrogen Supply Piping	Fixed water spray suppression with thermal detection which annunciates in the Control Room Extinguishers, Hose Station and Hydrant	None	(1)
88	Negligible	Cable	Extinguishers and Hose Station	None	(1)
89	Negligible	Cable	Extinguishers and Hose Station	None	(1)
91	Negligible	Cable, <20 gal. Lube Oil in each of 3 Condensate Pumps	Wet pipe sprinkler coverage of pump pit and beneath turbine lube oil piping Extinguishers and Hose Stations	Condensate Pumps	Spurious Action ONLY Concern (1)
92	Negligible	Cable, <20 gal. Lube Oil in each of 3 Condensate Pumps	Wet pipe sprinkler coverage of pump pit and beneath turbine lube oil piping Extinguishers and Hose Stations	Condensate Pumps	Spurious Action ONLY Concern (1)
105	Negligible	Cable, Guarded Turbine Lube Oil Piping	Wet pipe sprinkler coverage beneath turbine lube oil piping Extinguishers and Hose Stations	None	(1)
117	18.58×10^5	6400 ft^3 Hydrogen Gas Blanket in Generators, Bearing Lube Oil	Extinguishers and Hose Stations	Steam Generator Pressure Transmitters	(1)

(1) For cable, separation is in accordance with the requested exemption.

A. Layout of the Open Turbine Building

The Open Turbine Building configuration at Turkey Point Units 3 and 4 is unique in the industry. It is an assembly of platforms, walkways and open deck supported by structural steel, a virtually open structure rather than an enclosed building. As such, the turbine area is open to weather and prevailing breezes. The main and startup transformers are located just west of the structure, and the load center and switchgear rooms are enclosed and located within the Open Turbine Building perimeter.

The building layout consists of three major platforms (refer to Figures 1 and 2). The grade level is a reinforced concrete slab at plant elevation El. 18'0" and provides walk-in access from all sides. The steam generator feed pumps and heater drain pumps are located at grade. The condensate pumps are located near the condenser in a pit below grade and the auxiliary feedwater pumps are located just east of the Open Turbine Building perimeter. The auxiliary transformers are located in an open area just inside the west column line. Hydrogen seal oil units are near their respective auxiliary transformers.

The mezzanine level is at approximately El. 30'0" and consists of a series of access platforms and walkways. The platforms are a combination of reinforced concrete and checker plate construction supported by structural steel. The mezzanine platforms do not extend over the areas where the condensate pumps, hydrogen seal oil units and auxiliary transformers are located. Much of the area beneath the turbines and generators are open to grade below the turbine deck. The only major electrical components located at this level are the exhaust fans for the steam generator feed pump areas.

At plant El. 42'0", the turbine deck is a substantial reinforced concrete platform, with small sections of grating and supported by building structural steel members. The turbine deck supports the turbine building crane and provides maintenance access to the turbines and generators. There are no sides or roofs for the turbine deck.

The Open Turbine Building is a substantial structure, supported independently of the control building, auxiliary building and containments. The structure is designed to withstand hurricane force winds per the South Florida Building Code. No structural damage resulted from Hurricane Andrew.

B. Combustible Loads

In situ combustible materials consist of transformer cooling oil, turbine lube oil, generator hydrogen and seal oil, pump lube oil, grease and cable insulation. The primary combustible loading source in the Open Turbine Building is the volume of cooling oil contained within the transformers. The combined combustible loading of a hydrogen seal oil

unit and auxiliary transformer is less than 6000 gallons (56 lb/ft^3) of oil with an assumed heating value (high end of range) of 20,000 BTU/lb.

The small quantity of lubricating oil in pumps is considered an insignificant in situ combustible because the oil is contained in reservoirs encased within the pumps. The relatively massive steel casings would mitigate the propagation of flame from a credible exposure fire to the oil in the reservoirs.

The remaining in situ combustible material loads are sparsely populated cable trays, primarily located 18 to 20 feet above grade, and Thermo-Lag. The wrapped raceways contain cables for a number of control and power supplies, including the control power for the emergency diesel generators, switchgear and load centers. The fuel load is so low and spread out, that cable and Thermo-Lag are not considered significant and are represented as such in the preceding tabulation. Also, since the in situ combustibles are not significant, there is no threat to wrapped conduits.

For reasons which are explained more fully in Sections IV.F and V.D, the hydrogen supply lines and turbine lube oil piping are not considered to be major combustible sources or credible fire hazards to wrapped fire barrier assemblies. Nevertheless, an oil fire scenario, involving lube oil leakage from low-pressure turbine and/or generator bearing oil seals, was selected and evaluated for its potential effect on plant safe shutdown capability. Modifications are proposed to protect the areas subject to this scenario.

In addition, transient combustibles are permitted within the Open Turbine Building under administrative controls. Transient combustibles may include lube oil, paint, acetylene, cleaning fluids and rags as necessary for maintenance. During unit power operation, these materials are only brought in during use and removed when work is completed. Fluids are transported in appropriate shipping containers. No transient combustible materials are stored in or near the Open Turbine Building. As such, transient combustibles are not considered to be a significant combustible load or to create a significant fire hazard.

C. Fire Prevention Features

The Open Turbine Building structure is constructed of fire resistant materials. Fire prevention features are also applied to minimize the fire potential of specific hazards.

The primary method of fire prevention is containment of fluids. Turbine lube oil piping is encased in guard pipes which drain to the lube oil reservoir located outside of the Open Turbine Building. Leakage from the auxiliary transformers or hydrogen seal oil units is prevented from spreading by being contained within concrete curbs and channeled to safe drainage areas outside of the Open Turbine Building.

D. Fire Detection Features

In general, plant areas containing safety related or safe shutdown equipment which are susceptible to substantial fire hazards are provided with fire detection. Some of these and other areas which contain relatively high in situ combustible loading, or could significantly affect plant operation in event of a fire, are provided with fire suppression as well. As such, only the transformers and hydrogen seal oil facilities are provided with thermal detection which alarms in the Control Room.

E. Fire Suppression Features

Transformers and hydrogen seal oil units are protected by fixed water spray fire suppression systems, supplemented by local fire extinguishers. Secondary protection is also provided by nearby standpipe hose stations and hydrants.

Since there is no hot piping or exposed circuits directly beneath the turbine lube oil piping, the absence of in situ ignition sources makes a lube oil fire extremely unlikely. Even so, wet-pipe sprinkler systems provide coverage for plant floor areas below the turbine deck, beneath turbine lube oil piping and in the condenser pit. Any leakage from lube oil piping falling to the floor will flow towards local area drains and the condenser pit sump. Similarly, flow from the sprinkler heads would tend to flow along the same paths.

F. Credible Fire Scenarios

Auxiliary transformers and hydrogen seal oil units are acknowledged as significant combustible loads and fire protection features are applied accordingly. This section addresses the credibility and consequences of fires from other combustible sources.

Westinghouse Electric Company, the vendor for the Turkey Point Unit 3 and 4 turbines, has stated that there have been very few reports of significant fires associated with their turbine and auxiliaries. This was attributed to the guard pipe design around the lube and control oil piping as well as the welded joints in the lube oil piping. However, of the oil leaks known to have occurred, the most common is lube oil leakage resulting from failure of the bearing oil seals. Such leakage's can range from a few drops to gross leakage of several gallons per minute.

A turbine failure causing a failure to the lube oil system is considered an extremely low probability event at Turkey Point because of the fully integral turbine rotor design and the regular maintenance and testing of the turbine control features. Nevertheless, because such events have occurred in the past, aspects of these events were considered as they relate to Turkey Point. The following is a summary of the review, with more details provided in Sections V.F, V.G and V.H herein.

Applicability of Industry Events.

As a result of turbine blade failure, Fermi experienced a brief hydrogen fire, an oil/water spill and damage to the exciter, generator, condenser, No. 3 low-pressure turbine, and the turbine building, service and stator cooling water systems. Although of substantially different design (BWR with a General Electric Corporation turbine and closed turbine building), it is worth noting that the hydrogen fire was limited due to the "charge-and-isolate" method of hydrogen supply operation. A similar method of operation is used at Turkey Point and would limit any hydrogen fire.

As a PWR with a Westinghouse turbine, the Salem event is more relevant to Turkey Point. This event occurred during testing, where multiple failures led to a turbine overspeed condition. Many of the preventive design and control features at Turkey Point were either not available or not operable at Salem. Overspeed resulted in missile generation and a hydrogen fire.

None of the guarded lube oil piping was ruptured, which is not unexpected if the Salem lube oil piping configuration is similar to that at Turkey Point. The main turbine lube oil piping header at Turkey Point is located outside of the turbine pedestal, just below the operating deck. In the zone of influence for the trajectory of any low-pressure turbine missile, the line of sight between turbine rotor and lube oil piping is effectively blocked by the pedestal. Therefore, lube oil piping is not vulnerable to direct impact from a postulated turbine missile.

Furthermore, the occurrence of a missile from turbine overspeed is extremely unlikely at Turkey Point by virtue of turbine design and its control and protection features. The main governor controls turbine speed. The auxiliary governor arrests the turbine speed increase at approximately 103% of rated speed, and is also equipped with an acceleration feature which closes valves in anticipation of overspeed. As additional backup, a mechanical overspeed device is provided to trip the turbine at approximately 111% of rated speed.

In addition, the original Turkey Point turbine rotor has been replaced by a fully integral rotor design. Analyses show that fully integral rotor designs significantly reduce the likelihood of missile generation. Although stress corrosion was found to be the dominant mechanism for determining the potential for missile generation, analysis for 120% overspeed shows that the probability of rotor burst by this mechanism does not exceed 1 in 10,000 even after 30 years of running time.

In summary, based on the preceding, the potential for turbine missile generation is extremely low, and the vulnerability of turbine lube oil piping to any credible postulated turbine missile is virtually zero. Therefore, there is no credible mechanism for gross failure of turbine lube oil piping.

Even so, because Salem is also a Westinghouse plant and because turbine missiles were involved in the event, additional turbine missile scenarios were evaluated for Turkey Point. Regardless of the mechanistic credibility, a scenario was postulated that a turbine missile could rupture condenser tubes, that lube oil leakage would occur at the low-pressure turbine and/or generator bearings, and that the lube oil would ignite and spill to the floor beneath the generator and into the condenser pit. The evaluation concluded that there is no mechanism for rupture of circulating water piping or waterbox expansion joints, and that there are sufficient automatic and procedural controls to prevent flooding the condenser shell to overflow at the condenser-turbine joint seal. Furthermore, circulating water flooding would be contained in the pit, and burning oil would be suppressed by sprinkler actuation inside the building. Therefore, the combination of a turbine lube oil fire and unmitigated flooding of circulating water is not a credible scenario at Turkey Point.

Lube Oil Fire Hazard Analysis

FPL has evaluated the impact of a lube oil fire scenario postulated to result from failure of low-pressure turbine and/or generator/exciter bearing oil seals. Failures elsewhere in the lube oil piping would be contained by the guard pipe and drained back to the lube oil reservoir. Therefore, lube oil leakage from pipe areas other than at the bearing oil seals is not considered credible.

Lube oil leaking from the generator/exciter and/or low-pressure turbine bearings would fall to the area directly below the bearings. Oil that did not fall directly into the condenser pit would fall to the turbine building floor at grade elevation. A walkdown was performed to identify the flow paths of oil leaking from the turbine bearing seals. Turbine bearing oil leakage would either flow to area drains or flow toward the condenser pit sump.

An analysis was performed to determine the impact of a fire in these areas. Cables and raceways in the immediate proximity were identified and evaluated. The assumptions and methodology are consistent with those described in UFSAR Appendix 9.6A. In addition, sprinkler coverage and area drainage designs were evaluated. The drainage design with curbs will be sufficient to limit flow spread. The existing sprinkler system is being augmented in the area east of the turbine centerline and near the condensate pumps to provide additional protection for raceway in the Control Building vestibule area. Even so, circuits and raceways subject to exposure fire and which are necessary to support safe shutdown were identified as requiring 1-hour rated fire protection, and therefore require modifications accordingly.

Hydrogen Supply Lines

A hydrogen supply header is routed in the Open Turbine Building serving the main generator manifold. The primary supply header enters the turbine building from the north along column line A. The header continues along the far west side of the turbine building, where it connects with a north-south header serving both nuclear units.

The header serves the main generator hydrogen manifolds, located west of the turbine shaft centerline. Not only are the manifold stations over 50 feet from protected circuits, but the associated pipe sizes are no larger than 1/2-inch. In addition, a wet pipe fire suppression system is provided where the hydrogen manifolds are located.

The hydrogen supply header is 1-inch, Schedule 40 piping with welded fittings. As such it is well contained and not considered a combustible threat. Furthermore, due to the open nature of the surroundings, any hydrogen leak that might occur would be quickly diluted and dissipated.

G. Smoke Migration

There is almost always a breeze at the Turkey Point plant site. Winds can come from any direction, but prevailing winds are from the east and southeast. As such, the prevailing tendency would be for smoke and hot gases from a lube oil fire to be pushed westward out of the Open Turbine Building and away from the main power block. Furthermore, since the Open Turbine Building is open on all sides, winds from any direction tend to blow through. This would prevent any significant accumulation of smoke and hot gases within the Open Turbine Building.

In its coastal location, having no breeze at Turkey Point is an extremely rare occurrence. This could happen during a temperature inversion in the atmosphere. Even so, should a fire occur within the Open Turbine Building, most of the smoke and hot gases would flow out from the open sides of the building, and dissipate while rising in the open air. The small portion of smoke and hot gases remaining in the Open Turbine Building that is not cooled by the sprinkler system would tend to collect beneath the turbine deck. The turbine deck is a substantial, reinforced concrete platform supported by comparable structural steel beams and columns. The beams themselves would form pockets and barriers for outflow. Even so, the integrity of this massive structure would not be compromised by any smoke and hot gases that may collect there.

Even so, the potential effects of smoke from a postulated turbine lube oil fire on facilities outside the direct influence of the fire were considered. The facilities considered potentially affected are the Unit 3 emergency diesel-generator building, control building and the auxiliary building. The diesel building lies northeast of the Unit 3 condenser pit. The closest building opening is for the 3B diesel room ventilation (includes engine air intake) which is approximately 90 feet from the condenser pit. If the wind were out of the southwest (toward the diesel building) it would be obstructed on the ground elevation (in order of obstruction) by the condensate polishing system components, then by the main/startup and auxiliary transformers and finally by motor control centers and feedwater heaters. Also, two rows of security/missile grating and the condensate storage tank lie between the condenser pit and the 3B diesel room air intake. Plus, the diesel radiator fans exhaust toward the condenser pit, which would tend to push ground level air away from the diesel building. Finally, in addition to all this, a manually operated water curtain is available for smoke mitigation at the diesel air intake grating. As such, smoke from a postulated turbine lube oil fire will not compromise Unit 3 diesel-generator operation.

For the control building, specifically the control room,-there are three supply intakes, one for normal operation and two for operation under emergency conditions. The control room air conditioning system can operate with normal intake, as direct makeup to the system, emergency intake with high-efficiency filtration and purification (charcoal filters), or operation with no air intake. If necessary, the emergency dampers may also be closed resulting in a 100% recirculated airflow. Should a fire occur outside the control room resulting in smoke intrusion into the control room, control room operators could close the normal supply damper and go to the emergency recirculation configuration. Depending on the severity of the smoke intrusion, the operators may elect to go to emergency recirculation with minimal outside supply air or to 100% recirculation. An air duct smoke detector is located in the makeup air supply duct which would provide indication in the control room upon detection of smoke.

The control building is situated between the condenser pits and the auxiliary building. The once-through ventilation system supply and exhaust locations are on the roof of the auxiliary building. The supply fan intake is over 100 feet from the edge of the auxiliary building. Assuming a favorable wind for this scenario, the smoke would need to rise to the roof elevation and then descend across the roof to the ventilation intake. This is not a credible scenario, thus the auxiliary building is not vulnerable to the effects of smoke from a fire in the condenser pit areas.

H. Safe Shutdown Capability

Plant areas containing safety related or safe shutdown equipment which are susceptible to substantial fire hazards are provided with detection. Some of these and other areas which contain relatively high in situ combustible loading or could significantly affect plant operation in event of a fire are provided with fire suppression as well. Outdoor areas without automatic fire detection capabilities either do not contain in situ combustibles or ignition sources which will cause a significant fire, or potential losses have been deemed of no consequence to plant safe operation or safe shutdown capability.

An additional Open Turbine Building transient has been analyzed. The transient is a postulated turbine lube oil fire resulting from failed low-pressure turbine and/or generator bearings. The exposure fire is restricted to the condenser/condensate pump pit and to a floor area pool contained within nominal column lines B and D east-west, and north-south at column lines 23 and 25 for Unit 3 and column lines 30 and 32 for Unit 4. The wet-pipe sprinkler systems protecting these areas will be designed to meet or exceed NFPA 13 requirements. Safe shutdown circuits in these areas will be protected by 1-hour rated fire barriers.

In these areas, while transient combustible materials could potentially cause a significant fire, those materials are strictly controlled. In these cases, plant personnel are required to continuously accompany a transient combustible liquid and, therefore, provide the primary means of detection and reporting for a fire, even in areas where detection facilities are installed. This control is supplemented by fire watch rove. Thus, a study to determine what percentage of time these areas are occupied by plant personnel was deemed unnecessary.

Based on the preceding, a fire which could challenge an outdoor fire barrier system is extremely unlikely. Even so, the fire brigade staffing and training complies with requirements as provided in 10 CFR 50, Appendix R, Sections III.H and III.I. All fire brigade members are trained at an accredited fire training facility once a year. This facility exercises the leadership skills of the fire brigade members through training with live fires.

In addition, fire brigade response/control times for actual fires at Turkey Point have been recorded. "Response Time" is defined as the time it takes for the fire brigade to arrive at the scene. "Control Time" is defined as the time required to extinguish the fire. The fire brigade control/response time data for unstaged fires during the period 1989-1997 is presented in Section V.J. It should be noted that some of the fires were extinguished before the full fire brigade complement arrived. Based on the preceding, the fire detection features are sufficient for fire fighting support.

The fire zones listed in Section II.C are located in the Open Turbine Building and are included in the "Transient Combustible Control Area" for the plant.

Operator actions are vital to maintaining safe operation or achieving safe shutdown of the plant in event of a fire. Training for proper response to a fire event is fully integrated in the Turkey Point training program, and is based on the Procedure 0-ONOP-016.10, *Pre-Fire Plan Guidelines and Safe Shutdown Manual Actions*. This procedure contains detailed information and prescriptions on fire fighting and ventilation facilities, safe shutdown equipment availability, and manual actions required to mitigate equipment spurious actions.

In summary, the use of fire barriers and separation of safe shutdown circuits, substantial safe shutdown circuit coverage by fire detection and suppression system, well-trained operators, and a well-trained and responsive fire brigade provide defense-in-depth for assuring safe shutdown capability.

I. Proposed Modifications

Modifications are required, based on a postulated turbine lube oil fire, to support the bases, assumptions and conclusions presented in support of this exemption request. The proposed modifications will be evaluated with respect to 10 CFR 50.59 requirements, and are summarized as follows:

<u>Augmented Suppression</u>

In determining the scope of additional suppression required, two principal items were considered: The location of the potential fire hazards and the location of the cables to be protected. Figures 1 and 2 illustrate the scope of the existing suppression coverage, the proposed additional suppression and the general location of the Thermo-Lag protected cables. As discussed above, there was a concern for the area below the generator since this was a potential location for the accumulation of lube oil in the postulated turbine bearing seal failure event. There is also a significant inventory of cables along the east side of the Turkey Point Unit 3 and 4 Open Turbine Buildings to be protected from effects of the postulated fire. The evaluation demonstrates that the existing and proposed additions to the sprinkler system between column lines A and J provide adequate protection to those raceways in the Open Turbine Building and east of column line J, combined with the barrier upgrades described below.

Also proposed is the replacement of sidewall sprinkler heads in the condenser pit. A previous inspection questioned the coverage provided by the existing sprinkler heads. Although the head type and spacing were in accordance with industry practice at the time of installation, the sprinkler heads will be replaced to assure coverage in accordance with National Fire Protection Association (NFPA) standards. The augmented

coverage will include the area below the circulating water expansion joints.

Thermo-Lag Upgrades

In concurrence with the postulated fire hazard discussed in Section IV.F above, FPL will provide a 1-hour fire rating for Thermo-Lag protection required and located between column lines A and E, and within the condenser pits in both the Unit 3 and 4 Open Turbine Buildings. The intent of the proposed scope of the upgrades is to provide a 1-hour fire barrier with suppression between column lines A and E and in the condenser pits for both Units 3 and 4.

In concurrence with the postulated fire hazard discussed in Section IV.F, FPL will provide 25-minute rated fire barriers for raceway protected by fire barrier between column lines E and J_c. The proposed augmented suppression and containment of the postulated fire hazard to the west of column line D and in the condenser pit minimizes the threat to the east. Also, the augmented suppression proposed east of column line D provides additional protection. Finally, the Open Turbine Building itself, with varying elevations precluding the accumulation of hot gases, also serves to mitigate the threat of the postulated fire hazard.

Supplemental Facility Modifications

Curbs, or ramps, will be installed north-south at grade elevation between column lines B and D to limit lube oil flow westward and divert flow to the condenser and condensate pump pits. The combination of these curbs, the turbine pedestals, switchgear room walls and local equipment pads will limit the spread of lube oil spilled from the generator and low-pressure turbine bearings.

The condenser inlet water box and piping expansion joints will be protected from direct exposure fire by augmented sprinkler coverage.

Conclusion

This information demonstrates that, except for cables and appurtenances requiring protection and located between column lines A and E, separation by one of the means described in the exemption request in Section II.B provides a level of fire protection consistent with the fire hazards, both in situ and transient, identified for these fire zones. This information also demonstrates that these features provide a high level of assurance that at least one train of safe shutdown equipment and cables will remain free of fire damage. Additional protective features would not materially enhance the safety of the plant.

V. Supplemental Evaluations

The purpose of this section is to reflect responses to previous NRC requests for additional information, and to provide added details to topics addressed above within the context of this exemption request. Note that most of this information has been included with the FPL request for exemption in outdoor areas excluding the Open Turbine Building, as submitted via FPL letter L-96-318, dated December 12, 1996 for Turkey Point Units 3 and 4.

A. Fire Test Applicability for Outdoor Configurations

The purpose of this subsection is to compare Turkey Point outdoor configuration-specific fire endurance testing (NEI Fire Test 2-2, center assembly) and generic industry fire endurance testing (NEI Fire Test 2-1), and to demonstrate that the industry generic testing is applicable to the Turkey Point outdoor configurations.

The two center conduits in NEI Fire Test 2-2 are representative of the Turkey Point outdoor installations by:

(1) using 3M caulk in the joints,

(2) using a weather-resistant topcoating, and

(3) having weep holes installed in the enclosure for potential water drainage.

Establishing that the results of Test 2-2 are similar to the Test 2-1 results of the standard installations, then the results of the standard testing is applicable to these specific features in these configurations. This test included a hose stream test following completion of the 1-hour test interval.

Tested Configurations

The purpose of the test configurations in NEI Test 2-2 was to evaluate the effectiveness of three specific Turkey Point configuration features, namely the 3M joint compound, weep holes and topcoat.

The testing of two specific configurations is sufficient to justify these features. The first feature (the joints) is a critical design feature in that failure of a joint would constitute failure of the assembly. The smaller the conduit, the lower the fire rating of the assembly (all other parameters remaining the same), because smaller conduits provide a lesser heat sink inside the fire barrier. The specifications for the joint gap prior to installing a joint compound are the same for small and large conduits. Therefore, testing the smaller conduit would test the worst case joint for any conduit size.

In NEI Fire Test 2-2, a 3/4-inch (small) conduit and a 2-inch (medium) conduit were tested with the 3M Fire Dam 150 Caulk. These results are compared to results for equivalent NEI Fire Test 2-1 testing with trowel grade material as the joint compound. The results are found to be consistent such that the 3M Fire Dam 150 Caulk functions in a similar manner as the trowel grade material when used as a joint compound.

The second feature (drainage holes) is a unique characteristic of the Turkey Point outdoor installations. If the small (1/4-inch) hole failed to seal itself up or depleted the material at a faster rate than a continuous barrier, it would reduce the fire resistance of the assembly. A failure at this location would not depend on the conduit size or orientation, only on the effect of the hole to seal itself. Thus, a single test is sufficient to determine the effect of this feature. The results of NEI Fire Test 2-2 demonstrate that small drainage holes do not reduce the fire rating of the assembly, as compared to similar testing without drainage holes.

The third feature is the topcoat (paint) used for weather (water) resistance in the outdoor locations. This coating is external to the barrier, and does not affect any of the installed parameters of the barrier. The only potential adverse effect could be additional fire loading on the surface of the assembly, which may somehow affect the rating, or a chemical reaction with the Thermo-Lag which may degrade the performance of the fire barrier material. Again, a single test is sufficient to determine if there is any significant effect of this feature. The results of NEI Fire Test 2-2 support the conclusion that the topcoat does not reduce the fire rating of the assembly, as compared to similar testing without the topcoating.

<u>Acceptance Criteria</u>

The thermal acceptance criteria, as stated in ASTM E-119 and NFPA-251; and reiterated in Generic Letter 86-10 Supplement #1, are:

- The average unexposed side temperature of the fire barrier system, as measured on the exterior surface of the raceway or component, does not exceed 250°F above its initial temperature; and
- Any single thermocouple does not exceed 30 percent of the maximum allowable temperature rise (i.e. 325°F above its initial temperature).

Test Results

Applying this criteria to the 2-inch aluminum conduit in NEI Fire Test 2-2, the allowable average temperature was exceeded at 40 minutes and the allowable maximum temperature was exceeded at 35 minutes. Also, the maximum temperature was exceeded on the radial bend at 35 minutes. Even so, this assembly passed the hose stream test and still had virgin material remaining after testing was completed.

For the 3/4-inch aluminum conduit, the allowable average temperature was exceeded at 27 minutes and the allowable maximum temperature was exceeded at 26 minutes. Also, the allowable maximum temperature was exceeded on the radial bend at 31 minutes. For most of the conduit, no uncharred material was evident following the 1-hour fire and hose stream testing.

Testing of conduits with Thermo-Lag 330-1 protection has indicated that, with all other factors the same; the smaller the conduit, the lower the fire rating. Additionally, testing has indicated that conduits do not have a structural failure mode as do cable tray 1-hour configurations. For these reasons, two small conduit sizes (worst case) were selected for testing using the installation techniques unique to Turkey Point outdoor installations. The differences in the Turkey Point installations versus the standard baseline installations were not expected to have any appreciable effect on the fire rating of the barriers. The differences and the reason for assuming consistency in fire rating is as follows:

1) Fire Dam 150 (3M) Caulk is used as a joint filler for Turkey Point, where Thermo-Lag 330-1 Trowel Grade material is used for the standard baseline installations. The Fire Dam 150 Caulk is used in other fire rated assemblies, and has a similar fire rating to the trowel grade, which it is replacing, for the thickness tested.

2) Drainage holes of 1/4-inch diameter are provided at low points on raceways to permit any moisture trapped in the enclosure to escape. Due to the expansion of the Thermo-Lag material in fire conditions, these holes are expected to seal up rapidly and provide a fire barrier equivalent to the remainder of the assembly.

3) A topcoating system (paint) is applied over the completed assembly for waterproofing. Although topcoating systems are generally flammable out of the can, when they cure (dry) the flammability is greatly diminished. Also, the flammability of a thin layer of topcoat would be overwhelmed by the furnace heat flux, and no effect on the fire rating was expected.

The following is a comparison of conduit tests of similar configuration, so that the other tested configurations would be applicable for the analysis of Turkey Point outdoor configurations. A comparison is made to NEI Test 2-1, where baseline construction techniques were employed.

	NEI Test 2-1		NEI Test 2-2	
	3/4" Conduit	2" Conduit	3/4" Conduit	2" Conduit
Minutes to Max. Single Temperature	27	41	26	35
Minutes to Max. Avg. Temperature	27	39	27	40

The time to the average maximum temperature is essentially the same for these two tests. The data demonstrates that no new failure modes were generated with the use of the three new aforementioned construction techniques, and testing performed to baseline construction methods are valid for Turkey Point outdoor conduit configurations to determine fire rating.

Fire endurance and hose stream testing was performed per ASTM E-119 and NFPA-251, as reiterated in Generic Letter 86-10 Supplement #1. Specific outdoor applications were hose stream tested in NEI Test 2-2.

The NEI testing assessed (among other things) the performance of two 1-hour outdoor configuration baseline fire barriers constructed using preshaped Thermo-Lag conduit sections on 3/4- and 2-inch diameter conduits (center assemblies). The testing was conducted for 60 minutes. No barrier openings occurred for the 2-inch diameter conduit, even though it received an additional fire exposure of 25 minutes beyond the point where temperature criteria were exceeded. The 3/4-inch conduit barrier had observable openings after having been subjected to 34 minutes of fire exposure beyond when it initially exceeded temperature criteria (at 26 minutes into the test).

Although it is difficult to determine exactly when the openings occurred, it is reasonable to assume, based on the 2-inch conduit performance, that openings did not occur at 26 minutes and may have occurred well after that point. Based on temperature profile data recorded during the test, no joint openings (or any structural failure) occurred for the 3/4-inch conduit barrier during fire exposure. Instead, the openings were characterized as "burn-through" where the Thermo-Lag material had been consumed to the underlying stress skin. Therefore, it is reasonable to conclude that this burn-through occurred well after exceeding temperature criteria, and that openings more likely occurred as a result of hose stream testing.

Based on the preceding, the 2-inch conduit barrier passed the hose stream test requirements at one hour, and there is a very high confidence level that the 3/4-inch conduit barrier had sufficient fire and firefighting

endurance capability to have met the hose stream requirements for the fire endurance rating (26 minutes) provided.

When using the applicable guidance documents to rate a particular existing fire barrier, if the rating is less than the applicable 1-hour or 25-minutes (as applicable), then the barrier does not meet the requirements of the exemption request and modifications will be performed.

Extent of Test Applicability

The drainage holes and the topcoat are features independent of the overall configuration (conduit, tray, box, etc.) of a raceway fire barrier assembly. However, the extent of the applicability for the use of the FD-150 as a joint compound is limited to conduits. When structural integrity of an assembly is the failure mode or when a joint would be stressed due to the effects of a fire, then the applicability of the FD-150 as a qualified joint compound is questionable. In these cases, additional testing would need to be performed or the assemblies would require upgrade to meet a tested configuration.

Significant industry testing has been performed for the upgrade of boxes, trays and banked conduit configurations. The baseline for these tests are typically dry or post-buttered joints. Turkey Point will upgrade all cable tray, junction box, pull box and banked conduit configurations in outdoor areas based on tested configurations for the fire rating required to address the use of a qualified joint configuration or compound. Thus, no credit will be taken for the use of Fire Dam 150 joint compound in these types of assemblies.

B. Installed Barrier Parameters

The design parameters and construction attributes used to install the fire barriers at Turkey Point were verified to be the same as or bounded by those used to construct the test specimens by comparing NEI test specimen features with Turkey Point installation requirements and as-built conditions. This was accomplished by reviewing the NEI Application Guide, NEI Test 2-2, and FPL Construction Specification MN-3.21, and by disassembling and inspecting (destructive testing) various fire barrier installations.

The following is a listing of destructive tests performed on various types of barriers:

- One (1) Pull Box
- Four (4) Support Boxes
- One (1) 1-1/2" Conduit
- Three (3) 2" Conduits
- Three (3) 3" Conduits

The quantities (111 linear feet of conduit) and sizes of Thermo-Lag fire barrier assemblies provide a sufficient sampling because (a) destructive tests were performed on sections found to be damaged or degraded during routine inspection, and are therefore randomly obtained, and (b) the methods and techniques used to construct each barrier are the same regardless of the protected barrier size. A comparison of parameters and attributes is provided in the table below. The results of the destructive tests confirm that the Turkey Point installations are consistent with plant-specific installation instructions and guidelines and the NEI Application Guide. The following table compares the attributes of a representative outdoor 2" conduit installed at Turkey Point Plant with corresponding construction specification requirements and NEI Application Guide Test 2-2 parameters.

REPRESENTATIVE 2" CONDUIT, 1 HOUR FIRE BARRIER, in OUTDOOR AREA			
	NEI Test 2-2	AS SPECIFIED	AS INSTALLED
COMMODITY PARAMETERS			
Size	2"	2"	2"
Material	aluminum	steel	steel
Contents/Total Enclosed Mass (lbs./linear ft.)	Empty/ 1.16	not stated	3.32
Orientation	H and V	not stated	Skew and V
BARRIER PARAMETERS			
Material Type	pre-shaped	pre-formed	pre-shaped
Material Thickness	1/2" nom.	1/2" min.	1/2"+1/4"-0"
Stress Skin Location	inside	inside	inside
Joint Type	butt	butt	butt
Joint Gap	1/4" max.; 3M caulk	1/4" max; 3M caulk	<<1/4"; 3M caulk or Trowel Grade
Fastener Size/Material	1/2" wide bands	18 g SS wire or 1/2" band	18 g Steel
Fastener Spacing	12"	12" max.	8" to 10"
Fastener Distance from Joints	2"	2" min.	< 2"
Joint Reinforcement Mechanisms	none	none reqd	none
Structural Support and Intervening Steel Protection	none	9"	9"

In summary, NEI used minimum thickness Thermo-Lag material and aluminum conduit with 0% fill. The installed configuration used up to 50% thicker Thermo-Lag material (more thermal protection), steel conduit (higher thermal mass) and an actual cable fill (more thermal mass to resist heat rise). Other as-built parameters were the same as or more conservative than the test specimens. Therefore, the configurations installed at Turkey Point provide a higher fire rating than the NEI tested configurations. On this basis, the NEI test results are bounding for Turkey Point.

Criteria for Proposed Modifications

The following describes the criteria to be used for installations and modifications for electrical raceway fire barriers at Turkey Point Units 3 and 4. An evaluation was performed which compared the installed fire barrier configurations at Turkey Point against those qualified by fire endurance testing in the industry for Thermo-Lag 330-1. The evaluation assessed the following for fire barrier applications at Turkey Point:

- Applicability of previous industry fire endurance testing to bound existing (i.e., "as-installed") barrier system configurations.
- Determination of whether design upgrades are necessary to achieve the required barrier rating, including identification of appropriate designs which have been qualified by test.
- Assessment of barrier system attributes which either differ from those qualified by test or have not been specifically tested.

Description of Proposed Modifications

Raceways requiring an 1 hour fire barrier will be upgraded based on 1 hour configurations qualified by industry testing (e.g., NEI Test 1-6 and TVA Test 6.1.2). FPL plans to protect essential raceways and enclosed circuits with the upgrades described below to ensure a 1 hour fire endurance rating:

- Conduits greater than or equal to 3 inch diameter will use 1/2 inch minimum Thermo-Lag 330-1 pre-shaped conduit sections and prefabricated panels. The upgrade consists of an external encapsulation of stress skin and Thermo-Lag 330-1 trowel grade material.
- Conduits less than 3 inch diameter will use the 1/2 inch minimum Thermo-Lag 330-1 pre-shaped sections and prefabricated panels. The upgrade consists of a 1/4 inch minimum Thermo-Lag 330-1 overlay and an external encapsulation of stress skin and Thermo-Lag 330-1 trowel grade material.
- Intervening commodities are protected with 1/2 inch minimum Thermo-Lag 330-1 prefabricated panel installed for a 9 inch minimum distance along the shortest continuous thermally conductive path from the baseline layer of the essential raceway. The upgrade will consist of joint reinforcement using stress skin and Thermo-Lag 330-1 trowel grade material a minimum of 3 inches in each direction of the interface joints between the essential raceway and intervening commodity.
- Protection on essential flexible conduits and air drop assemblies will be stripped and protected to bound the configuration in TVA test 6.1.2.

- Raceway commodities protected by box enclosures use 1/2 inch minimum Thermo-lag 330-1 prefabricated panel. The upgrade will consist of joint reinforcement using stress skin and 330-1 trowel grade material a minimum of 2 inches in each direction of the joint.

- Cable trays enclosures use 1/2 inch minimum Thermo-lag 330-1 prefabricated panel. The upgrade is joint reinforcement using stress skin and 330-1 trowel grade material a minimum of 5 inches in each direction of the joint.

Use of Topcoat Formulations Over Existing Thermo-Lag 330-1

The presence of topcoat does not compromise the ability to provide the required fire endurance rating. Fire endurance tests have demonstrated that topcoat formulations have no effect on the performance of Thermo-Lag 330-1 fire barriers when directly exposed to fire test conditions. Industry testing demonstrated satisfactory performance and bounds anticipated upgrades to 1-hour fire barrier systems. On this basis, where topcoat has been applied at Turkey Point, removal of topcoat is not required prior to upgrade of existing barrier systems. -

Repairs to Existing Thermo-Lag 330-1 Fire Barriers

Existing Thermo-Lag 330-1 installations at Turkey Point may be repaired as well as upgraded. Minor repairs, such as dents and surface discontinuities, are made using trowel grade material. Moderate repairs for areas where damage is more extensive, a combination of trowel grade material and cuts from prefabricated sections are used. For severe damage where Thermo-Lag installations exhibit signs of structural damage, delamination or loosening from the raceway, the damaged sections are removed and replaced.

Alternate Design and Construction Methods For Enclosures

Construction methods are governed by Florida Power and Light Co. Specification MN-3.21, *Installation and Inspection Guidelines for Thermo-Lag Fire Barrier Material*. Designs are based on NEI and other applicable industry testing. Alternative designs used to accommodate Turkey Point specific applications are supported by fire protection evaluations performed to the guidelines of Generic Letter 86-10 Supplement 1.

Conclusion

Based on the preceding, proposed upgrades to Thermo-Lag fire barrier systems at Turkey Point described above will provide a 1 hour fire barrier to ensure safe shutdown capability as described in section II.B of this exemption request. Modification designs are based on

qualification from existing industry testing. Where direct comparison of the planned modifications to tested configurations is not available, the test data was analyzed to justify the modification FPL plans to use.

C. **Major Combustibles**

The auxiliary transformers and hydrogen seal oil units are the major in situ combustible sources in the Open Turbine Building.

The methodology for fire hazard analyses of Turkey Point nuclear facilities is provided in UFSAR Appendix 9.6A, Section 4.0. Existing analyses are provided in the UFSAR 4.OD series subsections and describe zone features, combustible loading sources and fire control facilities. The following fire hazard evaluations are provided.

Auxiliary Transformers

The auxiliary transformers are located just inside the Open Turbine Building. The primary combustible loading source is the volume of cooling oil contained within the transformers. The auxiliary transformers are mounted in a reinforced concrete dike to contain oil leakage. The transformer oil volume is the most significant component of the loading described in the UFSAR subsections.

Each transformer is provided with facilities to either contain oil leakage and/or to channel it to a safe drainage area. Additionally, thermal detection is provided which activates the fixed water spray system and alarms in the Control Room. The transformers are primarily protected by fixed water spray fire suppression systems. Secondary protection is also provided by local fire extinguishers, and supplemented by nearby standpipe hose stations and hydrants.

Hydrogen Seal Oil Units

The hydrogen seal oil units are located in the open area west of the turbine shaft centerline and near the auxiliary transformers. The combined combustible loading of a hydrogen seal oil unit and auxiliary transformer is less than 6000 gallons (56 lb/ft^3) of oil with an assumed heating value (high end of range) of 20,000 BTU/lb.

The hydrogen seal oil units are mounted on a reinforced concrete slab with concrete curbs. Any significant oil leakage will flow to a safe drain. The hydrogen seal oil units are provided with thermal detection

which alarms in the Control Room. The units are primarily protected by fixed water spray fire suppression systems, supplemented by local fire extinguishers. Secondary protection is also provided by nearby standpipe hose stations and hydrants.

D. Combustible Loading

A detailed description of the combustible load, fire control and fire protection features for each outdoor fire zone is provided in Appendix 9.6A, Section 4.0 of the UFSAR and for the applicable fire zones in Section IV herein. Due to the extensive volume of information contained in the UFSAR, it will not be duplicated here. However, the highlights of this information are summarized in Section IV.

The combustible loading consists of in situ combustible materials at any one time. Transient combustibles are discussed in Section V.E. Therefore, this section will focus on in situ combustible loading.

The small quantity of lubricating oil in pumps is considered insignificant as an in situ combustible hazard because the oil is contained in reservoirs encased within the pumps. The relatively massive steel casings would mitigate flame propagation from a credible exposure fire to the oil in the reservoirs.

The only in situ fire loads east of the open turbine building structure are sparsely populated cable trays (most of which are located 13 to 20 feet above grade), and Thermo-Lag. The cable in trays was either coated with Flammastic 71A or 77 (and certain of these cable coatings are maintained, as provided in UFSAR Appendix 9.6A, paragraph 2.4.D.3.f) or qualified to IEEE-383, 1974 standards, and the enclosures are generally constructed with fire-resistant materials. The fuel load is low and spread out such that fuel contribution from cable and Thermo-Lag is considered insignificant.

Hydrogen Supply Lines

A hydrogen supply header is routed in the Open Turbine Building to serve the main generator manifolds. The main hydrogen supply is provided from the fossil units and approaches the turbine building from the north. The supply headers to each unit generator is isolated during normal power operation. Another header exits the turbine building to the east. Due to the open nature of the surroundings, any hydrogen leak would be quickly diluted and dissipated. Also, there are no ignition sources in close proximity to the pipe. As such the hydrogen line is not considered a credible fire threat.

Lube Oil Piping System

The turbine lube oil system in the areas of concern is not considered a major fire hazard. There is no exposed high pressure oil piping or valves under the turbine deck within 50 feet of any Thermo-Lag installations. Only low-pressure (atmospheric), return lube oil piping is exposed and routed around the turbine pedestal just below the turbine deck. Any oil leakage will flow toward area drains and the lube oil sump.

The high pressure supply piping is welded pipe encased in an atmospheric guard pipe which drains to the turbine lube oil reservoir. In event of a high pressure lube oil line leak, leakage will be diverted toward the lube oil reservoir via the guard piping. Rupture of the high pressure piping will not result in a pressure-type or spray fire. Therefore, a pressure-type fire is not credible.

In addition, the turbine lube oil system has annunciators that respond to low-pressure conditions that would alert the operators to a high pressure lube oil pipe break. These annunciators include:

Annunciator	Setpoint
Turbine bearing lube oil pressure low	8 psig
Emergency bearing oil pump start	7 psig
Turbine auxiliary oil pump start	10 psig
Guarded oil actuation	2 psig
Turbine bearing oil low-pressure trip	5.5 psig

Therefore, low lube oil pressure due to a leak in the high pressure portion of the system will annunciate in the control room and may, ultimately, result in turbine trip and/or turbine valve closures.

E. Transient Combustible Control Program

The Turkey Point Combustible Control Program prohibits storage of combustibles in outdoor areas that contain safety related equipment or cables. Procedures require that flammable liquids be attended at all times and a special permit is required for quantities greater than 5 gallons. Hence, transient combustible controls provide added assurance that a worst case transient fire caused by a spill would be far below a hazard level that could challenge a 25-minute fire barrier. Additionally, the fire brigade response time for outdoor fires is documented (via fire drills) to be less than 15 minutes from detection, which is well below a 25-minute fire barrier fire endurance rating.

There are several levels of fire prevention involving control of transient flammable and combustible materials at Turkey Point. Overall, transient combustible and flammable substances located or used anywhere in the plant area are controlled by housekeeping. In addition, they are

further restricted in certain areas to prevent the possibility of a fire from interfering with proper operation of systems required for safe shutdown. These restrictions address storage and handling of transient combustible and flammable substances, and become even more definitive and restrictive for increasingly sensitive areas.

The restrictions are specifically implemented under FPL Administrative Procedure 0-ADM-016.1, "Transient Combustible and Flammable Substances Program". This procedure generally defines the term "transient combustible" as "any combustible or flammable material that is not permanently installed...or stored in a designated storage area." The procedure also defines the restricted areas by illustration. These areas include safe shutdown component areas as well as safety related component areas.

A Transient Combustible Permit (TCP) is required under specifically defined conditions, including where Class A materials exceed 100 pounds (10 pounds for sensitive areas), where Class B liquids exceed 5 gallons (1 gallon for sensitive areas), or where more than five flammable or combustible aerosol containers are to be used. TCPs are issued and tracked by the Fire Protection Representative who also determines the need for additional fire prevention measures at the work site. The TCPs remain in force for the duration of its respective task. No transient combustible or flammable liquids are allowed to be unattended unless specifically exempted by procedure or by the Fire Protection Representative.

With regard to the accumulation of transient combustibles in a specific location due to multiple work activities, there is no need for procedural restrictions for the following reasons:

- Maintenance activities performed during plant power generation are restricted from an operations standpoint, and usually do not require transient combustibles.

- Transient combustible liquids are normally attended by those performing the task in the area.

- By nature of the work, most maintenance activities cannot be performed in close proximity with one another, so that work space often limits exposure to more than the transient combustibles required for the task.

- Plant work controls require that a TCP be prepared for any work which involves transient combustible material as applicable, and that flammable and combustible liquids be removed and properly stored by the end of every work shift.

- Restrictions imposed by the TCP are very conservative with respect to the exposure hazard required to challenge fire protection features in work areas.

In light of the preceding, there are very few transient combustibles in the plant at any one time, and those that are have sufficient controls. Therefore, the potential accumulation of combustibles would not challenge the fire-resistive capability of fire barriers.

F. Turbine Building Fire Protection

An evaluation was performed to provide a technical justification for augmenting fire protection facilities within the Turkey Point Unit 3 and 4 Open Turbine Buildings. A review of potential fire hazards within the Open Turbine Buildings, inclusive of industry events as well as the existing conditions, was performed. Based on this review, for areas exposed to fires caused by turbine lube oil seal leaks, augmentation of the level of fire protection is proposed via upgrades to the Thermo-Lag fire barriers, an expansion of the existing sprinkler systems and some minor modifications.

In order to establish the technical justification for the requested exemptions, it is first necessary to establish the potential fire hazards which pose a viable threat to safe shutdown equipment. A review of industry fire events was conducted to identify areas which were not considered as potential hazards. This review included an overview of power plant incidents in and a detailed review of three specific events at other nuclear facilities. Based on this review, applicability of these areas to Turkey Point was established. The next action was to identify the location and quantity of combustibles within the Open Turbine Buildings. With consideration for the potential fire hazards applicable to Turkey Point, the most likely types and locations of fire initiating events were established.

Having established the potential fire hazards within the Open Turbine Buildings, an assessment of the existing fire protection facilities and their ability to respond to the postulated events was performed. The proposed augmentation of the facilities was developed to provide fire protection for those viable potential hazards not fully addressed by the existing configuration.

1. Review of Industry Events

Based on fire incidents which have occurred in recent years, concerns have been raised with regard to the scope of fire protection programs. As evidenced by these events, there is some potential areas of concern in the design of plant fire protection features. Appendix A provides a synopsis of major turbine building fire incidents, occurring at both nuclear and fossil facilities dating back to 1965. A review of this document supports the conclusions reached in a paper entitled *Turbine Building Hazards at U.S. Light Water Reactors*, presented at the American Nuclear Society (ANS) 1993 Winter Meeting.

The following is excerpted from the Transactions of the ANS 1993 Winter Meeting:

> "The turbine building events ... that were reviewed indicate that attention may be needed in the following areas:
>
> 1. damage to lube oil systems and hydrogen systems from turbine vibration or missiles from turbine overspeed
> 2. smoke dissipation from fires in enclosed turbine buildings
> 3. turbine building flooding
> 4. collateral damage due to collapsing walls"

Therefore, based on the above each of these areas will be evaluated for applicability to Turkey Point Units 3 and 4.

2. Lube Oil and Hydrogen Systems

Portions of the lube oil and hydrogen systems are located within the Open Turbine Building. The major components, the lube oil transfer skid and the hydrogen seal oil skid, are protected by fixed water spray systems. The lube oil piping is encased in a guard pipe except at the turbine bearing housings. Hydrogen piping within the building is limited and the hydrogen supply is normally isolated. However, the incidents reviewed demonstrated that events which result in significant turbine vibration will most likely result in lube oil leakage from the generator and low-pressure turbine bearing seals. For the main generator, both hydrogen and lube oil leakage would most likely result from the bearing seal failures. The situation is further degraded since excessive vibration often leads to bearing failure and seal rubs, which provides an ignition source for the escaping hydrogen and lube oil. A review of the current fire protection features installed in the Turkey Point Unit 3 and 4 Open Turbine Buildings indicates that this event may not be adequately addressed by the installed configuration, regarding safe shutdown capability, and is assessed accordingly in Section V.G herein.

3. Smoke Dissipation

As noted in the ANS Transaction of the 1993 Winter Meeting, this issue is of greater concern in an enclosed turbine building. The Turkey Point Unit 3 and 4 turbine buildings are open. Furthermore, a significant portion of the ground floor (EL 18.0') is open to the underside of the operating deck (EL 42.0'), providing a very high overhead clearance, which would assist in the dispersion of smoke within the structure. Based on the above, smoke dissipation within the Turkey Point Unit 3 and 4 Open Turbine Buildings is not a significant concern.

4. Open Turbine Building Flooding

The potential for Open Turbine Building flooding has been examined in detail considering the following possibilities:

1. a missile severs circulating water tubes in the condenser
2. failure of the circulating water inlet piping expansion joints
3. failure of the circulating water outlet piping expansion joints
4. failure of turbine auxiliary systems

Because of the plant physical arrangement with regard to equipment locations, elevations, fire suppression and protection facilities augmentation over the condenser inlet expansion joints, pump capacities and redundant operational controls, none of the above flooding events are considered credible for the Turkey Point Unit 3 and 4 Open Turbine Buildings. More details of the supporting analysis is described in Section V.H herein.

5. Damage Due to Collapsing Walls

As stated above, Turkey Point Unit 3 and 4 turbine buildings are open buildings. As such, very few walls are located within the structure. This alone minimizes the potential for damage from collapsing walls. Also, walls within the Open Turbine Building, such as the switch gear and load center rooms and the main feedwater pump enclosures, are substantial seismically analyzed structures. Based on the above, collateral damage due to collapsing walls is not a concern for the Turkey Point Unit 3 and 4 Open Turbine Buildings.

6. Review of Specific Industry Events

Three specific events have been reviewed in detail and evaluated for applicability to Turkey Point. The events selected are recent and reflect areas of potential concern to Turkey Point. The events are:

- Salem Nuclear Generating Station, Unit 2 - Turbine Failure Caused By Overspeed
- Fermi 2 - Failure of Main Turbine Results in Extensive Equipment Damage
- Narora Atomic Power Station Unit 1, India - Turbine Failure Results in Hydrogen Fire and Subsequent Station Blackout with Concurrent Loss of DC Power

Salem Nuclear Generating Station, Unit 2

This section is based on review of SER 7-92. On November 9, 1991, with Salem Unit 2 operating at 100% power, plant personnel were testing the mechanical turbine protection features. As a result of a combination of equipment problems, i.e., mechanical binding of solenoid valves, foreign material intrusion in the control oil, etc., a momentary reduction in control oil pressure resulted in a reactor trip. The generator load

breakers opened in response to the reactor trip. When the oil pressure recovered, some of the turbine inlet steam valves re-opened admitting steam to a now unloaded turbine. The turbine oversped to approximately 160% of rated speed. A low-pressure blade failure occurred in which missiles were ejected from the turbine. The test lever was released and the turbine was manually tripped. Excessive vibration from the turbine overspeed caused a generator hydrogen seal failure resulting in a hydrogen leak and subsequent fire.

The overspeed event caused not only a failure of a low-pressure turbine blade, but also the failure of the low-pressure exhaust flow guide due to blade impact. The resultant imbalance led to vibration induced failures of the generator hydrogen oil seals and the exciter bearing oil return lines.

The following table lists items which were contributors to the initiation of the event and the precautions in place at Turkey Point to preclude the occurrence of a similar event:

Table 1
Salem Event Contributors

Feature	Salem Unit 2	Turkey Point Units 3 and 4
OPC/AST/ASB Solenoids	Insufficient Periodic Maintenance and Testing	Periodic Maintenance and Testing Every Refueling Outage
Control Room Communication	Communication with Test Personnel was Not Maintained	Communication established with the Control Room as a Test Prerequisite
Local Tachometer	Not Available at Test Lever	Available at Test Lever
Fully Integral Rotor	Disc Type Rotor Design	Fully Integral Rotor
Foreign Material Exclusion	Metal Chips Found in Control Block	Overspeed Trip Mechanism Hand Cleaned Each Refueling Outage
Local Trip Indication	Not Available at Test Lever	Not Available at Test Lever

As a result of the Salem overspeed event, Westinghouse issued Customer Advisory Letter (CAL) 92-02. CAL 92-02 contained 20 preventative and corrective actions to preclude a repetition of the Salem overspeed event. Several of those actions are related to the items listed in Table 1. The CAL was reviewed and 9 of the recommended actions already existed in the Turkey Point maintenance and testing program, 2 more of the recommended actions were incorporated as a result of the CAL, 4 of the recommended

actions were addressed by alternate methods. The remaining 5 recommendations were not applicable to Turkey Point as they pertained to electro-hydraulic control (EHC) fluid.

In addition, fundamental component differences exist at Turkey Point which reduce the likelihood of initiating such an event. The Salem rotor design is the previous disc type rotor. The Turkey Point low-pressure turbine rotors have been replaced with rotors of a "fully integral" design. In a report submitted to NRC, *Analysis of the Probability of the Generation of Missiles from Fully Integral Nuclear Low-pressure Rotors*, (WSTG-4-P) Westinghouse documented the improved reliability of the fully integral design. In fact, the report concludes that for the fully integral design "...Considering typical use factors for nuclear turbines, and considering that the crack locations are readily observable during normal turbine maintenance, it is concluded that periodic safety related inspections are not required within the expected life of the turbine."

Based on diligent performance of the required maintenance and testing of the turbine overspeed protection devices and the improved design of the fully integral rotor, the probability of occurrence of an overspeed event or the failure of a low-pressure turbine blade independently is greatly reduced. It can be concluded, therefore, that preventative measures are in place to the extent practical to preclude an event as experienced at Salem.

Additional damage was done to the Salem facility as a result of the hydrogen explosion and subsequent hydrogen and lube oil fire. The only viable means of preventing the hydrogen explosion is to preclude the occurrence of the event. The measures described above are sufficient for this area. However, as previously identified above in the review of potential areas of concern, the occurrence of a hydrogen and lube oil fire does require further evaluation and is discussed below.

Additional collateral damage as a result of this event included damage to the condenser wall, rupture of circulating water tubes within the condenser and the remaining exhaust stage blading had visible tip damage. The most effective measures to preclude this type of damage are those described above to reduce the probability of occurrence. The review for this event does not indicate any further consequences as a result of the tube ruptures inside the condenser. It can only be assumed that the increased inventory did not create a problem other than water quality.

Fermi Unit 2

Based on the review of INPO SER 14-95, on December 25, 1993, while operating at 93 % power, Fermi 2 experienced a turbine trip and subsequent reactor scram. The turbine trip was initiated by the overspeed trip mechanism resulting from severe vibration following the failure of an low-pressure turbine blade. The failed blades and excessive turbine vibration caused considerable damage to the turbine-generator,

its auxiliaries and the condenser. The turbine vibration also damaged the generator hydrogen seals releasing hydrogen and lube oil. The heat, most likely caused by seal rubs, ignited the hydrogen and lube oil.

As a result of the significant damage to the low-pressure turbine rotors, a definitive root cause could not be established. However, below, in Table 2, are potential root causes for the event.

Table 2
Fermi-2 Potential Root Causes

Potential Root Cause	Fermi - 2	Turkey Point Units 3 and 4
Torsional Vibration	Not Verifiable	N/A via Westinghouse Analysis
Steam Path Water	Inspections are Indeterminate	Not Identified during Inspection
Blade Fatigue Failure	Not a Generic Concern	N/A - Fully Integral Rotor
Lacing Rods	Not Verifiable	N/A - Fully Integral Rotor
Steam/Water Chemistry	BWR Generic Issue	N/A
Low Condenser Backpressure	Not Verifiable	N/A based on CW temperatures

The issues identified above are evaluated independently for applicability to Turkey Point.

The potential for torsional vibration to have caused the blade failure at Fermi - 2 cannot be established. The configuration of the turbine-generator prior to the event cannot be reasonably reconstructed for verification testing. However, the potential for torsional vibration to have a detrimental effect on the Turkey Point turbine-generator-exciter rotor train has been evaluated by Westinghouse Corporation. This evaluation is documented in Westinghouse Engineering Customer Report EC-95205, entitled *Florida Power and Light Turkey Point 3 and 4 Torsional Study*, dated September 15, 1995. The analysis was conducted using a continuum model of the entire turbine-generator train including branches, or subsystems, to represent the blade disc coupling effect of the longer low-pressure turbine blade rows. The results of the analysis show that the Turkey Point units are not susceptible to distress due to torsional vibrations caused by "steady state" unbalance excitation or to stresses resulting from "short-circuit" occurrences. The maximum resultant stress is only 13% of the stress required to cause cracking at the critical frequency. Validation of the Westinghouse model has been established with the performance of over seventy (70) field tests.

The steam path water potential cause has two categories; accumulation of steam path water and water induction. Steam path water is formed as steam condenses while passing the turbine stages. These droplets accumulate on the blades and form larger droplets. The droplets are shed outwardly by the centrifugal force of the rotating element forming an annular ring. If a blade were to extend further than the other blades in the same row, the longer blade would be subjected to additional forces as it passes through the annular ring. Water induction is the result of flow reversal or blockage of extraction lines that causes an interruption in the normal water extraction process. Turbine and extraction steam system inspections, analyses of postulated events, and review of historical operating data have not substantiated or eliminated the accumulation of steam path water or water induction as causes of this event. Inspections during refueling outages have not produced any evidence of either phenomenon at Turkey Point Units 3 and 4.

The possibility of blade fatigue failure is considered related to specific deficiencies in a single blade. Detailed inspection and metallurgical examinations of Blade No. 9 of the Fermi-2 turbine reveal two characteristics which could have made it vulnerable to fatigue failure. The trailing edge of the foil section at the point of fracture was approximately 40% thinner than blades which had not failed. Also, a residual tool mark was found in the location where the crack was initiated. Inspection of the remaining eighth stage blading of the Fermi-2 rotor did not show any evidence of fatigue cracking. Therefore, it is reasonable to assume the fatigue life of the eighth stage blades is not a generic issue. As described above, Turkey Point Units 3 and 4 have fully integral rotors and as such the probability of blade fatigue failure is very low. Furthermore, regular maintenance inspections are performed for the purpose of ensuring the physical integrity of each blade. Therefore, this item is not a concern at Turkey Point.

Lacing rods are a design feature of the Fermi-2 low-pressure rotor. A rod ties the rotor blades so as to provide additional support to each individual blade from the blades on either side. If the ends of two rods could separate from one blade, it would leave the blade free standing, a configuration for which the turbine is not designed. Excitation of the free standing blade could then occur. Physical evidence was destroyed as a result of the failure, preventing a conclusive determination of the possibility of a lacing rod failure at Fermi-2. The Turkey Point design is substantially different. The last three stages of the Turkey Point low-pressure rotors are free standing as a result of the fully integral design. Due to the fundamental design differences, this item is not applicable to Turkey Point.

Steam/water chemistry as it is discussed here relates to inherent chemistry problems associated with Boiling Water Reactors (BWRs). The higher oxygen levels in BWR steam, when compared to Pressurized Water Reactor (PWR) or fossil plant steam, have been shown to have a deleterious effect on the fatigue strength of turbine blading material.

While potentially a causal factor at Fermi-2, it is not considered to be generically applicable to Turkey Point.

Low condenser backpressure, as referred to here, is the result of low circulating water temperature assisting to increase vacuum in the condenser. The greater the vacuum, the greater the steam velocity and differential pressure across the last row of low-pressure rotor blades. The Fermi-2 incident occurred on December 25. As noted in the SER, on the day of the event, the backpressure was near its lowest point in history. However, this is not considered applicable to Turkey Point since the circulating water temperatures at Turkey Point do not approach the winter water temperatures at Fermi.

Based on the above, it can be concluded that the potential event initiators of the Fermi-2 event do not require any additional precautions at Turkey Point. However, significant damage resulted from this event and warrants further review. The exciter separated from its coupling to the generator shaft. A number of condenser tubes were severed. Severe vibration resulted in failures of the service water, turbine building closed cooling water, hydrogen, seal oil and lubricating oil systems. The failed condenser tubes resulted in a approximately 250,000 gallons of circulating water, flowing into the condenser hotwell. The circulating water was discharged through the condensate polishers demineralizers, compromising the effectiveness of the demineralizers. The water was discharged to the condensate storage tank to compensate for rising hotwell water level. Reactor water quality deteriorated as the reactor core isolation cooling and stand-by feedwater systems used the condensate storage tank to maintain reactor water level. The service water and turbine building closed cooling water combined with the fire suppression system to flood the turbine building and radwaste building basement areas with approximately 550,000 gallons of water, disabling the radwaste system. The turbine lubricating oil system spilled 17,000 gallons on the turbine building floor areas which mixed with the water in these areas.

It should be noted that, unlike the Salem event, the vibration was caused by an imbalance which occurred at normal operating speed. Also, the turbine-generator supplier is English Electric Company. Since the Turkey Point turbine-generator set is a similar design and vintage to the Salem turbine-generator, the Salem event is considered to be representative of the potential response expected from such an event. In addition, as a PWR, the intrusion of the circulating water into the condensate system would pose only a secondary water chemistry concern, and as noted above, turbine building flooding as a result of condenser tube ruptures is not a concern.

Intake cooling water, the equivalent of service water at other plants, is not located within the Open Turbine Building. Therefore, it is reasonable to assume that the piping would not be subjected to the transient and not contribute to building flooding. The turbine plant cooling water is routed to the generator stator and to the exciter

pedestal. It is not considered credible that these connections would fail based on the vibration of the rotating elements. The enormous weight of generator stator will tend to resist any movement and the turbine plant cooling water piping system is not rigidly supported. However, should the piping rupture, floor drains within the building are routed to the discharge canal, since the radwaste system is not tied into the building drains. Overflow not carried away by the floor drains divides between flowing out the open building to the roadway at the ground elevation (EL 18.0') and flowing into the condenser pit. The lube oil system is generally constructed with welded connections and protected by a guard pipe. Piping rupture is not considered credible. Furthermore, the inventory of the lube oil system is less than 14,000 gallons.

Based on the above, design differences between the two stations preclude the possibility of an event as severe as the Fermi-2. Although Turkey Point has similar hydrogen isolation features, it is noteworthy that the INPO SER did credit the normally isolated hydrogen supply valve as limiting the hydrogen consumed in the fire. Therefore, the Fermi-2 system failures do not pose new concerns for Turkey Point.

In summary, the particular event that caused the hydrogen and lube oil fires at the Fermi-2 bearings is not applicable to Turkey Point. Therefore, the potential for a hydrogen and lube oil fire by other causes has been identified as a concern at Turkey Point and, accordingly, is evaluated further in Section V.G herein.

<u>Narora Atomic Power Station Unit 1</u>

The following is based on review of INPO SER 18-95, on March 31, 1993, while operating at 80% power, Narora Atomic Power Station Unit 1 suffered a catastrophic turbine blade failure, resulting in unbalanced loading of the turbine-generator shaft, bearing failure and damage to the generator seals. The hydrogen release from the generator and the turbine oil released from ruptured lubricating oil lines ignited. Cables in the vicinity also caught fire, ultimately resulting in a loss of all plant AC and DC power.

The sudden failure of two turbine blades in the final low-pressure stage has been attributed to low-cycle fatigue. This has been discussed above as not being applicable to Turkey Point. The fully integral rotor design combined with normal turbine maintenance is sufficient to preclude this type of blade failure. A Westinghouse report indicated that non-destructive examination of the low-pressure rotors at their normal maintenance interval is sufficient to preclude high cycle fatigue failure and the probability of low cycle fatigue failure is reduced as to no longer be a concern.

Typical of the resulting rotor imbalance, generator hydrogen seal and lubricating oil failures occurred. As noted above, the Turkey Point

maintenance and testing of the overspeed protection devices and the fully integral rotor design provide adequate protection to preclude the initiation of events which cause a rotating element imbalance. This is sufficient protection to prevent the initiation of a generator hydrogen seal failure. Lubricating Oil piping system failures are not considered credible for the same reasons as discussed with regard to the Fermi-2 event. The Narora Unit 1 turbine-generator set was supplied by Bharat Heavy Electricals, Ltd. The Salem Unit 2 turbine-generator is considered to be representative of the Turkey Point design. Welded lube oil piping contained in a guard pipe provides assurance to preclude a piping rupture. Should an unbalance of the rotating element occur, however, seal leakage at the generator or turbine bearing is not unexpected and as stated previously, requires further evaluation.

The damage which resulted at Narora Unit 1 was extensive. The turbine-generator suffered damage as a result of the rotating train imbalance and subsequent fire. Bus ducts and excitation panels sustained damage from a hydrogen explosion. Portions of the neutral bus ducts and the vertical section of the phase bus ducts below the generator melted as a result of sustained oil fires in this area. Cables, cable trays, Emergency transfer relay panels, electrical distribution panels, transformer panels and generator panels were all damaged and made inoperable as a result of the spread of the fire. The damage resulted in a station blackout concurrent with the loss of DC power within eight minutes of the turbine trip. As a result of the fire and a lack of dampers, the Unit 1 and 2 control rooms were evacuated due to smoke.

As previously discussed, the features of the fully integral rotor design and normal turbine maintenance inspections are sufficient assurance to preclude the type of blade failure and subsequent turbine-generator damage which occurred at Narora Unit 1. Concern for hydrogen and lube oil leakage and ignition at Turkey Point is an issue that is evaluated below. However, the extensive damage to electrical components was the result of a deficient fire protection program. Fire suppression was, in general, inadequate. Cables with flammable insulation were unprotected. Neither cable separation nor fire barriers were used to protect critical cables for redundant systems. The use of fire walls and fire barriers was minimal. There was no evidence of fire penetration seals. The control room environment was not protected by fire dampers. By contrast, all these fire protection features are installed at Turkey Point. Cables are either IEEE qualified or protected with flame resistant coatings. Fire walls with fire penetration seals are used to isolate appropriate fire areas. Both cable separation and fire barriers are used to protect cables and equipment required for safe shutdown. And, though not within the scope of this evaluation, it should be noted that control room air quality is ensured by isolation dampers and emergency recirculation capability.

Based on the above, it is not believed the Narora Unit 1 event is a credible scenario. As stated earlier, further evaluation is required for

generator hydrogen seal oil and bearing lube oil leakage, and is set forth in Section V.G below.

7. Potential Fire Hazards

Discussed below are common combustibles associated with the turbine generator and its auxiliaries:

Lubricating Oils

Lubricating oil performs several functions. The lubrication oil is used for bearing lubrication, generator seal oil and control oil. Inventory is maintained in two lube oil reservoirs, one each for Units 3 and 4. In addition, each unit is equipped with a seal oil skid, a lube oil transfer skid and guarded oil piping which contains piping for these functions. Each lube oil reservoir is located at grade elevation (EL 18.0') adjacent to the southern end of its respective turbine building on the west side. The lube oil transfer skid is located at grade elevation (EL 18.0') inside the building, east of the lube oil reservoirs. The seal oil skid is located at grade elevation (EL 18.0') inside the building, also on the west side, but at the north end of each turbine building. The guarded oil piping is located primarily beneath the operating deck (EL 42.0') and above the mezzanine level (EL 30.0'), with north-south headers extending along each side of the turbine pedestals. Branch lines extend up to the control, intercept and reheat stop valves and the bearings and down to the seal oil skid and lube oil reservoir.

Hydrogen Gas

The hydrogen gas is confined within the generator. The make-up supply to the generator is isolated at all times except when make-up is in progress. While the make-up is proceeding, an operator is stationed at the valve continuously. It is reasonable to conclude the hydrogen inventory hazard is limited to that within the generator and the instrumentation and fill lines.

Electrical Equipment Materials

The greatest hazard associated with electrical equipment is the arcing caused by equipment shorts. This is potentially a source of ignition for other materials. Cables used in original construction were not flame retardant but were coated with a fire retardant material, i.e., Flammastic. As cables are replaced or new cables installed throughout the plant, the insulation specified today is flame retardant, i.e. IEEE 383 qualified.

8. Protective Features

Turbine Protective Features

The turbine-generators at Turkey Point were manufactured by Westinghouse Corporation. The overspeed trip mechanism in this unit, consists of an eccentric weight mounted in the end of the turbine shaft, which is balanced in position by a spring until the speed reaches the point at which the trip is set to operate. Its centrifugal force then overcomes the spring and the weight moves away from the axis of rotation to strike a trigger which trips the overspeed trip valve releasing the autostop oil pressure. The autostop pressure is connected to a governing emergency trip valve which releases control oil to drain. Therefore, both autostop and control pressure go to zero and all valves capable of admitting steam into the turbine will go closed. A momentary pulse in auto stop oil will cause the load limit governor to unlatch. To regain control oil will then require an operator to reset the load limit governor. This feature will prevent the steam admission valve from re-opening even if auto stop oil pressure recovers.

Protective trip devices are hydraulically connected to the overspeed trip valve through the overspeed trip relay. The protective trip devices are all included in a separate assembly and include a low bearing oil pressure trip, a solenoid trip, a thrust bearing trip and a low vacuum trip. As discussed previously, testing and maintenance of these devices is performed every refueling outage.

Fire Protection Features

Within the Turkey Point Unit 3 and 4 Open Turbine Buildings are a comprehensive network of fire protection features to mitigate the consequences of a fire. These features include a wet pipe sprinkler system, fixed water spray system and fire barriers. The wet pipe sprinkler system provides coverage for most of the guarded oil piping. Sprinkler systems are also located in the east side of the condenser pit.

Fixed water spray systems and curbs or retaining walls are provided for the lube oil reservoir, generator hydrogen seal oil skid, transformers, and lube oil transfer skid. Walls which are 3-hour fire barriers encase the switchgear and load center rooms. Penetrations through these walls are protected by penetration fire seals. And finally, cables required for safe shutdown have been protected by Thermo-Lag.

9. Postulated Fire Hazards

Based on the concerns identified above for the industry events, the potential for bearing and generator hydrogen seal leakage and the review of fire protection features, the potential exists for ignited lube oil to reach an unprotected area. Although significant preventive measures are in place to preclude blade failure, should the rotating train of the

turbine-generator become unbalanced, the most likely occurrence would be seal leakage at the low-pressure turbine and generator bearings. For the purposes of quantifying lube oil leakage flow, Westinghouse was contacted to provide bearing flow information. Based on this information, a conservative estimate of 150 gallons per minute leakage from each of three bearings was established. This considers an increase of bearing flow of 100% based on increased bearing clearances. This would result in lube oil and hydrogen leakage.

It is credible to assume that burning hydrogen could ignite the lube oil. Based on the Salem Unit 2 event, failure of the guard pipe or the bearing casings is not postulated. The unprotected area is located at the ground floor elevation under the generator between column lines B and D and between the condenser pit and switchgear room in both Unit 3 and 4 Open Turbine Buildings. A detailed evaluation of this postulated event has been performed. Based on an assumed lube oil leakage rate and considering the response of suppression systems, a pool size was established and heat release calculated. The calculation accounted for an augmented suppression system and also recommends the installation of spill control features between column lines B and C and at column line D. The final results demonstrate that adequate protection is provided by the proposed additional suppression and pool containment, together with the proposed upgrades of the Thermo-Lag fire barriers.

10. Proposed Upgrades

Based on the potential fire hazard discussed above, several modifications to the existing fire protection features in the Open Turbine Building are proposed. These upgrades are discussed in Section IV.I.

CONCLUSIONS

Based on a general review and several specific event investigations, it can be concluded that design features at Turkey Point Units 3 and 4 serve to mitigate several potential fire hazards, such as described for the Salem and Fermi events. The potential fire hazard in the event of bearing and generator hydrogen seal oil leakage has been conservatively analyzed for Turkey Point Units 3 and 4. Based on the analyzed hazard, the following modifications are proposed:

1. Additional suppression within the Unit 3 and 4 Open Turbine Buildings, as outlined in Figures 1 and 2,

2. Upgrade Thermo-Lag protected cables to 1-hour fire rating between column lines A and E and in the condenser pits in the Unit 3 and 4 Open Turbine Buildings,

3. Install spill control features between column lines B and C, and at column line D.

G. Turbine Lube Oil Fire

An evaluation was performed to review the existing and proposed, active and passive, fire protection features to determine if the protection is adequate to protect those Thermo-Lag raceways in the Open Turbine Building from a postulated fire which results from a release of turbine lube oil from failed generator and/or low-pressure turbine bearing seals. Existing and proposed fire protection features were reviewed for their mitigating effects on the fire and protected raceways. This evaluation showed that the effects of a postulated turbine lube oil fire on Thermo-Lag protected raceways will not challenge the raceway protection, as upgraded between column lines A and E, to the point of failure. In addition, the anticipated temperatures in the transition areas were shown to be below the furnace temperatures at 25 minutes during ASTM E-119 fire tests. The scope included those raceways in the transition area located between the D and J_c column lines along the entire length along the east side of the Open Turbine Building, and other raceways in the Open Turbine Building. Therefore, no fire barrier upgrade is planned for raceways East of column line E.

The approach was to identify the worst case fire exposure for the Thermo-Lag protected raceways, evaluate existing and proposed fire protection and mitigating features, determine anticipated temperatures based on postulated fuel loading and environmental conditions, and determine the effects of fire on the protected raceways in the transition area. The postulated fire life and intensity are based on actual turbine lube oil characteristics, a conservatively assumed fuel supply rate of 450 gpm (150 gpm from each of three turbine bearings) and that turbine coastdown could last as long as 45 minutes. The assumptions are conservative because a high flow rate greater than expected for gross bearing seal failure is postulated, and turbine vibration significant enough to cause such severe seal failure is also likely to cause severe rubbing that would reduce coastdown time.

The evaluation determined the effectiveness of existing active and passive fire protection features, considering original plant design bases and design calculations. Full coverage of sprinklers over the areas where the lube oil will pool is the predominant factor for assuring integrity of the Thermo-Lag protected raceways in event of a postulated generator and/or low-pressure turbine bearing seal failure. Full coverage sprinklers have been shown to be effective in extinguishing fires involving combustible liquids with flash points of 200°F (93.3°C) and higher. The lube oil used at Turkey Point has a flash point of 395°F (202°C) which is well in excess of the above stated value. Predominant in situ combustible loading throughout the Open Turbine Building is limited to the materials which are presently protected by fixed water spray systems with other minor amounts of combustibles protected by the existing sprinkler coverage.

1. Fire Protection Features

Effectiveness of Automatic Sprinklers on Lube Oil Fires

The National Fire Protection Association (NFPA) 13, *Standard for the Installation of Sprinkler Systems*, specifies design densities for hazards such as the lube oil hazard which the Open Turbine Building sprinklers will be designed to suppress. The design densities in NFPA 13 are considered to reflect historical experience with the concept of fire control/containment. Existing sprinkler head spacing in the Open Turbine Building in the area of the postulated fire is more conservative than that required to meet the minimum requirements of NFPA 13 and design densities will meet or exceed those required by NFPA 13.

Factory Mutual Research Corporation (FMRC) performed sprinkler discharge testing over lubricating oil fires for the Atomic Energy Commission (AEC), *Fire Tests of Automatic Sprinkler Protection for Oil Spill Fires*, (September 9, 1957). The oil used was more volatile (ignition temperature approximately 360°F) than the lube oil used at Turkey Point. The oil and floor were preheated to approximately 165°F and 130°F respectively. In all cases the oil was difficult to ignite and required the use of accelerants (gasoline soaked products). The ceiling height in the test facility was 33 feet with vented openings at the ceiling and around the perimeter. Standard 212°F, 1/2" orifice sprinklers were installed on a 10'x10' spacing. Sprinkler operation began to occur at 17 seconds after the pool fire had grown to 5 feet in diameter. The ceiling temperatures in Test #2 never exceeded 600°F (316°C). The maximum pool radius was 6 feet which was at 18 seconds after the first sprinkler operated. However, it was noted that the fire had been knocked down to a lingering flame at the pool surface within one minute of the first sprinkler operating with an application rate of 0.13 gpm/sq.ft. Another test was performed to establish the effectiveness of sprinklers over a large pool fire. Gasoline/kerosene mixtures were spilled over the lube oil pool and ignited. Water was manually controlled to the sprinklers and not allowed to discharge until the pool fire had grown in size to approximately 1400 sq.ft. Fire control was achieved between 2-1/3 and 4 minutes. Although ceiling temperatures reached 1200°F and flames extended up to 10 feet beyond the vent openings in the structure, the fire was brought under control quickly and without damaging effects to the building. Steel temperatures with automatic sprinkler protection in the area indicated that temperatures which would result in failure would not be reached.

The FMRC testing shows that effective control of temperatures and fire can be achieved for lube oil pool fires with a minimum of discharge density. The FMRC testing results support the conclusion that the sprinkler head type, temperature rating, and discharge density as used in the Open Turbine Building will effectively control the fire and prevent structural steel failure.

Existing Wet Pipe Sprinklers

The wet pipe sprinklers were installed to protect against the hazard of lube oil leakage. Sprinkler installation follows the routing of the guarded oil pipe and provides coverage of areas where localized pooling of lube oil may occur, at the 18′0″ elevation between the switchgear rooms and the condenser pit and within the condensate pump pit. The lube oil, with a flash point of 395°F (202°C), is considered to be a Class IIIB combustible liquid. Hydrogen in the generator is not a contributor to the fire hazards within the Open Turbine Building other than serving as an ignition source for the lube oil in the event of bearing seal failure on the generator and/or low-pressure turbine.

The original system design density was to provide 0.3 $gpm/ft^2/3000\ ft^2$. In accordance with NFPA 13, lube oil hazards in piping, such as those considered in the original design, are classified as an Extra Hazard Group 1 occupancy. The required density for a similar design area in such an occupancy is 0.28 $gpm/ft^2/3000\ ft^2$. Therefore, the original design density used at Turkey Point exceeds the NFPA 13 required density for this hazard type. Spacing along the majority of the existing wet pipe sprinkler system is conservative in that it is below the maximum of 100 ft^2/head for an extra hazard occupancy allowed by NFPA 13.

Sprinklers provide full coverage in the condensate pump pit and partial coverage in the condenser pit and throughout the remainder of the Open Turbine Building, primarily located where guarded oil pipe is routed. The head spacing in the lowest area of the condensate pump pit was observed to be conservatively installed at approximately 50% of the maximum 100 ft^2/head spacing. In addition, the configuration of the condensate pump pit may be considered as an enclosure due to the massive equipment obstructions, and the presence of multiple coverings over various elevations. Therefore, the production of steam in this area will result in aiding in extinguishment via smothering.

Existing High Hazard Areas

The high-hazard facilities consist of lube oil reservoirs, lube oil transfer pump skids, main transformers, auxiliary transformers, hydrogen seal oil units, start-up transformers. Design criteria for the fixed water spray systems provide for a minimum design density for the systems is 0.25 gpm/ft^2 over the protected surface. The actual design density has been shown by calculation to be higher for the as-installed system protecting the auxiliary transformer. Spray heads are spaced in accordance with the requirements of NFPA 15 (1977 and 1979) and test documentation for the spray nozzles installed.

Each of the high hazard areas is provided with a diked area for containment of fluid leaks from equipment thus preventing combustible fluids from migrating to other areas. Each system is also equipped with heat actuated (rate-of-rise) detectors. This type of detection will

sense both a fire involving the equipment being protected as well as a fire adjacent to it. In the event of a fire involving equipment in one of these areas or adjacent to these areas, exposure protection is provided by the spray system to prevent damage to the equipment.

Proposed Augmentation of the Wet Pipe Sprinkler System

Areas of the Open Turbine Building will be augmented by additional wet pipe sprinklers in order to enhance the level of protection of Thermo-Lag protected raceway. Sprinklers will be provided to complete coverage in areas where pooling of lube oil will occur, and in areas where Thermo-Lag protected raceways is provided, between the D and J column lines. Sprinklers in the condensate pump pits will be evaluated to assure compliance with code requirements. The addition of sprinklers in areas where Thermo-Lag protected raceways is provided results in the complete coverage of all Thermo-Lag protected raceways throughout the Open Turbine Building between the A-J column lines.

The additional wet pipe sprinklers will enhance protection in two areas. Sprinklers will be added to provide complete coverage where lube oil will pool on the 18'0" elevation, bounded by the B-D and 23.1- -25.1, and B-D and 30.1-32.1 column lines. Sprinklers will also be added where Thermo-Lag protected raceways are installed along the length of the Open Turbine Building between the D-J column lines. The sprinklers for this particular area will be installed where appropriate to protect both the 18'0" elevation and the 30'0" elevation. The additional suppression will provide both cooling of smoke/hot gases from a lube oil fire in an adjacent area as well as protect against the effects of a transient fire beneath the raceways.

The original design density for the existing system was to provide 0.3 $gpm/ft^2/3000\ ft^2$. The area of coverage will be increased to 5000 ft^2 for the lube oil hazard, and because the intensity of a combustible liquid fire may create elevated temperatures adjacent to the areas of the fire and activate the sprinklers therein. As such the design density will be equivalent to or in excess of the NFPA 13 recommended and sprinkler spacing will be in accordance with NFPA 13, which allows a maximum of 100 ft^2/head for an Extra Hazard Group 1 occupancy. Although Open Turbine Building coverage will remain partial, the areas where lube oil is postulated to pool after a generator and/or low-pressure turbine bearing seal failure will be protected by full sprinkler coverage.

Thermo-Lag Protected Raceways

The Thermo-Lag protected raceways located within the area bounded by column lines A-E and 23.1-25.1, and column lines A-E and 30.1-32.1 and located within and over the condensate pump pits, will be upgraded to meet a 1-hour fire resistance. Thermo-Lag protected raceways located between column lines E-J_c throughout the length of the Open Turbine Building will meet a 25 minute fire resistance.

a. Temperature Profile

The NFPA Handbook (17th Edition) provides descriptions of various occupancies surveyed to develop the characteristic time-temperature curves based on occupancy and fire loading. High hazard occupancies are depicted by the "E" curves in the time-temperature figure. The maximum fire loading which could occur on the 18'0" elevation prior to runoff to other areas would be 483.7 gallons, which equates to a combustible loading of approximately 3.1 lb/ft^2. This fire loading when compared to the NFPA fire severity time-temperature "E" curve produces a fire of approximately 15 minutes in duration and maximum temperatures of approximately 760°C (1400°F). This approximated temperature does not account for cooling, which would result from sprinkler discharge in the area, and is therefore higher than the temperatures that would be exposed to for the postulated Turkey Point fire.

V. Babrauskas, *Temperatures in Flames and Fires* (May 1997), indicates that the peak value for fire temperatures is governed by the ventilation and fuel supply characteristics. The maximum value documented is approximately 1200°C (2192°F). Experiments of large scale fires (668kW - 105MW) without sprinkler protection indicated a maximum temperature for a large scale fire at a 15' ceiling height was 927°C (1700°F), and temperatures at higher elevations were lower during the same fire. Industry analysis of temperatures of laminar or turbulent diffusion flames show that an upper temperature limit of 1250°C (2282°F) was observed for natural gas. Other fuels yielded lower upper limit temperatures as well as lower temperatures for the intermittent and continuous flaming regions. Average continuous flame region temperatures of 900°C (1652°F) and intermittent flame temperatures of 320°C (608°F) have been documented for a variety of fuels. Discussion regarding the adiabatic flame temperature (i.e. no loss of heat occurring) for methane and propane indicate temperatures of 1949°C (3540°F) and 1977°C (3591°F), respectively. However, adiabatic temperatures are not realistic in an actual fire scenario due to the continuous loss of heat to surroundings through various means (i.e. radiative, convective, etc.). In addition, the ASTM E-119 time-temperature curve has a maximum temperature of 1260°C (2300°F) which is reached at 8 hours.

The Factory Mutual Research Corporation testing described above indicates that ceiling temperatures at 33' over the base of the fire never exceeded 600°F (316°C) with automatic sprinkler protection and control was established within minutes of operation of the first sprinkler.

The fire duration is postulated to occur over the time frame in which the entire contents of the lube oil storage tank are assumed to be discharged as a flaming stream. This was postulated in order to present a very conservative analysis. However, due to the complete coverage with sprinklers of the area where pooling will occur at the 18'0" elevation and the manual fire fighting efforts which will be involved, suppression is likely to occur at an earlier time within the postulated scenario.

Therefore, based on the above discussion, temperatures predicted for the duration of the fire are significantly conservative in view of the documented maximum temperatures for gas layers, and flame temperatures. As such, the areas east of the "E" column line do not require a 1 hour fire barrier, since temperatures at the "E" column line are conservatively calculated to be below the temperatures in the ASTM E-119 furnace at 25 minutes.

b. Tubular Steel Survivability

Conduits and pipes, which are located above Thermo-Lag protected raceways, in the vicinity of the fire scenario are supported by tubular steel (unistrut). Failure of the supports for these unprotected conduits or pipes could affect the integrity of the Thermo-Lag protected raceways located beneath them. Therefore, a review of the potential for steel failure was included in this evaluation.

Steel failure is expected to occur when the steel temperature reaches approximately 649°C (1200°F). However, steel does not fail at the same time that a room or ceiling jet temperature of 649°C (1200°F) is reached. Heat transfer within the steel itself must occur for a period of time before the member will reach its critical temperature. The discussion above regarding temperatures in the fire scenario has concluded that the temperatures predicted for the ceiling jet and in the intermittent and continuous flaming regions are lower than those postulated. As such the only areas of concern based on the temperatures documented in the referenced section are within the area bounded by the B-D column lines where temperatures are postulated to be in excess of the temperatures at which steel failure can occur. Additional protection of supports in the area of the fire are not recommended or considered necessary based on the following points of consideration:

- Sprinkler discharge provides water impingement on supports of raceway/pipe within the boundaries of the flaming fire. This discharge provides direct cooling to the support steel for the raceways.

- Postulated temperatures are very conservative. Actual temperatures are expected to be much lower, thereby reducing the threat to steel support integrity.

Retention of Lube Oil - 18'0" Elevation

The areas bounded by column lines B-D and 23.1-25.1 and column lines B-D and 30.1-32.1 are where an accumulation of lube oil released due to failed generator and/or low-pressure turbine bearing seals will occur. Due to the open areas associated with normal ingress/egress from these areas to other areas of the Open Turbine Building, the potential exists for the migration of turbine lube oil beyond the D column line toward the J column line and beyond the B column line to the west. Retention curbs

are proposed to prevent the migration of released lube oil and sprinkler discharge beyond the B and D column lines.

Physical Arrangement

Mitigating physical arrangements within the 18'0" elevation of the Open Turbine Building exist which could shield or otherwise inhibit the flow of smoke and hot gases from an oil release and fire to the areas where Thermo-Lag protected raceways are located. This is due to the presence of the structures or equipment in the area with respect to generator and/or low-pressure turbine bearing locations and postulated pooling areas. The area to be bounded is within, but smaller than, the area bounded by column lines 23.1-25.1 and B-D and was determined to present the worst case scenario for transmission of heat to the Thermo-Lag protected raceways due to several points where a direct line of sight is present from the postulated pooling area to the protected raceways. In addition, the location of the generator and/or low-pressure turbine bearings postulated to leak are located such that one is directly over the area mentioned, a second is located directly over the condensers and the third is located over both areas. Therefore, it is reasonable to postulate only half of the 450 gpm flow of lube oil to the condenser and condensate pump pits and half to the area between the switchgear room and the condenser (for this evaluation, the area bounded by column lines B-D and 23.1-25.1). Sloped curbing will be introduced to confine the lube oil spill between and column line D and approximately 6.5 feet west of column line C, thus providing a limited pool size which will be channeled to runoff to the condenser and condensate pump pits.

2. Drain Flows

Floor drainage and spill control features, flow paths to the condenser and condensate pump pits, and existing equipment in the area affect fire spread and configuration. The lube oil spread at the El. 18' floor level is limited by "curbs", existing equipment pads and the turbine pedestals between column lines B and D. Lube oil and water flow to drains and overflow to the condenser and condensate pump pits. Water from sprinkler coverage beyond the curbed area flows to area drains, the condenser pits and out of the Open Turbine Building via floodgate openings.

No credit is taken for drain flow from the 18'0" elevation through the waste oil floor drains due to the low capacity of the waste oil separator. The waste oil separator is located at the Turkey Point Fossil Facility.

Based on a 2" depth of oil over the drain opening and using Bernoulli's equation, where the slotted drain covers provide an effective diameter opening of 3.3 inches each, the effective flow into any one of the 4" diameter drains is approximately 87.5 gpm, or approximately 175 gpm from the two available drains in each area.

Full flow of oil/water output at the catch basin through the 4" drains is not anticipated due to the lower flow rate calculated through the drain covers (175 gpm). However, a reduced flow rate of 66 gpm will be used in the evaluation as the maximum rate that the turbine lube oil or other fluid will drain from the 18'0" elevation.

3. Fluid Retention Around Drains

The presence of drains with top-of-drain-elevations below the grade elevation of 18'0" coupled with slope indications toward those drains are indications that configurations similar to inverted pyramids exist over the drains.

Although the drain areas are not mirror images of one another, it is assumed that dividing the non-occupied area equally between the two drain areas would present a reasonable representation of the volume of fluid which could be retained over the drains as a whole. Calculating the volume of a quadrant as a pyramid yields approximately 194.6 gallons per section, or a total potential retention of 483.7 gallons over the drains prior to runoff.

4. Critical Values Associated with the Turbine Lube Oil

A comparison of characteristics of the turbine lube oil used at Turkey Point Texaco Regal R&O was performed against similar parameters of other combustible liquids.

Table 1
Material and Burn Characteristics of Various Petroleum Based Hydrocarbons

	Flash Point °F (°C)	Ignition Temp. °F (°C)	Spec. Gravity	Boiling Point °F (°C)	NFPA Fire Hazard Rating[4]	MJ/kg	Mass Loss Rate kg/m²s
Mineral Oil	380°F (193C)		0.8-0.9	680°F (360C)	1	45.8-46.0	
Lube Oil, Mineral	300°F-450°F (149°C-232°C)	500°F-700°F (260°C-371°C)	<1	680°F (360°C)	1		
Turbine Oil	400°F (204C)	700°F (371C)	<1		1		
Regal Oil[1]	395°F (202°C)		0.8681		1	45.37[6]	
Fuel Oil No. 1	100°F-162°F (38°C-72°C)	410°F (210°C)	0.825[5] <1	482°F (250°C) 305°F-574°F (152°C-301°C)	2	43.1[5] - 46.5[2]	
Fuel Oil No. 2	126°F-204°F (52°C-96°C)	494°F (257°C)	<1		2		
Fuel Oil No. 4	142°F-240°F (61°C-116°C)	505°F (263°C)	<1		2		
Light Fuel Oil No. 5	156°F-336°F (69°C-169°C)		<1		2		
Heavy Fuel Oil No 5	160°F-250°F (71°C-121°C)		0.94-1[3] <1		2	39.7[3]	0.035[2]
Fuel Oil No. 6	150°F-270°F (66°C-132°C)	765°F (407°C)	1+/-		2	42.5[2]	

Notes:

1 All values except heat of combustion are from the Texaco Material Safety Data Sheet for 00700 Regal R&O Oil.

2 Fire Protection Handbook, 17th edition, Table A-3

3 Handbook of Fire Protection Engineering, 2nd Ed, Table 3-1.2

4 Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids, NFPA 325M-1991
5 Handbook of Fire Protection Engineering, 2nd Ed, Table C-1
6 Fire Protection Handbook, 17th edition, Page A-7

In comparing the known values for flash point, ignition temperature, specific gravity, boiling point, and fire hazard rating there is a distinct similarity in values associated with the lubricating oils, and the Texaco Regal Oil. The characteristics of the fuel oils demonstrate that fuel oil is more volatile than the lubricating oils with flash points and ignition temperatures lower in almost all cases.

The comparison of heats of combustion shows a small deviation in values for all fuel chosen including the approximated value for the Texaco Regal Oil. Although the heat of combustion may be determined from empirical rules characterizing petroleum products due to it being a material property, the mass loss rate ($\dot{m}''$) is typically found experimentally. Due to the limited information available on mass loss rate values, the mass loss rate value associated with heavy fuel oil will be used throughout the remainder of this evaluation where necessary as that of the Texaco Regal Oil. This assumption is valid based on the comparison and similarity of the material properties of several petroleum based hydrocarbons.

The turbine lube oil used at Turkey Point is Texaco 00700 Regal R&O 32 a lubricating oil consisting of 95-99% solvent dewaxed heavy paraffinic hydrocarbon distillates (mineral oil) with the remainder being composed of additives. Burning characteristics of the lube oil will be slightly different from 100% mineral oil since the lighter fractions will ignite earlier and are likely to burn faster. However, due to the small amount of additives in the total volume it is not likely to have a significant impact on the mass loss rate to be used.

5. Lube Oil Pool Depth

Based upon assumptions related to the flow rate and dispersion of the turbine lube oil, 225 gpm is postulated to flow to the 18′0″ elevation. The pool depth at any point in time will be affected by the following factors:

- Drain capacity
- Mass loss due to burning of the fuel
- Runoff to the condenser and condensate pump pits or through flood gates

The postulated flow of lube oil to the 18′0″ elevation is 225 gpm. Bearing seal failures at three bearings (generator bearing and bearings 7 and 8 of the low-pressure turbine) are postulated. The bearing locations are such that one is directly over the area bounded by column lines C-D and 23.1-25.1, the second is over the column line separating the

condenser from the 18′0″ elevation and the third is over the condensers. Therefore, it is postulated that 50% of the lube oil released due to the postulated bearing seal failures will discharge to the 18′0″ elevation and the remaining 50% will discharge over the condensers and collect in the condensate pump pit.

The calculated drain capacity at the 18′0″ elevation was determined to be 175 gpm. For conservatism this value was reduced by approximately 62% to 66 gpm for calculation of the effects of a lube oil fire with or without sprinkler interaction. The capacity over the drains before spill-over to the condenser or condensate pump pits is calculated to be approximately 483.7 gallons.

The total width of openings from the area of concern at the 18′0″ elevation to the condenser and condensate pump pits is 11′2″ per unit. The approximate discharge for the total width present in the area of concern is used and applied such that the flow associated with the fluid height calculated is extrapolated from industry data. Based on no sprinkler activation, the discharge rates of oil (225 gpm) and drain flow rates (66 gpm) results in fuel accumulation with time on the 18′0″ elevation.

The burning lube oil will be primarily contained within the curbed area. Minor splashing is expected to occur but will be limited due to the position of the curbs. Addition of water via sprinkler activation will increase the effective pool area and pool diameter due to spreading of the fuel across the area bounded by the curbing on the 18′0″ elevation. The effects of water addition are calculated on a one-minute time step basis in order to determine the effective curb height, the mass loss and heat release due to burning. For the purposes of calculating heat release from the fire, an effective pool diameter is calculated based on a circular pool with an equivalent area equal to the unoccupied area bounded by the proposed curbing.

Based on potential lube oil flow patterns and assumed drainage rates from the 18′0″ elevation, the heat release and resulting ceiling jet temperatures prior to sprinkler activation are based on streaming burning combustible liquid which is estimated to cover the entire unoccupied curbed area which is equivalent to 109 m^2 (1173.23 ft^2).

Activation of the spray systems which protect the hydrogen seal oil unit and the auxiliary transformer will discharge approximately 105 gpm and 390 gpm respectively. The diked areas surrounding each of these hazards will contain the system discharge for approximately 5.23 minutes and 11.11 minutes respectively, conservatively assuming no discharge to the oil/water separator. After these discharge times, overflow will occur onto the 18′0″ elevation in the area being evaluated. It is postulated that at approximately 2 minutes into the fire scenario the temperature rise in the vicinity of these spray systems will activate the respective detection systems which are set to respond to a temperature rise of

5°F/minute. Therefore, when overflow occurs, the discharge of these systems is added to the amount of fluid on the 18'0" elevation outside of the curbed area.

Prior to runoff occurring down to the condenser and condensate pump pits the maximum pool depth of 2" must be reached (~ 483.7 gallons of lube oil on the 18'0" elevation must exist).

6. Postulated Fire - Pre-Sprinkler Activation

Hydrogen release as a result of the failed hydrogen oil seals is assumed to ignite and cause the subsequent ignition of the lube oil. As stated above, 225 gpm of turbine lube oil is calculated to be flowing across the 18'0" elevation during the initial phase of the postulated fire. There is no runoff from this floor to the condenser and condensate pump pits during the early stages of the postulated fire based on floor slopes in the areas of concern. Flow of oil beyond the B and D column lines is prevented by retention curbs. Initial release of lube oil is postulated to generate a pool with an area of approximately half the total unoccupied floor space in the curbed area.

Sprinkler response times are affected by the radial distance of the sprinklers with respect to the fuel package, fire plume temperatures, ceiling jet temperatures and ceiling jet velocities. Sprinkler response times in the areas of concern are affected by uneven ceiling heights in the area. Since sprinklers are located at various heights in these areas, response times in both are calculated using ceiling heights of 3.66 m (12'0") and 7.315 m (24'0").

Heat Release

The heat release in the area from the postulated fire does not include any in situ or transient combustibles other than the released turbine lube oil. This is based on minimal combustible loading as documented in the UFSAR for those fire zones in the area and adjacent fire zones. The combustibles documented are either insignificant or consist of combustible liquids contained within equipment which is bermed and protected with automatic water spray systems.

The following assumptions pertain to determining fire heat release:

- Transient effects, such as unsteady burning during the initial stage of the fire as a result of gradual heating of the ground underneath and surrounding boundaries, are ignored. These effects cannot be quantified particularly for a non-enclosed structure. This is a conservative measure resulting in greater heat releases in the early stage of the fire.

- Wind effects are not considered. The UFSAR states that prevailing winds in the area are from an easterly direction. As such, the affects

of prevailing winds in the area could actually benefit this analysis. However, the configuration of the Open Turbine Building is such that other structures and equipment provide partial shielding from the effects of the wind. Further, it has been observed that the effects of moderate breezes are dampened to the point of insignificance in the area where the fire is postulated to occur. Therefore, in an effort to provide conservative results the effects of wind are not considered.

The heat release generated by the pool fire size postulated is found by using the SFPE Handbook (2nd Edition):

$$Q = \dot{m}''*\Delta h_c * A$$

where: Q = heat release in kilowatts

$\dot{m}''$ = mass loss rate in kg/m^2s

Δh_c = heat of combustion in kJ/kg

A = pool area in m^2

A semitheoretical analysis together with a study of available experimental data showed that the following formula can be used to represent the mass loss rate of a pool fire burning in the open.

$$\dot{m}'' = \dot{m}_\infty''(1 - e^{-k\beta D})$$

where:

$\dot{m}_\infty''$ = mass loss rate for an infinite diameter pool = $0.035 kg./m^2 s$ (for heavy fuel oil)

k = the extinction - absorption coefficient of the flame

β = the mean - beam - length corrector

$k\beta$ = 1.7 m^{-1} (for heavy fuel oil)

D = pool diameter in meters

Calculating the effects of fire based on a circular unrestricted pool entirely involved provides conservative results by postulating more complete combustion, unrestricted air flow and entrainment, an unrestricted flame structure and that turbine lube oil will be present across the surface of the pool. However, a 20% reduction in the mass loss rate is typically used for pool sizes greater than 10 meters which is based on test results showing incomplete combustion for pool diameters of this size. Additional tests conducted to evaluate the fraction of total heat release which resulted from the combustion of various fuels showed heptane releasing as low as 69% of the total potential heat release during its combustion phase. Therefore, since actual heat release rates will be significantly lower than the theoretical heat release rates, a 20 % reduction of the total heat release is used for all estimates of actual heat release.

Ceiling Jet Temperatures

The area of concern has an uneven ceiling configuration such that the ceiling at the center of the area (A-D, 23.1-25.1) directly below the generator is higher than the remainder, thus forming pockets. Although some heat will pocket in the center, the remainder of the ceiling area which is lower will transport heat from the plume laterally to the exterior of the structure and to the east of the column line D. The ceiling height east of the D column line is higher than west of column line D. As such, the higher ceiling elevation is used to postulate temperatures anticipated at Thermo-Lag protected raceways in this area.

R. L. Alpert, *Calculation of Response Time of Ceiling Mounted Fire Detectors* (Fire Technology, 1972) reported on the behavior of fire plume and fire induced flow near ceilings. Testing used to justify equations derived considered a variety of flammable liquids and combustible materials. The fire sizes varied as well as ceiling heights and room sizes. Room sizes in many cases were up to 100 m in width. Therefore, the use of these formulas for the postulated case is sound. The following formulas show that the maximum temperature of the plume is dependent upon the ceiling height and radial position from the center of the plume.

For $r > 0.18H$:

$$T_{max} - T_{\infty} = \frac{5.38\left(\dot{Q}/r\right)^{2/3}}{H}$$

and for $r \leq 0.18H$:

$$T_{max} - T_{\infty} = \frac{16.9\left(\dot{Q}\right)^{2/3}}{H^{5/3}}$$

Where: $\dot{Q}$ = heat release (kW)
r = radius from the centerline of the fuel package (m)
H = height above the fuel package (m)
T_{∞} = ambient temperature in the area (°C) assumed to be 29.4°C (85°F)

Velocity of Ceiling Jet Flow

Similarly with ceiling temperatures, there are correlation's for ceiling jet velocities which are dependent on both ceiling height and radial distance from the center of the fuel package.

For $r > 0.15H$:

$$U_m = 0.195\left(\frac{\dot{Q}^{1/3}}{r^{5/6}} h^{1/2}\right)$$

and for $r \leq 0.15H$:

$$U_m = 0.96\left(\frac{\dot{Q}}{h}\right)^{1/3}$$

Where: $\dot{Q}$ = rate of heat release (kW)
r = radius from the centerline of the fuel package (m)
h = height above the fuel package (m)
U_m = gas velocity (m/s)

Sprinkler Response Times

Sprinkler response times depend on the characteristics stated above as well as a value for the Response Time Index (RTI). The RTI is a value which results from the sprinkler or heat detector time constant (obtained from controlled testing) multiplied by the square root of the velocity.

The formula shown below for determination of the sprinkler response time is used to determine the time for activation of sprinklers at various distances from the center of the fuel package. This is a rough correlation since varying ceiling heights affects sprinkler responsiveness. In addition, this formula is based on instantaneous transport and detection of heat, and does not account for transport lag time. On this basis, and due to the open nature of the Open Turbine Building, sprinkler response times are assumed to be delayed beyond those times indicated below to consider heat transport and dissipation. However, the lag time is considered to be insignificant.

$$t_{operation} = \frac{RTI}{\sqrt{U_m}} \log_e\left(\frac{T_m - T_\infty}{T_m - T_{operation}}\right)$$

where:

$t_{operation}$ = time to operation (seconds)
RTI = Response Time Index value (110.415 $m^{1/2}/s^{1/2}$ (200 $ft^{1/2}/s^{1/2}$))
U_m = maximum gas velocity (m/s)
T_M = plume or ceiling temperature (°C) (dependent on distance from center of pool)
T_∞ = ambient temperature (°C)
$T_{operation}$ = operating temperature of the sprinkler head (100°C (212°F))

The calculation is based on a 225 gpm turbine lube oil spill rate onto the 18'0" elevation and an approximate pool diameter equal to 1/3 of the available unoccupied area on the floor bounded by the curbs. The table shows the time required to operate sprinklers at various radial distances from the center of the fuel package. Note that this formula is not used in this evaluation to determine the sprinkler operation in the remainder of the area after the first sprinklers in the area operate over the fire plume. This is due to cooling effects by the operated sprinklers on the fire below, thereby resulting in lower ceiling jet temperatures and affecting whether additional sprinklers will or will not operate.

Table 2
Characteristic Temperatures and Velocities and Sprinkler Response Times Associated with Turbine Lube Oil Fire on the 18'0" elevation Pre-Sprinkler Activation

Pool Area 38.18 m² (411 ft²)								
Effective Pool Dia. 6.97 m (22.88 ft)								
	Radial Distance From the Center of the Fuel Package							
					D Column		E Column	J Column
	0.01 m.	1 m.	2 m.	4 m.	6.97 m.	8 m.	10.66 m.	17.37 m.
Heat Release (kW)	48,501.61	48,501.61	48,501.61	48,501.61	48,501.61	48,501.61	48,501.61	48,501.61
Plume Centerline Temperature (°C)								
@3.66 m (12 ft.)	2,614.98							
@7.31 m (24 ft.)	845.47							
Ceiling Jet Temperature (°C)								
@3.66 m (12 ft.)		1,985.07	1,261.36	805.47	565.33	518.28	433.13	320.95
@7.31 m (24 ft.)		845.47	645.80	417.70	297.55	274.01	231.40	175.28
Velocity of Ceiling Jet (m/s)								
@3.66 m (12 ft.)	22.71	13.60	7.63	5.45	2.70	2.41	1.89	1.26
@7.31 m (24 ft.)	18.03	18.03	10.79	7.70	3.81	3.40	2.68	1.78
Sprinkler Response Times (sec)								
@3.66 m (12 ft.)	0.64	1.10	2.36	4.51	9.49	11.10	15.42	27.26
@7.31 m (24 ft.)	2.35	2.35	4.09	7.99	17.28	20.39	29.02	54.72

7. Postulated Fire with Sprinklers Activated

The varying ceiling heights in the Open Turbine Building affect the responsiveness of the sprinklers in the area. Therefore, sprinkler response times are assumed to be delayed beyond the times used in the analysis due to non-uniform ceiling jet flow patterns. Sprinkler activation is assumed to occur in 1 to 2 minutes near the centerline of the fuel package. In reality, since the fluid will be burning as it is running down from the bearings, the plume temperatures are likely to result in the activation of the sprinklers in the plume earlier than those assumed for temperatures associated with ceiling jet temperatures.

Cooling Effects and Production of Steam

The design density stipulated during the original design of the existing wet-pipe systems in the Open Turbine Building was 0.3 gpm/ft²/3000 ft². This design density is in excess of NFPA-13 (1996) requirements for an Extra Hazard Group 1 hazard. NFPA 13 design densities are considered to

reflect historical experience with the concept of fire control and containment. This presents an area where additional cooling and steam production effects are anticipated due to increased water application.

The fire postulated herein is three dimensional. Lube oil coming from the failed bearing seals is presumed to be flowing down from the 42'0" elevation. Upon activation, the sprinklers begin wetting and cooling the burning fuel near the elevation at which they are installed; i.e., cooling the burning fuel before it reaches the floor elevation.

The production of water droplets leads to significant cooling of surrounding equipment and structures, thereby reducing the radiative feedback which is necessary to sustain the combustion process. Evaporating water droplets create steam, having a volume more than 1700 times that of liquid, which aids in smothering the fire since it inhibits the flow of oxygen to the fire. Steam production over the fire removes heat from the fire resulting in lower radiative feedback to the pool. It is not necessary for the sprinkler discharge to remove the heat as fast as it is being released since the fire is transferring heat to the surroundings as well. In some cases only a small additional loss of heat is sufficient to upset the balance in the combustion process resulting in extinguishment. Further, manual fire fighting efforts are expected to be implemented within 5 minutes of the fire which provides hose stream flow directed at the base of the fire. Cooling by the hose streams provides additional heat removal from the fire. Droplets from the sprinkler discharge, which contain sufficient momentum to penetrate the plume, provide cooling of the fuel pool. Steam from fire suppression in the condensate pump pit rises directly adjacent to the edge of the fuel pool on the 18'0" elevation, and is entrained into the base of the fire (combustion zone) which aids in smothering the fire. These effects reduce the overall heat release and plume temperatures in the area and thus reduce the temperatures resulting within the areas where the Thermo-Lag protected raceways are installed.

<u>Basic Parameters for Area Wet Pipe Sprinkler Discharge</u>

The original design criteria for the closed head sprinkler system (0.3 gpm/ft^2/3000 ft^2) is applied to the area of concern which has a gross floor area at the 18'0" elevation of 3026 ft^2. Based on flows stipulated by previous system calculations for the wet pipe systems in the Open Turbine Building, the demand for the 18'0" elevation over the lube oil fire is postulated to be 1000 gpm based on the gross area of coverage with all sprinklers operated. Discharge over the curbed and non-curbed areas are determined based on a proportional comparison for the size of the overall gross floor area. Therefore, the flow of sprinklers over the curbed area where lube oil will be present is approximately equal to (1630.23 ft^2/3026 ft^2)*1000 gpm, or 539 gpm, and the flow over the remainder of the area outside of the curbs is approximately 461 gpm.

The sprinkler discharge is expected to cover the entire area bounded by the curbs and result in overflow to the condenser and condensate pump pits. Sprinkler discharge over the area not bounded by the curbs but located between the A-D and 23.1-25.1 column lines either drains or overflows to the condenser pit and through the flood gates located on the west side of the area.

The time step sequence for the addition of water due to sprinkler operation conservatively assumes that half of the sprinklers over the area of concern operate at 2 minutes into the fire and the remainder operate at 5 minutes into the fire. The addition of hose streams from manual fire fighting efforts is assumed to occur at 5 minutes into the fire. The 5 minutes for initiation of manual fire fighting is based on average response times by fire brigade members during training and actual fire events.

Water Contribution by Fixed Spray Systems

The imminent activation of fixed water spray systems was considered. The auxiliary transformer and hydrogen seal oil unit spray systems are located within the area under evaluation. Flow rates from the spray systems have been determined to be approximately 389 gpm for the auxiliary transformer and approximately 100 gpm for the hydrogen seal oil unit.

Volumes of the diked areas were determined to be ~523 gallons for the hydrogen seal oil unit, and ~4,321 gallons for the auxiliary transformer. The drains in each of these diked areas are routed to the oil-water separator which allows through-flow without separation in the event of a high flow situation. Under normal conditions the oil-water separator can accommodate a flow of ~100 gpm and still continue to perform its function. In the event of larger flow rates the separator allows flow directly to discharge. Therefore, backup of this drain system is not anticipated.

From a conservative standpoint, and based upon the discharge rates of the two aforementioned spray systems, overflow is assumed to occur. This presents a worst case runoff scenario for the 18'0" area under review. This is conservative as flow is anticipated to be drained to the oil-water separator. Therefore, the auxiliary transformer pit is postulated to overflow its dike at 11.11 minutes after activation, and the hydrogen seal oil unit is postulated to overflow its dike at 5.23 minutes after activation. Activation is postulated to occur at 1 minute into the scenario. The effects of the overflow of these systems are shown below based on the available floor area outside of the diked area where the lube oil is contained.

Calculations assure that a curb height is sufficient to prevent overflow from/to either side of the curb. The maximum width of openings from this area is 255 inches. The unoccupied floor space and amount of fluid that

can be retained prior to runoff are approximately 714 ft^2 and 461 gallons, respectively. The total flow rate to this area from sprinklers and spray system overflow is approximately 1000 gpm, which is less than that calculated for the area where lube oil would be contained. Lube oil discharge plus sprinklers presents the greater challenge for containment based on the greater width of openings in the area beyond the lube oil containment area. Therefore, all other factors being nearly equal, calculations for runoff from the area beyond the lube oil containment are not necessary.

Pool Width and Depth

Calculations show that as much as 483.7 gallons of fluid can be retained over the drains, and that the maximum pool width is assumed to occur at 2 minutes into the scenario due to the activation of the sprinklers. The maximum pool area would be equivalent to the floor area not occupied by structural components or equipment. The unoccupied area bounded by the curbing will be 1173.21 ft^2 (151.4 m^2).

For purposes of this evaluation the curbed area is used to determine water/fuel pool depth and flow through available openings. Revised heat release rates and ceiling jet temperatures are based on the smaller area bounded by the curbing being the location of the fire. The effective pool diameter which corresponds to the unoccupied floor area bounded by the curbs is 38.65' (11.78 m).

The pool diameter is based on a circular pool area and the pool edge is assumed to reach the D column line, which is conservative. The actual pool is essentially made up of smaller interconnected pools due to intervening equipment in the area. Calculating the effects based on a large unrestricted pool results in larger heat release values and temperatures. A 20% reduction in the mass loss rate is used due to the pool sizes being greater than 10 m (32.81 ft) in diameter, which is based on test results that show incomplete combustion for pool diameters of this size.

From the 2-minute time until final release of turbine lube oil a maximum pool area is assumed. The lube oil reservoir has a nominal capacity of 10,000 gallons. Based on the postulated 450 gpm total flow rate from failed bearing seals, an approximate release time of 23 minutes will result. As such, the total scenario time is assumed equal to the release time plus five minutes to stop all manual and automatic fire suppression activities, and the time to drain the fluid over the drains at the 18'0" elevation. Therefore, based on the drain flow of 66 gpm via the drains and the fluid retention over the drains of 483.7 gallons, a scenario time of 35 minutes is postulated throughout the remainder of the evaluation.

Parameters for the Determination of Heat Release

In calculating the heat release from this fire, a reduction of 75% is credited due to the following mitigating factors, many of which have been discussed elsewhere in this evaluation:

- Full coverage of sprinklers over the postulated lube oil pool.
- Cooling of the burning fuel prior to reaching the floor.
- Transient effects of heating the surroundings are not credited.
- Cooling of other facility surfaces which reduces radiative feedback to support combustion.
- Design densities which meet or exceed NFPA 13 (1996) requirements for Extra Hazard Group 1 occupancies.
- Sprinkler spacing over the pool fire is conservative at approximately 60% of the maximum allowed by NFPA 13 which will aid in droplet penetration.
- Large area of ceiling is open to the atmosphere which should aid in promoting a larger loss of heat away from the Thermo-Lag raceways.
- Proposed sprinkler additions between the D-J column lines will provide additional cooling of the ceiling jet temperatures.
- NRC approved FIVE methodology allows for a 30% reduction in heat release due to absorption by boundaries in enclosures.
- Large pool fires are known to exhibit incomplete combustion.
- Steam generated as a result of sprinkler discharge over burning fuel in the condensate pump pit is entrained into the fire at the 18′0″ elevation which aids in flame smothering and cooling.

Based on the amount of turbine lube oil calculated to be present during the time steps shown in Table 3 below, it can be seen that the available capacity of ~483.7 gallons over the drains is exceeded during the first 2 minutes of sprinkler operation. This results in runoff to the condenser and condensate pump pits.

Table 3
Heat Release for the Postulated Turbine Building Lube Oil Fire

Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J	Column K	Column L	
									Potential	Actual		
Time	Fluid	Spill	Pool area	Pool area	Eff. Dia. of	Eff. Dia. of	Mass loss	Depth over	Overflow	Overflow	Heat Release	Heat Release
minutes	gallons	cu ft.	sq. ft.	sq. m.	Pool (ft)	Pool (m)	gpm	floor	to pit	to pit	kW	MW
1	225.00	30.08	411.00	38.18	22.88	6.97	19.58	—	—	—	48,501.61	48.50
2	633.92	84.74	1,173.23	108.99	38.65	11.78	27.95	0.17	184.81	150.22	69,225.73	69.23
3	884.25	118.20	1,173.23	108.99	38.65	11.78	27.95	0.51	563.18	400.35	69,225.73	69.23
4	884.25	118.20	1,173.23	108.99	38.65	11.78	27.95	0.51	563.18	400.35	69,225.73	69.23
5	1,653.75	221.06	1,173.23	108.99	38.65	11.78	13.97	1.58	1,824.23	1,170.05	34,612.86	34.61
6 - 23	1,667.73	222.93	1,173.23	108.99	38.65	11.78	13.97	1.60	1,848.84	1,184.03	34,612.86	34.61
23-28	1,442.73	192.85	1,173.23	108.99	38.65	11.78	13.97	1.29	1,460.02	959.03	34,612.86	34.61
29	403.73	53.97	979.25	90.97	35.31	10.76	—	—	—	—	—	—
30	337.73	45.14	819.17	76.10	32.30	9.84	—	—	—	—	—	—
31	271.73	36.32	659.08	61.22	28.97	8.83	—	—	—	—	—	—
32	205.73	27.50	499.00	46.35	25.21	7.68	—	—	—	—	—	—
33	139.73	18.68	338.91	31.48	20.77	6.33	—	—	—	—	—	—
34	73.73	9.86	178.83	16.61	15.09	4.60	—	—	—	—	—	—
35	7.73	1.03	18.74	1.74	4.89	1.49	—	—	—	—	—	—

Ceiling Jet Temperatures with Sprinkler Flow

Using the formulas shown earlier, the ceiling jet temperatures are calculated using the heat release data above. The formulas used depend on heat release, radial distance from the centerline of the pool and ceiling height. Therefore, where the heat release shown above remains constant, one calculation shows the temperatures for the associated time frame. The temperatures shown in Tables 4 and 5 for the ceiling jet are conservative in nature as actual fire temperatures would be significantly lower than those shown below (Refer to discussion under "Temperature Profile"). It is also important to note, in reviewing these temperatures, that maximum temperatures of the ASTM E-119 time-temperature curve are as follows: 25 min, 821°C (1510°F); 1-hour, 927°C (1700°F); 2-hour, 1010°C (1850°F); and 3-hour, 1052°C (1925°F). Therefore, the data shows that to the east of column line D, temperatures do not exceed the ASTM E-119 curve at 25 minutes.

Table 4
Temperatures of the Ceiling Jet at 3.66m (12'0")
Above the Pool Fire at the 18'0" elevation

			Temperature (°C) of the ceiling jet at the following distance from the centerline of the fuel package						
						D Column Line		E Column Line	J column line
Time	Eff. Dia. of	Heat Release	1 meter	2 meters	4 meters	6.97 meters	8 meters	10.66 meters	17.37 meters
minutes	Pool (m)	kW	(3.281 ft)	(6.562 ft)	(13.124 ft)	(22.868 ft)	(26.248 ft)	(34.975 ft)	(57 ft)
1	6.97	48,501.61	1,985.07	1,261.36	805.47	565.33	518.28	433.13	320.95
2 to 4	11.78	69,225.73	2,508.58	1,591.15	1,013.22	708.80	649.15	541.20	399.00
5 to 28	11.78	34,612.84	1,591.15	1,013.22	649.15	457.38	419.81	351.81	262.23

Table 5
Temperatures of the Ceiling Jet at 7.31m (24'0")
Above the Pool Fire at the 18'0" elevation

			Temperature (C) of the ceiling jet at the following distance from the centerline of the fuel package						
						D Column Line		E Column Line	J column line
Time	Eff. Dia. of	Heat Release	1 meter	2 meters	4 meters	6.97 meters	8 meters	10.66 meters	17.37 meters
minutes	Pool (m)	kW	(3.281 ft)	(6.562 ft)	(13.124 ft)	(22.868 ft)	(26.248 ft)	(34.975 ft)	(57 ft)
1	6.97	48,501.61	1,008.57	646.22	417.97	297.73	274.18	231.54	175.38
2 to 4	11.78	69,225.73	1,270.68	811.34	521.98	369.56	339.70	285.65	214.45
5 to 28	11.78	34,612.84	811.34	521.98	339.70	243.68	224.87	190.82	145.97

8. Flame Height

Industry data has been correlated from diffusion flames including pools fires using the equation:

$$\frac{l}{D} = 15.6N^{1/5} - 1.02$$

where:

l = flame height above the fuel surface in meters

D = diameter of the fuel bed in meters

N is a dimensionless number derived from a modified Froude number and is given by the formula

$$N = \left(\frac{c_p T_\infty}{g\rho_\infty^2 \left(\frac{\Delta H_c}{r}\right)^3} \right) \frac{\dot{Q}_c}{D^5}$$

where:

c_p = specific heat of air

ρ_∞ = density of ambient air

T_∞ = temperature of ambient air

g = acceleration due to gravity

ΔH_c = heat of combustion

r = stoichiometric ratio of air to volatiles

$\dot{Q}_c$ = rate of heat release (kW)

D = diameter of the pool in meters

However based on standard values ($T_\infty = 293K, g = 9.81m/s^2$, etc.) and that $\frac{\Delta H_c}{r} \approx 3000 - 3100\frac{kJ}{kg}$, then the equation for flame height can be reduced to

$$l = 0.23\dot{Q}_c^{2/5} - 1.02D$$

which has been shown to be a satisfactory correlation for values within the range:

$$7kW^{2/5}/m < \frac{\dot{Q}_c^{2/5}}{D} < 700kW^{2/5}/m$$

The values of $\dot{Q}_c^{2/5}/D$ for all postulated heat releases and pool diameters but one fall within the acceptable values for which this formula can be used. The lowest heat release is outside the lower bounds of the acceptable range. Therefore, although the flame heights are shown below for all heat release values and are presented for consideration, caution must be applied in using the flame height value for the lowest heat release value.

Table 6
Flame Heights for Varying Heat Release

Heat Release (kW)	Effective Diameter (m)	$\left\|\frac{\dot{Q}^{2/5}}{D}\right\|$	Approx. Flame Height (m)	Approx. Flame Height (ft)
48,501.61	6.97	10.74	10.11	33.17
69225.73	11.78	7.33	7.84	25.72
34612.84	11.78	5.55	3.03	9.94

It was also noted that for $\frac{l}{D} < 1$ the flame breaks up into a number of smaller flamelets that are apparently independent. Although the value of $\frac{l}{D} > 1$ is based on the results shown in the above table, it must be noted that the above values are based upon a circular unrestricted pool. The area in which the postulated spill would occur is occupied by numerous obstructions including structural components and equipment. Due to the nature of the postulated spill and the intervening equipment and structural components, the phenomenon of smaller flame heights associated with smaller pool diameters may be observed under actual conditions. However, it is not possible to conclusively establish that this would occur due to a lack of documented tests conducted of pool fire configurations with intervening equipment and structural components, such as those anticipated in the Open Turbine Building.

In addition, where a fire source is close to the wall or in a corner formed by the intersection of two walls, the resulting restriction on free air entrainment has a significant effect on the flame length. Flame extension occurs along the wall to allow for air entrainment as needed for combustion of the volatiles. It is further discussed that where the vertical extent of the flame is confined by the ceiling, hot gasses are deflected as a horizontal ceiling jet.

Flame extension for a configuration similar to that postulated here as related to interference's, ceiling and boundary conditions that exist in the area under evaluation have not been studied. Therefore, there is no attempt to correlate the potential flame extension which may be experienced during this scenario.

9. <u>Effects of Not Installing Sprinklers in Portions of the Open Turbine Building</u>

Unit 3 areas bounded by column lines A, D, 27 and 29 are similar to Unit 4 areas bounded by column lines A, D, 34 and 36. The respective units' lube oil transfer pump and the steam generator feed pump room are found in these areas. Those sections of each of these areas which contain fire related hazards are currently protected by fixed protection systems. These include the steam generator feed pump room (partial wet pipe sprinklers), lube oil transfer pump (fixed water spray system) and the pit south of the condensers (wet pipe sprinklers at two elevations). The lube oil reservoir is adjacent to each of these areas to the west of the Open Turbine Building, is diked to contain a spill and is protected by an

automatic fixed spray system. Essential raceways are not located within these areas.

The evaluation of a postulated turbine lube oil release shown above presents worst case for proximity of burning oil to Thermo-Lag protected raceways. Therefore, the scenario is a bounding case for resulting temperatures from lube oil related fires in the Open Turbine Building. As a result, the fire related incidents in this area, being adequately protected and contained, do not present a hazard to safe shutdown raceways located in other areas of the Open Turbine Building and further augmentation of the suppression systems in these areas are not necessary.

CONCLUSIONS

The existing and proposed additions to the active and passive fire protection for the Open Turbine Building provide adequate protection of those raceways in the Open Turbine Building (column lines A-J_c and 22-36) such that further upgrades to the Thermo-Lag protected raceways beyond the E column line throughout the Open Turbine Building are unnecessary to assure the protection of the raceways.

The fire analysis presented within this report supports the review of the existing and proposed features. ASTM Test Standard E-119 uses the standard time-temperature curve to establish furnace temperatures during testing of fire barriers. The standard time-temperature curve temperature of 821°C (1509°F) corresponds to the furnace temperature at 25 minutes into the fire test. This is the temperature at which the 3/4" diameter conduits protected with baseline Thermo-Lag failed the test criteria. The temperatures presented in this evaluation for the ceiling jet temperatures do not indicate that this temperature will be exceeded based on the distance at which the protected raceways are located between the D and J-J_c column line during a postulated Open Turbine Building lube oil fire. These temperatures are based on cooling effects due to sprinkler discharge at the 18'0" elevation and fuel pool within the curbed area.

The configuration of diamond plate over the length of the condensate pump pit presents only two areas where surface flaming in the pit has the potential for communicating with the 18'0" elevation. These areas are at the stairway leading to the pit from the 18'0" elevation and directly over the condensate pumps. The overall size of the openings and the complete coverage of sprinklers in these areas within the pit does not lend itself to becoming a significant contributor of heat or flame height which would further threaten the protected raceways which are located beyond the E column line during a postulated Open Turbine Building lube oil fire.

H. Turbine Building Flooding from Internal Events

A review was performed of the potential for Turkey Point Units 3 and 4 Open Turbine Building flooding as a result of selected industry events. Items reviewed were the potential for condenser waterbox piping expansion joint failure, turbine-to-condenser boot seal failure, condenser overflow as a result of severed tubes and accumulation of fire suppression and lube oil systems inventory.

Internal flooding has occurred in the industry. Therefore, the events themselves are considered credible. However, the potential for and consequences of internal flooding vary from plant to plant. As such, the particular plant conditions and configurations must be considered to establish applicability.

The postulated scenario is an extrapolation from the turbine missile design basis and involves aspects from several other events separately evaluated as part of the plant design basis. The probability of a turbine missile being generated will not be reconsidered here. It should be noted, however, that the overall probability of the Turkey Point fully integral rotor design generating a missile is decreased with respect to the original disc-type rotor design.

For purposes of this evaluation, turbine blade ejection is assumed to result in rotor imbalance and vibration significant enough to induce hydrogen leakage and lube oil system failures at the turbine-generator seals and bearings. The fire suppression system will actuate if the hydrogen or oil has been ignited. Since fluid accumulation and drainage at grade elevation is addressed in the turbine lube oil fire section, only fluid accumulation in the condenser pit is considered here.

In one case it is postulated that the turbine throws a blade into the condenser tubes, creating a gross in-flow of circulating water which begins filling the condenser shell up to the "dog bone" boot seal connecting the condenser with the turbine. If the "dog bone" is damaged, a path could be created for circulating water to spill into the Open Turbine Building and spread burning oil. The second case is similar, except that the focus is on potential flooding directly from the circulating water pipe or waterbox seals.

Flooding in the Open Turbine Building from the intake cooling water and turbine plant cooling water systems is not a concern here. The turbine plant cooling water system is a closed system and is not considered a significant contributor. On the other hand, while the intake cooling water system is an open system with significant water contribution capability, the piping is located outside of the Open Turbine Building. Therefore, only scenarios involving circulating water and fire suppression systems are being considered as the results are likely to envelop effects from other systems.

Evaluation

The design basis turbine missile is a low-pressure turbine blade as described in Appendix 5E of the Turkey Point UFSAR. By its size and location along the turbine rotor, it is conservatively estimated that this blade, assuming it turns broadside, could pass through as many as half the tubes in one waterbox bank. This amounts to about 25% of the tubes in one condenser shell (two inlet waterboxes per shell), or 12.5% of all tubes. Each shell is served by two of the four circulating water pumps. Condenser vacuum is initiated by the steam jet air ejector and maintained during power operation by steam condensing on the tubes.

The circulating waterboxes (tube-side) operate at a vacuum because the system is designed with a siphon-type configuration to lower pump head. The condenser tubes and waterboxes are filled by drawing a vacuum on the waterbox vents. Vacuum in the waterboxes is maintained above 15" HgV, which is the auxiliary priming ejector start setting. Low vacuum alarm is actuated at about 16" HgV, but readings in the field are normally steady and indicate vacuum closer to 20" HgV. For conservatism, the low-end of normal vacuum range (16" HgV) is assumed.

Ruptured "Dog Bone"

A thrown turbine blade is postulated to damage condenser tubes, allowing circulating water in-flow to the condenser shell. A ruptured seal opens a path for circulating water overflow from a flooded condenser. Since design information indicates that the "bone" is near El. 35'0" and the circulating water pump deadheads at 42', it would seem possible that, given sufficient time, the condenser could be filled to the "bone" by circulating water pumps. However, this is not necessarily the case.

When tubes rupture, circulating water initially pours into the condenser hotwell from affected waterboxes at both ends. Three conditions begin to change immediately: Condenser vacuum decreases, hotwell water level increases and condensate contamination increases. For the latter, increasing circulating water in-flow would quickly result in condensate high conductivity which is annunciated in the control room.

The circulating water in-flow is fairly rapid at first, because the higher shell-side vacuum draws water in. Initially, in-flow diverts more of the pumped circulating water flow to the affected waterbox, and away from the intact tubes. This reduces available heat sink for condensing steam, which tends to decrease the shell vacuum.

Correspondingly, the hotwell water level would also rise quickly, at first. If water in-flow were allowed to continue, the rising water level would begin covering the tube bank, beginning with the lower tubes. This would further decrease the available heat sink and, correspondingly, the shell vacuum.

Continued reduction in steam condensation rate can eventually reduce shell vacuum below 22" HgV where in response to an alarm the Nuclear Plant Supervisor would determine if unit rapid load reduction is warranted. The turbine is automatically tripped at 20" HgV. These would occur long before all tubes were covered.

However, likely to occur sooner (aside from response to high turbine vibration) is operator response to alarms for high conductivity in the condensate system and/or high water level in the hotwell. These are indications of tube leakage. The initial response is to reduce power to decrease vacuum (in-flow driving force), then identify and isolate the affected waterbox. If not isolable, then reduce power to hot standby. As power is reduced, circulating water pumps are shutdown as appropriate.

If the circulating water pumps continue to operate with the affected waterbox unisolated, the water level could continue to rise until equilibrium is reached where the height of water in the condenser shell equals the sum of the waterbox-to-shell vacuum driving force (assuming the "bone" is not ruptured and the shell vacuum is not broken) and line resistance from the condenser to discharge canal. It should be noted that assuming condenser vacuum has not broken or become significantly degraded is very conservative because it reduces the backpressure on the pump head, thus maximizing the in-flow. On this basis, since the initial driving force is conservatively estimated as...

[(27.5" HgV - 16" HgV)(34'wg/30"Hg)=] 13' of water head

...and the condenser neck section to be 12'4" high. Considering the additional distance between the tubes and the "bone", it is expected that the full calculated water head could be accommodated. Also, well before this time a significant flow increase would have been diverted from condenser in-flow to the remaining intact tubes to further mitigate rising water level.

Based on the preceding, circulating water flooding in the Open Turbine Building via the "dog bone" seal is not considered credible. Mitigating actions would be implemented long before water levels neared the "dog bone". Furthermore, even if no operator action were taken, the water is likely to reach an equilibrium between in-flow and out-flow before reaching the "dog bone".

<u>Ruptured Waterbox or Pipe Expansion Joint</u>

Waterboxes are located on both the east and west sides of the condenser. All but the very tops of the waterboxes are located in pits below grade. The west pit is the tube-pull area and is as large as the condenser. The east pit is smaller and includes the condensate pumps. The pits are joined by passages between condenser shells and between the condenser and turbine pedestal.

Both east and west sides of the condenser have sprinkler system coverage. Sprinkler piping is located just under the turbine deck. The east side also has sprinklers in the pit itself. Any oil fire draining to the east pit will be suppressed in the pit. Also, fire damage to the waterbox thick rubber expansion joints would be limited by suppression on the outside as well as water cooling the inside so that burn-through is unlikely. As such, east waterbox expansion joint rupture as a result of exposure fire is unlikely.

On the west side, sprinkler coverage is provided above the condenser but not in the pit. As such, any oil fire that is not suppressed over the condenser may continue to burn in the west pit. This is an outdoor area open to the sky so smoke and hot gases would freely dissipate. Also, the pit floor slopes eastward such that water or oil would tend to flow past the condenser to the east pit where an oil fire would be suppressed.

West waterbox expansion joint rupture due to exposure fire is extremely unlikely. The expansion joint is constructed of thick natural rubber, primarily for structural rather than pressure-retaining purposes, so as to substantially delay burn-through. Also, circulating water would tend to cool the inside of the seal so that complete burn-through is very unlikely. This should be valid regardless of seal coverage. As such, the seal boundary would not be breached by fire. Neither would it be breached by hydraulics, since the circulating water at this location is nearly atmospheric, or by structural deformation, because the waterboxes would be held in place by the remaining upper joint and bolting. Even so, shields are proposed to prevent dripping oil from falling onto the expansion joint material.

The west condenser pit also contains condenser continuous tube cleaning equipment, which includes pumps and piping. Piping connected to the waterboxes is normally filled with water. Pipe and fittings are constructed of Schedule 80 polyvinyl chloride (PVC), which is also a material that could melt from an exposure fire. Isolated lines are not flowing water sources, so do not create a flooding concern. Other lines filled with water will not burn through because of the internal water cooling effect described above. Hence, the continuous tube cleaning system is not considered a credible flooding source as a result of an exposure fire.

Accumulation of Fluid in the Condenser Pit

Fluid is assumed to enter the condenser pit due to oil spillage and sprinkler action. Based on the turbine lube oil fire evaluation, the oil/water fluid spill-over rate is less than 2100 gpm during an assumed 45-minute turbine coastdown period. Conservatively assuming 2100 gpm for the full coastdown yields a volume of 94,500 gallons. Even without taking credit for condenser pit sump pump operation, this total fluid volume would settle mostly in the east pit and the level would just barely reach the bottom of the condenser, which is about 16' below grade

elevation. Therefore, there is ample free-board in the condenser pit to accommodate the anticipated spill-over volume.

Conclusion

The potential for and consequences of Open Turbine Building flooding were evaluated for Turkey Point Units 3 and 4. There is no mechanism which would cause overfilling the condenser due to damaged tubes. It was also determined that both physical limitations and administrative controls would prevent unmitigated flooding in the Open Turbine Building.

I. Fire Detection/Fire Brigade Response

Fire detection outdoors is typically provided directly by the detection systems associated with the fixed water spray Suppression systems protecting the major combustibles (e.g., transformers). Indirect fire detection is provided from flow alarms which would sound in the event that a wet pipe sprinkler system was activated.

Ignition of transient combustible materials is the most likely of any cause for a fire, and these materials are strictly controlled. In many cases, plant personnel are required to accompany a transient combustible, and thus provide the primary means of detection and reporting a fire, even in areas where detection is installed.

Based on the preceding, a fire which could challenge an outdoor fire barrier system is extremely unlikely. Even so, the Turkey Point fire brigade staffing and training complies with requirements as provided in 10 CFR 50, Appendix R, Sections III.H and III.I. All fire brigade members are trained at an accredited fire training facility once a year. This facility exercises the fire fighting skills of the fire brigade members through training with live fires.

In addition, fire brigade response/control times for actual fires at Turkey Point have been recorded. "Response Time" is defined as the time it takes for the last assigned fire brigade member to arrive at the scene. "Control Time" is defined as the time required to extinguish the fire or when the fire scene is determined to be safe for occupancy.

The fire brigade response/control time data for fires during the period 1989-1997 (present) is as follows:

1989 There were two fires requiring fire brigade response from oil soaked lagging (caused by turbine oil seal leak during safeguards testing) in the Unit 3 turbine area. The first fire occurred on 2/6/89; the fire brigade (5 members) response/control times were 5/7 minutes. The second fire occurred on 2/7/89; the fire brigade (5 members) response/control times were 5/15 minutes.

1990 There was one fire requiring fire brigade response located behind Technical Support Center from a discarded cigarette igniting a piece of tarp on the ground. The fire occurred on 2/10/90; fire brigade (5 members) response/control times were 10/4 minutes.

1991 There were two fires requiring fire brigade response. The first fire occurred on 5/21/91 outside the Nuclear Administration Building from trash in roll-off dumpster box ignited by a discarded cigarette; the fire brigade (10 members) response/control times were 5/6 minutes. The second fire occurred on 11/1/91 in the Health Physics computer room from a computer transformer burning due to an electrical short; the fire brigade (13 members) response/control times were 1/5 minutes.

1992 No fires occurred requiring fire brigade response.

1993 There was one fire requiring fire brigade response located in the Radwaste Building from a smoldering mop head (caused by welding slag dropped onto the mop). The fire occurred on 12/6/93; fire brigade (11 members) response/control times were 7/8 minutes.

1994 There were two fires requiring fire brigade response. The first fire occurred on 3/21/94 in the Laundry Room from protective clothing in dryer #10 (caused by an overheated dryer element); the fire brigade (5 members) response/control times were 2/0.5 minutes. The second fire occurred on 12/6/94 at the new cafeteria site from an engine fire on a diesel powered back hoe (caused by an oil line on the engine failing; the fire brigade (9 members) response/control times were 2/5 minutes.

1995 There was one fire requiring fire brigade response located in the Laundry Room where protective clothing ignited in a dryer as a result of an exhaust fan malfunction. The fire occurred on 9/27/95; the fire brigade (10 members) response/control times were 3/10 minutes.

1996 There were no fires requiring fire brigade response.

1997 There was one fire requiring fire brigade response. The fire occurred on 3/4/97 in the Unit 4 M-G Set Room from an overheated bearing in the M-G Set. The fire brigade (19 members) response/control times were 8/34 minutes.

It should be noted that some of the fires described above were extinguished before the full fire brigade complement arrived. Based on the preceding, the fire detection features are sufficient for fire fighting support.

J. Effects of Smoke from a Condenser Pit Fire

The following sections will evaluate the potential effects of smoke from a severe turbine lube oil fire in the condenser pits on operator actions, access/egress and equipment operability outside the direct influence of the fire..

Unit 3 Emergency Diesel Generators

The Unit 3 emergency diesel generator (EDG) building lies northeast to the of the Unit 3 condenser pit. The closest building opening is for a ventilation fan (includes engine air intake) which is approximately 90 feet from the condenser pit.

Prevailing winds at the plant site are from the east and southeast. As such, prevailing winds would push smoke from a condenser pit fire westward away from the main power block. Wind would have to come from the west or southwest to transport smoke from the condenser pit toward the EDG building. Wind from a westerly direction and at ground elevation would be slowed by the condensate polishing facilities, station transformers, motor control centers and feedwater heaters. Also, security/missile grating and the condensate storage tank lie between the condenser pit and the air intake.

At the EDG building itself, the EDG radiator fans exhaust toward the west, which would tend to push ground level smoke away from the EDG building. Also, the EDG building is physically separated so that smoke leaving the Open Turbine Building would tend to billow upward before reaching the EDG building. In addition to all this, a manually operated water curtain is available at the air intake grating on the east side of the EDG building. Therefore, it is concluded that smoke from a lube oil fire in the condenser pit will not adversely impact operation of the Unit 3 EDGs.

Fire Fighting Capabilities

The fire brigade members would assemble from many watch locations in the plant. It is important that turnout gear and fire fighting equipment be placed in diverse locations in the plant. This assures that at least one of the locations is not affected by the fire and smoke. There are, in fact, three turnout gear locations provided at the plant. One is located at grade elevation between the units just north of the control building. The second location is adjacent to the Unit 4 laydown area and the third is in the auxiliary building hallway. Also, carbon dioxide and dry chemical extinguishers are placed so that several are readily available regardless of access direction.

The Open Turbine Building Structures are continuous in the north-south direction, and are readily accessible from any direction. Regardless of wind direction, personnel can access the fire and fire fighting equipment. Lighting in and around the Open Turbine Building structure is provided by security lighting which is powered from the security generator in the event that offsite power is lost, normal plant lighting which is not diesel backed, and by portable and fixed 8-hour battery backed lighting.

Control Room Habitability

There are three supply-air intakes to the control room, one normal (via damper D1A) and two emergency (via dampers D2 and D3). The control room air condition system can operate with normal intake, emergency intake or no air intake. During normal operation, approximately 1000 cfm of supply air is drawn into the system with two of the three air handling units circulating approximately 12,000 cfm.

During emergency operation, the 1000 cfm of outside air is replaced by 250 cfm of outside air (through the emergency dampers) mixed with 750 cfm of recirculated air. This 1000 cfm would pass through the recirculation filters (HEPA and charcoal) before being circulated to the control room. If necessary, the emergency dampers may also be closed resulting in a 100% recirculated airflow.

Should a fire occur outside the control room resulting in smoke intrusion into the control room, control room operators would manually close the normal supply damper and go to the emergency recirculation configuration. Depending on the severity of the smoke intrusion, the operators may elect to go to emergency recirculation with minimal outside supply air or to 100% recirculation. As such, there would be minimal impact on control room operating personnel.

Auxiliary Building Habitability

The control building is situated between the condenser pits and the auxiliary building. The once-through ventilation system supply and exhaust locations are on the roof of the auxiliary building. The supply fan intake is over 100 feet from the edge of the auxiliary building. Assuming a westerly wind for this scenario, the smoke would need to rise to the roof elevation and then descend and cross the roof to the ventilation intake. This is not a credible scenario, thus the auxiliary building is not vulnerable to the effects of smoke from a fire in the condenser pit areas.

K. Environmental Conditions

Environmental effects (specifically water damage) on the Thermo-Lag material were noted during initial installations at Turkey Point in outdoor locations. Rain water entered the Thermo-Lag enclosures. When weeping out through the enclosure walls, the water would also erode part of the binding material. Effects are detected visually by material swelling, cracking, pealing, delamination and discoloration.

This leaching process occurs only when liquid flows through Thermo-Lag material. It was observed that if wetted material were allowed to air-dry, there was no evidence of leaching. This led to the installation of weep holes in locations where water intrusion was most likely, and the use of a substantial topcoating system to prevent water intrusion.

The Thermo-Lag installations are monitored by fire protection personnel by periodic inspections, which are performed under the fire barrier inspection program and cover 100% of the Thermo-Lag over each 18-month period. If the material does not pass inspection criteria (i.e. cracks, gaps, hardness), it is declared inoperable and a Fire Protection Impairment (FPI) is initiated for repair.

Thermo-Lag replacement has been performed somewhere in the plant each year since installation of the material began (circa 1984). Although some of the repairs have been due to physical damage from construction or maintenance activities, most of the cases in outdoor installations appear to be the effects of weather. With the exception of repairs during post-Hurricane Andrew recovery, the more recent trend shows the number of weather-related cases as decreasing.

As long as the physical configuration, consistency and surface hardness (sponginess) of the material is maintained (that is, no visible swelling, cracking, pealing or delamination), then there is reasonable assurance that the fire-resistance performance capability of the installation is maintained. In this regard, the current inspection program is sufficient to provide this assurance.

L. Thermo-Lag as an Intervening Combustible

Appendix R contains three requirements that preclude the presence of intervening combustible materials. First, Section III.G.2.b requires (as one alternative) 20 feet of separation between redundant trains with no intervening combustibles. Second, Section III.G.2.d requires (as an alternative) 20 feet of separation between redundant trains in containment, with no intervening combustibles. Third, Section III.G.2.f requires that a radiant energy shield in containment shall be non-combustible.

There is no evidence that the authors of Appendix R conceived of safe shutdown raceways and equipment in outdoor locations. Since the fires in

relatively unconfined outdoor locations are well vented and unlikely to form trapped layers of hot gases, it is appropriate to apply the requirements of Sections III.G.2.d, e or f.

The term "combustible" covers a large range of products. On one end of the spectrum are the more volatile petroleum products. On the other end is Fire Retardant Wood and Thermo-Lag.

The purpose of the "20-foot combustible free zone" and the noncombustible radiant energy shield is to prevent a postulated fire from spreading to redundant safe shutdown components. FPL has applied this objective to the use of Thermo-Lag in open areas such as outdoors or containment. The radiant energy shields and intervening combustibles at Turkey Point take the form of raceway protection, rather than barrier walls.

Thermo-Lag requires a relatively high temperature (>1000°F) and/or a high radiant flux (>25 kW/m², 2.2 BTU/s-ft²) to ignite. It will also absorb large amounts of energy before ignition. Thermo-Lag on its own, will not spread a flame laterally. Considering the wide range of combustible products, and the objective of preventing a fire from propagating to 20 feet and redundant components, it is appropriate to determine if Thermo-Lag will or will not support fire propagation to a horizontal distance of 20 feet.

First, it is important to note that Thermo-Lag will not self-propagate horizontally. Second, it is necessary to determine the distance from a fire where the radiant flux will drop to less than 25 kW/m² (2.2 BTU/s-ft²). Looking at "Fire Induced Vulnerability Evaluation Methodology (FIVE) Plant Screen Guide, Table 10E "Critical Radiant Flux Distances"; it is evident that even at the end of the chart, the critical radial distance for 2.2 BTU/s-ft² is about 8 feet. This indicates that with a very large fire, redundant safe shutdown components at 20 feet will not be jeopardized by intervening Thermo-Lag. In addition, only the surface area of a small number of conduits will potentially add to the combustible load outside the fire plume. Based on this analysis, it is evident that Thermo-Lag does not qualify as an intervening combustible.

M. Top Coatings as Intervening Combustibles

Top Coatings are simply paint products used to keep adverse environmental conditions from affecting the Thermo-Lag. The contribution to fuel load from paint is very small. Paint is only flammable as a liquid, once cured/dried the combustible load is minimal.

In "Fire Tests of Building Interior Covering Systems", by David Waksman and John Ferguson (Interior Finish and Fire Spread, NFPA Pub. SSP-47), the authors provided experimental results of fire properties (flame spread, smoke generation and combustion products) of several surface coverings on combustible and relatively non-combustible substrates. The two substrates used were painted asbestos cement board (ACB) and painted

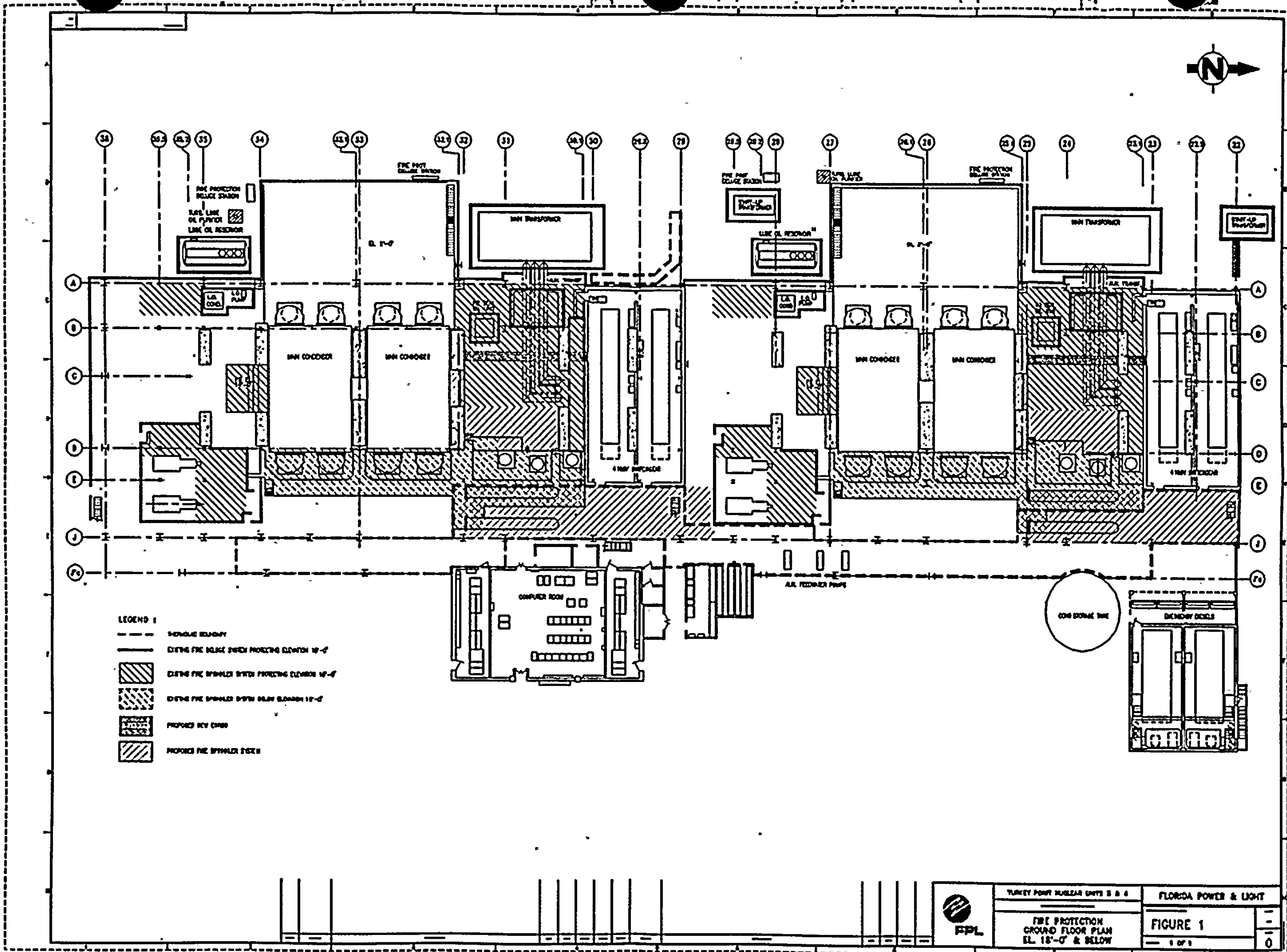
3/4" thick interior plywood. The flame spreads (per ASTM E-84) for these materials prior to applying surface coatings were essentially zero and about 300 respectively. The results were that the substrate has a significant effect on the results of the flame spread of the applied surface coating. A number of the coatings tested were paint products of various thickness. One example is a two component epoxy paint which had a flame spread of 281 on the plywood and a flame spread of 1 on the ACB. The worst case in the testing was a Nylon-Formulated Two-Component Paint w/Flexible Primer which had a flame spread of 341 on the plywood and a flame spread of 2 on the ACB. The nylon-formulated paints were the only paints tested which had a flame spread greater than 300 on the plywood substrate. Paint on relatively non-combustible materials (ACB) has a very low flame spread (1 to 7). In most cases the paint on a combustible substrate (plywood) had a flame spread of less than the substrate material.

Thermo-Lag 330-1 has a flame spread of about 25, based on Information Notice 95-32. Therefore, it is concluded that the application of a topcoat material (paint) will not increase the flame spread of the material. As such, the flame spread of the topcoat on Thermo-Lag 330-1 material would be in the range of 25. According to Information Notice 95-32 this correlates to about 8 feet in the ASTM E-84 Test Tunnel.

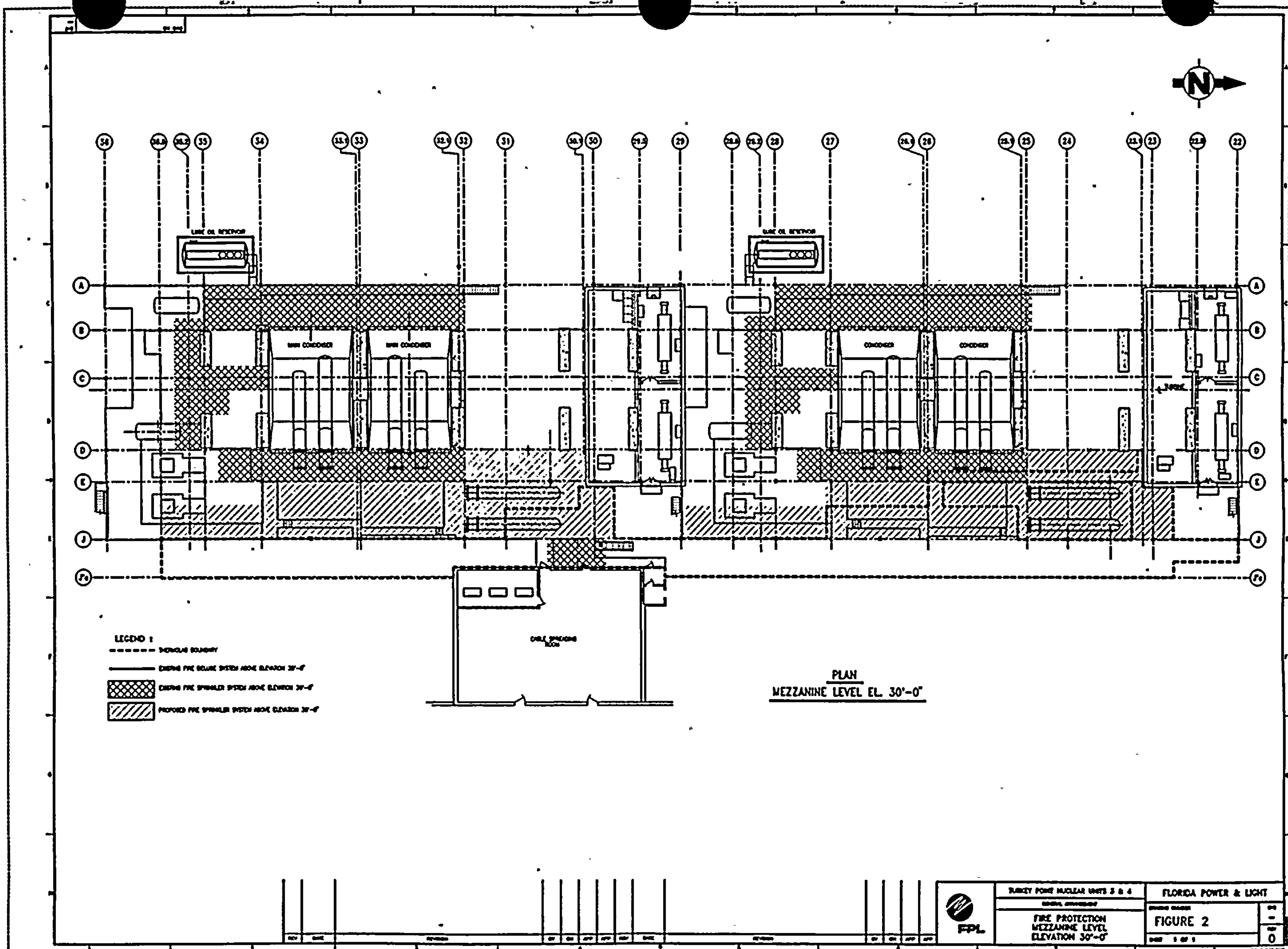
The conclusion is that the topcoating will not substantially increase the flame spread of the Thermo-Lag material and is acceptable for use at Turkey Point Units 3 and 4.

VI. Summary and Conclusion

Subsections III.G.2.a of Appendix R to 10 CFR Part 50 address fire protection features for assuring safe shutdown capability. Exemptions are provided under the provisions of 10 CFR §50.12 and, in effect, have been made a part of the fire protection regulations through the Court of Appeals decision in Connecticut Light. The exemption requested in Section II.B above is consistent with Section 50.12 of the Commission's regulations in that it is authorized by law, will not present an undue risk to the public health and safety, is consistent with the common defense and security, and presents special circumstances. Accordingly, the requested exemption should be granted.

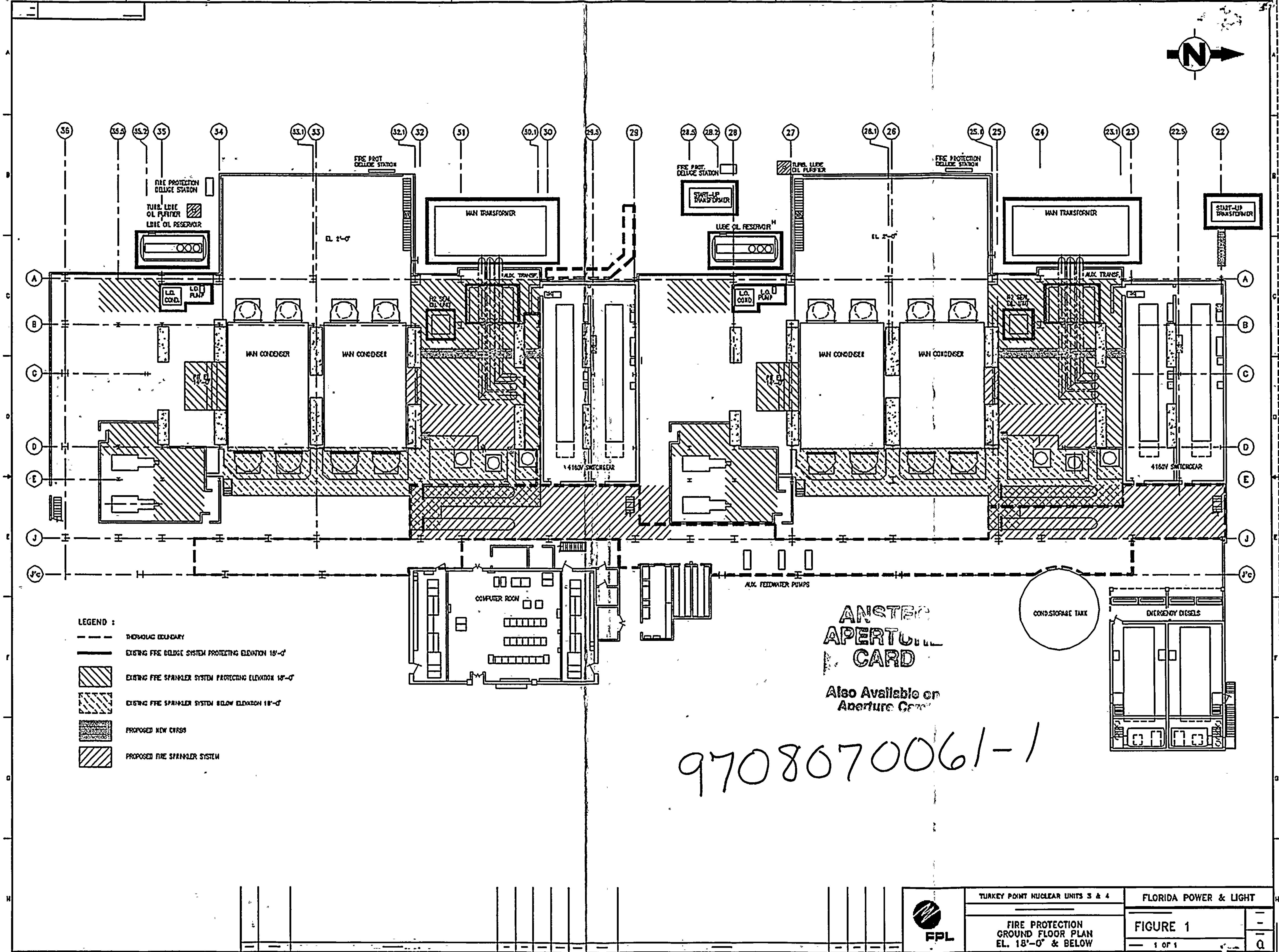


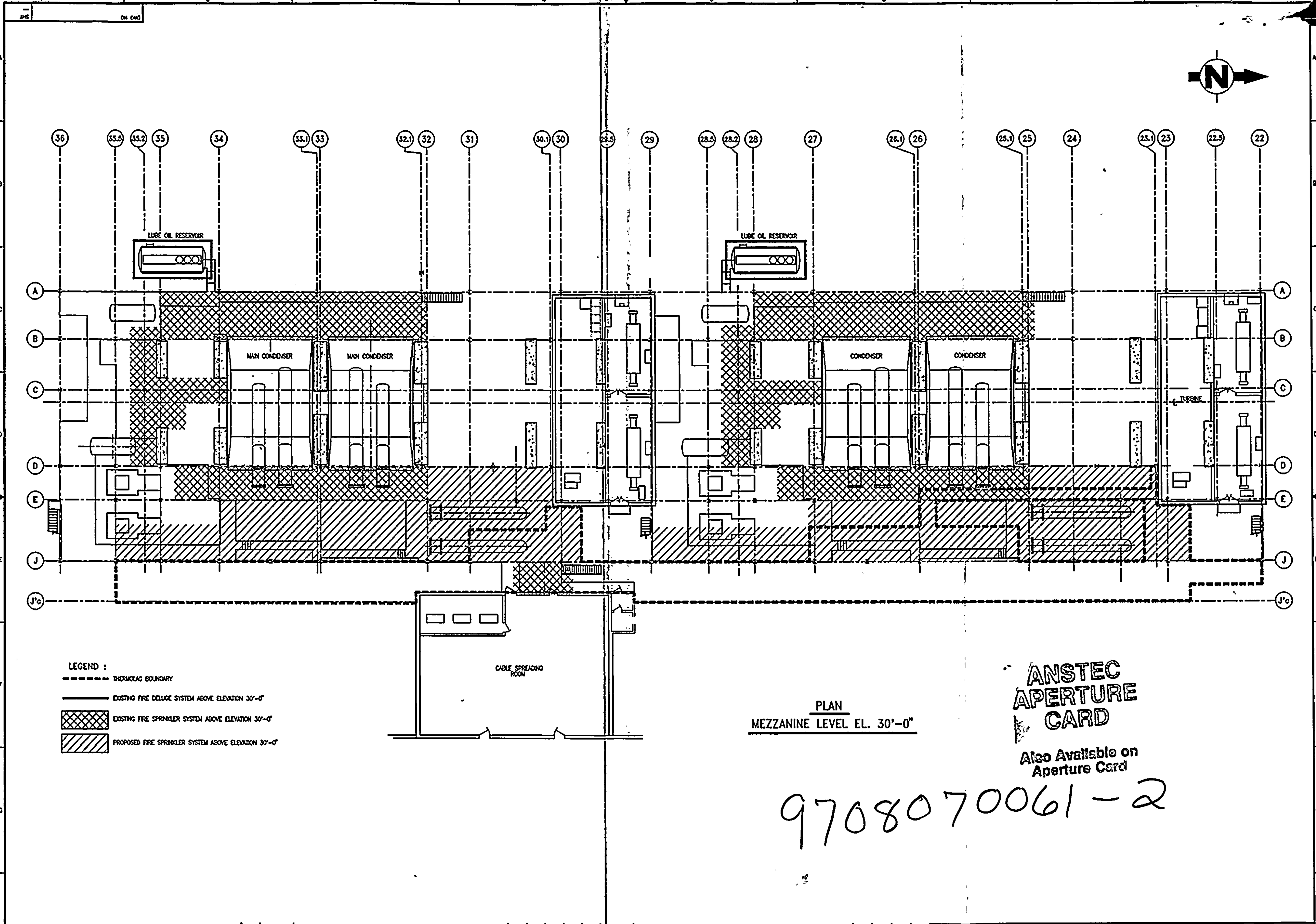
LEGEND :
MAIN CONDENSER
MAIN TRANSFORMER
COMPUTER ROOM
TURKEY POINT NUCLEAR UNITS 3 & 4
FLORIDA POWER & LIGHT
FIRE PROTECTION
GROUND FLOOR PLAN
EL. 18'-0" & BELOW
FIGURE 1
FPL



PLAN
MEZZANINE LEVEL EL. 30'-0"
LEGEND :
TURKEY POINT NUCLEAR UNITS 3 & 4
FIRE PROTECTION
MEZZANINE LEVEL
ELEVATION 30'-0"
FPL
FLORIDA POWER & LIGHT
FIGURE 2
0

[illegible]


FIRE PROTECTION DELUGE STATION
TURB. LUBE OIL PURIFIER
LUBE OIL RESERVOIR
FIRE PROT. DELUGE STATION
MAIN TRANSFORMER
AUX. TRANSF.
START-UP TRANSFORMER
MAIN CONDENSER
H2 SEAL OIL UNIT
L.O. COND.
L.O. PUMP
4160V SWITCHGEAR
COMPUTER ROOM
AUX. FEEDWATER PUMPS
COND. STORAGE TANK
EMERGENCY DIESELS
EL. 2'-0"
LEGEND :
THERMOLAG BOUNDARY
EXISTING FIRE DELUGE SYSTEM PROTECTING ELEVATION 18'-0"
EXISTING FIRE SPRINKLER SYSTEM PROTECTING ELEVATION 18'-0"
EXISTING FIRE SPRINKLER SYSTEM BELOW ELEVATION 18'-0"
PROPOSED NEW CURBS
PROPOSED FIRE SPRINKLER SYSTEM
ANSTEC APERTURE CARD
Also Available on Aperture Card
9708070061-1
TURKEY POINT NUCLEAR UNITS 3 & 4
FIRE PROTECTION GROUND FLOOR PLAN EL. 18'-0" & BELOW
FPL
FLORIDA POWER & LIGHT
FIGURE 1
1 OF 1
Q



TURKEY POINT NUCLEAR UNITS 3 & 4

GENERAL ARRANGEMENT

FIRE PROTECTION
MEZZANINE LEVEL
ELEVATION 30'-0"

FLORIDA POWER & LIGHT

DRAWING NUMBER FIGURE 2

SHEET 1 OF 1

SYS –

REV 0

5610M58F.DWG