SUPPLEMENTARY

Report of the Committee on

Electric Generating Plants

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Thomas C. Clayton, Black & Veatch, MO
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Rep. The Alliance of American Insurers
Donald A. Diehl, Alison Control Inc., NJ
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James G. Pittman, Seminole Electric Cooperative Inc., FL
Gregory W. Powell, Baltimore Gas & Electric Co., MD
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John G. Puder, F. E. Moran Inc., IL
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William D. Snell, TU Services Inc., TX
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Alternates

Fernando A. Caycedo, Ebasco Services Inc., NY
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Daniel J. Sheridan, Black & Veatch, MO
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Richard Wickman, Baltimore Gas & Electric Co., MD
(Alt. to G. W. Powell)

Staff Liaison: **Casey C. Grant**

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time changes in the membership may have occurred.

The Supplementary Report of the Committee on Electric Generating Plants is presented for adoption in 2 parts.

Part I of this Supplementary Report was prepared by the Technical Committee on Electric Generating Plants, and proposes for adoption a Supplementary Report which documents its action on the public comments received on its Report on NFPA 850-1990, Recommended Practice for Fire Protection for Electric Generating Plants, published in the Technical Committee Reports for the 1992 Annual Meeting.

Part I of this Supplementary Report has been submitted to letter ballot of the Technical Committee on Electric Generating Plants which consists of 28 voting members; of whom 26 voted affirmatively, 2 negatively, (Mr. Dobson and Ms. Lataille).

Mr. Dobson voted negatively stating:
"Inadequate protection for beneath the turbine-generator operating floor. Paragraph 5-7.4.1. A sprinkler density of 0.20 gpm/sq ft over a 10,000 sq ft area is needed below the turbine operating floor.
The present change to 0.3 gpm/sq ft over 5,000 sq ft was made due to lack of loss data and the belief that this will be effective in controlling fires involving substantial quantities of combustible liquids or where combustibles are shielded.
In fact the major problem in turbine building protection is the rundown time of the turbine following a fire. Rundown times of 30-60 min. should be expected during which time th elube oil system will remain in operation. There is no loss data for fully protected turbine buildings. Estimates of the number of sprinklers opening need to be obtained from a study of other occupancies involving oil systems under pressure. Seventeen (17) oil system fires reported to Factory Mutual were studied. In 9 of the fires the time of oil pump shutdown was recorded. For six fires where the pump was shutdown immediately the number of sprinklers opened was 12, 15, 15, 16, 18, and 26. For three fires where oil pumps operated for extended periods, as would be expected during turbine rundown, the number of sprinklers opened was 72, 87, and 120. In one loss 72 operated and from 800 to 1,000 gal of oil from a 1,400 gal tank was consumed. In a second loss 87 automatic sprinklers opened. The reservoir was 165 gal capacity. There was no sprinkler protection for two 4 x 8 ft hoods which contributed to the number of heads opening in this loss. In a third loss 120 automatic sprinklers operated. The oil pump was shutoff 30 min. after the fire with approximately 1,000 gal of oil consumed. All the above were wet pipe systems with 165°F rated sprinklers."

Ms. Lataille voted negatively stating:
"Two proposals, which would have revised 5-7.4.1 bringing it closer to the NFPA 850-1990 guidance, were rejected by Committee actions. These are described by Logs #7 and #11. The proposals included information showing turbine-generator fires involve areas larger than the 5000 ft^2 now contemplated by 5-7.4.1. The substantiation for rejection is weak. The standard does not limit fire areas to 5000 ft^2, and there are sufficient cases to document that fires have opened sprinklers in much larger areas. We believe NFPA 850-1990 guidance is superior to that approved by the Committe for the 1992 standard, and that this subject could benefit from further study. We therefore cannot support Committee action and plan to continue to recommend that the 5-7.4.1 guidance in NFPA 850-1990 be followed for sprinkler design."

Mr. Powell voted affirmatively with the following comment:
"I am concerned with Log #10 850-3 (2-7.2, Appendix C (New). In section 2-7.2 the 850 Committee provided some controversial procedures/actions that could be taken during a turbine lube oil fire. This included shutdown of lube oil while the turbine was still turning. As a precaution, it was noted in this section that the potential mechanical damage from such action must be weighed against the potential fire damage. The 850 Committee has now proposed an Appendix C with some limited fire loss information that narrowly focuses in on specific generating plant fire loss experience which documents use of this action during fire conditions. I am not opposed to fire loss data being provided; however, the presentation of turbine generator loss information should be more complete. There are many utility losses in which the loss of oil flow has caused substantial mechanical damage and prolonged unit outages. In addition, the loss scenarios listed provide information regarding the AC & DC emergency oil pumps, but the status of the shaft driven pump(s), of any, is not given. It is my understanding that during loss number 1 in the proposed appendix the lube oil was shut-off immediately after the rotation stopped and the unit was not put on turning gear. There was no bearing damage, but there was the potential for other significant shaft damage (bowing). Finally, if the NFPA 850 document is to be used to record fire loss data, it should include loss data for areas of the plant other than just the turbine generator.

In my opinion the emphasis of the fire loss data should be that a properly designed sprinkler system is needed to protect against lube oil spray fires and that sprinklers have been extremely successful. Where they have failed, there have been design deficiencies which have been major contributors to the failure. This emphasis is lacking in the loss information as proposed. A properly designed sprinkler system allows the fire to be controlled and the machine to be protected by supplying adequate lubrication.

I believe that Appendix C should be returned to the Committee for revisions addressing the problem areas outlined above."

Part II of this Supplementary Report was prepared by the Technical Committee on Electric Generating Plants, and proposes for adoption a Supplementary Report which documents its action on the public comments received on its Report on NFPA 851-1987, Recommended Practice for Hydroelectric Generating Plants, published in the Technical Committee Reports for the 1992 Annual Meeting.

Part II of this Supplementary Report has been submitted to letter ballot of the Technical Committee on Electric Generating Plants which consists of 28 voting members; of whom all 28 voted affirmatively.

PART I

(Log # 12)

850- 1 - (1-1): Accept
SUBMITTER: L. T. Warnick, Virginia Power
COMMENT ON PROPOSAL NO.: 850-6
RECOMMENDATION: Revise the proposed new section 1-1 to read as follows:

1-1 Scope. This document provides recommendations (not requirements) for fire prevention and fire protection for electric generating plants, except as follows: nuclear power plants are addressed in NFPA 803; hydroelectric plants are addressed in NFPA 851; and combustion turbine units of 7500 hp or less are addressed in NFPA 37.

SUBSTANTIATION: The current wording is indirect. Rewording as above makes a more clear distinction between the scopes of the respective documents.
COMMITTEE ACTION: Accept.

NOTE: Only Section 1-1 is revised per this public comment. Section 1-2 remains as shown in 850-6 (page 93) of the A92-TCR.

(Log # 9)

850- 2 - (1-1): Accept in Principle
SUBMITTER: Paul H. Dobson, FMRC
COMMENT ON PROPOSAL NO.: 850-6
RECOMMENDATION: Add after first sentence in Scope:

"This document is not intended to provide guidance for fire prevention and fire protection for nuclear power plants, hydroelectric power plants or for combustion turbine units of 7500 hp or less."

SUBSTANTIATION: Clarification.
COMMITTEE ACTION: Accept in Principle.
COMMITTEE STATEMENT: Refer to action on 850-1 (Log #12).

(Log # 10)

850- 3 - (2-7.2, Appendix C (New)): Accept in Principle
SUBMITTER: Paul H. Dobson, FMRC
COMMENT ON PROPOSAL NO.: 850-12
RECOMMENDATION: Add Appendix C "Loss Experience" describing the effect of shutting off lube oil to turbine as follows:

Appendix C Emergency Shutdown

The following describes loss experience which has occurred over the last several years in which lubricating oil supply was shutdown more rapidly than normal either intentionally or accidentally. Lubricating oil was shutoff at 0 rpm for loss #1, at 1,000 rpm for Loss #2, from 1,000-1,400 rpm for Loss #3 and in excess of 3,000 rpm for Loss #4.

1. On Aug 1989 a 640 MW(e) five casing, double reheat machine with inlet steam pressure at 3,675 psig and 1,000 F was operating normally when a fire was discovered near the main lube oil tank. Unsuccessful attempts were made to manually fight the fire when control cable burned through and control and throttle valves started to close. At 6 min the ac lube oil pump started. The operator sent an assistant to vent hydrogen from the generator and purge with carbon dioxide. A valve was then manually operated to break condenser vacuum. This action resulted in reducing the coast-down time to 30 min from 45-60 min. When the shaft stopped rotating the operator took the unit off turning gear and shut down the ac and emergency dc oil pumps. The Fire Department and Plant Fire Brigade quickly controlled the fire with one 2 1/2 in. and one 1 1/2 in. hose stream.

There was no damage to the bearings as a result of the shutdown. A runout check indicated that measured clearances were well within tolerance. Steel beams supporting the operating floor sagged from 2 to 3 in. over a 1500 sq ft area in front of the front standard. Cable in trays near the fire area was damaged. The action taken by the operator resulted in substantially reduced damage to the turbine and the building and was credited with substantially reducing the length of time the turbine was out of service. The turbine was put back on turning gear about 26 days after the fire. The operating floor could be reinforced and the unit operated until the next scheduled outage.

2. On July, 1987 a 35 MW(e) single flow, double automatic extraction, condensing machine with inlet steam pressure of 1250 psig and 900 F was operating normally while millwrights attempted to clean the oil cooler tubes on one of the two oil coolers. During the cleaning process one of the tubes dropped out of tube sheet and oil was ejected vertically at about 40 psi through a 5/8 in. opening in the tube sheet. The oil spray ignited off a steam stop valve overhead. Approximately 20 ceiling sprinklers and 16 spray nozzles directly below the operating floor opened. Oil mist and droplets passed up through a 6 in. wide opening between the operating floor and the wall and burned above the operating floor. Approximately 15 min into the fire, fearing building collapse, the ac driven lubricating oil pumps were shutoff. The fire intensity decreased noticeably. Approximately 15 min later (30 min into the fire) the dc pump was shutdown with the turbine turning at approximately 1,000 rpm. The oil fire was quickly extinguished.

The main shaft bearings were wiped and the thrust bearing destroyed. There were indications of minor rubbing at the high pressure end and hangars for the main steam stop valve were cracked. There was little evidence of high temperatures in the basement area, due to the effect of the automatic sprinkler protection. However, there was a large amount of deformed structural steel above the operating floor, on the wall and at roof level.

3. On Jan, 1989 a 12.5 MW(e) condensing, double automatic extraction turbine with inlet steam pressure of 475 psig and 750°F was operating normally when maintenance personnel, discovered a drip sized leak at an elbow on the control oil piping. Control room personnel were notified and since they had difficulty reducing load, they tripped the unit by opening the breaker. A fire started in the vicinity of the hydraulic cylinder. There was no fixed protection provided, personnel attempted to fight the fire with hand extinguishers and hose streams without success. Two minutes after the fire started with the machine turning at between 1,100 and 1,400 rpm the operator was ordered to stop the main and emergency oil pumps. Approximately 150 gal of oil was lost before pumps were stopped. The Fire Department responded 4 min after the fire started and using one 2 1/2 in. and two 1 3/4 in. hose lines brought the fire under control 23 min after it started.

There was damage to turbine bearings and the shaft ends were scored. In addition all control wiring under the turbine shroud was burned and there was damage to gauges, indicators and controls mounted in the turbine shroud. Structural steel was warped at the roof of the building. Repairs to the turbogenerator were estimated at 2 to 3 weeks.

4. On Feb, 1988 two 660 MW(e) units were operating at 550 and 530 MW(e) respectively. The units were end to end. Power and control cable for the lube oil pump motors for both machines were located above a control valve servomotor enclosure for one of the units. Piping to the enclosure was guarded and contained control oil at 250 psig. A leak occurred in the control oil piping within the guard pipe. The turbine tripped automatically. Oil flooded the guard pipe and backed up into the servomotor enclosure igniting in the vicinity of the main steam stop valves. The fire damaged power and control cable for both machines shutting down ac and dc oil pumps for both units. Both machines were rotating in excess of 3,000 rpm at the time lube oil was lost.

Extensive repairs were needed to mill bearing surfaces and to straighten and balance the shafts on both units. One machine was out of service for approximately 3 months, the other for 5 months.

SUBSTANTIATION: The new Paragraph 2-7.2 should reflect loss experience, showing that lubricating oil has been shutoff under emergency conditions and what the effect has been.
COMMITTEE ACTION: Accept in Principle.

Accept the submitters wording with the following editorial changes:
1. Change "loss" to "fire" in 5 places in the submitters opening paragraph.
2. Begin each of the four fire experiences with "In" instead of "On."
3. Add "(See Appendix C)" to the end of 2-7.2.

COMMITTEE STATEMENT: Editorial.

(Log # 5)

850- 4 - (3-2.2(b)): Accept
SUBMITTER: Daniel J. Sheridan, Black & Veatch
COMMENT ON PROPOSAL NO.: 850-19
RECOMMENDATION: Revise the phrase "unusual structures" to "special structures."
SUBSTANTIATION: This editorial change is based on The Life Safety Code, NFPA 101, which currently uses the term "special structures" in lieu of the previously used "unusual structures."
COMMITTEE ACTION: Accept

(Log # 8)

850- 5 - (4-6.1, Chapters 5, 6 & 7): Accept in Principle
SUBMITTER: Don Birchler, F. P. & C.
COMMENT ON PROPOSAL NO.: 850-1 and 850-30
RECOMMENDATION: Revise as follows:

Section 4-6.1 - Replace the second sentence with the following: "Fixed suppression systems should be designed in accordance with the following codes and standards unless specifically noted otherwise:

NFPA 11, Low Expansion Foam and Combined Agent Systems
NFPA 11A, Medium- and High-Expansion Foam Systems
NFPA 12, Carbon Dioxide Extinguishing Systems
NFPA 12A, Halon 1301 Fire Extinguishing Systems
NFPA 13, Installation of Sprinkler systems
NFPA 15, Water Spray Fixed Systems
NFPA 16, Installation of Deluge Foam-Water Sprinkler Systems and Foam-Water Spray Systems
NFPA 231, General Storage
NFPA 231C, Rack Storage of Materials"

Modify the references in the following sections as follows:

Section 5-4.6.2 - Delete parenthetical statement referencing NFPA 13.

Section 5-6.1.1 - Delete parenthetical statement referencing NFPA 13, NFPA 15 and NFPA 16.

Section 5-8.1.3 - a. Delete "designed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems" in the first sentence.

b. Delete "designed in accordance with NFPA 12A, Standard on Halon 1301 Fire Extinguishing Systems" in the second sentence.

c. Delete "designed in accordance with NFPA 12, Standard on Carbon Dioxide Extinguishing Systems" in the second sentence.

Section 5-8.2.1 - Delete parenthetical references to NFPA 12, NFPA 12A, NFPA 13, NFPA 15 and NFPA 16.

Section 5-8.6.1 - Delete parenthetical references to NFPA 15, NFPA 16 and NFPA 11.

Section 5-9.2.1 - Delete the second sentence referring to NFPA 13, NFPA 231 and NFPA 231C.

Section 5-9.3.1 - Delete the second sentence referring to NFPA 13, NFPA 231 and NFPA 231C.

Section 6-5.4.4 - Delete "they should be installed and maintained in accordance with NFPA 11A, Standard for Medium and High Expansion Foam Systems."

Section 8-4.3.2 (New Chapter 8) - Delete parenthetical references to NFPA 13, NFPA 231 and NFPA 231C.

Section 7-3.4.2 - Delete second sentence.

Section 7-4.4.3 - Delete second sentence.

Section 7-4.4.10 - Delete "in accordance with NFPA 15, Standard for Water Spray Fixed Systems."

SUBSTANTIATION: The change is submitted to ensure that references are given in a consistent manner in all paragraphs.
COMMITTEE ACTION: Accept in Principle.

Accept the submitters changes, but also include NFPA 17 in the list of documents shown in the change to 4-6.1.
COMMITTEE STATEMENT: Dry chemical systems are referenced in 5-3.9.1. and thus NFPA 17 should be included in the submitter list of references indicated in 4-6.1.

(Log # 2)

850- 6 - (5-7.3.3): Hold for Further Study
SUBMITTER: Robert E. Dundas, Norwood, MA
COMMENT ON PROPOSAL NO.: 850-44
RECOMMENDATION: Revise paragraph to read:

"5-7.3.3 It is desirable to ...vacuum break valve to shorten the deceleration time of the turbine in the event of a fire or break in a lube or hydraulic line.

Consideration should also be given to the use of excess-flow check valves in the main and branch lines of the lube and hydraulic systems. Such valves will prevent fires, in the event of line breaks, by shutting off oil flow instantly, at the same time, in the case of branch line in lube systems, limiting bearing damage to that bearing supplied by the broken line."

SUBSTANTIATION: It is recommended that the sentence "Breaking the condenser vacuum markedly reduces the rundown time for the machine and thus limits oil discharge in the event of a leak," be omitted. While it is desirable to shorten the rundown time of the machine in the event of a fire or oil leak, that sentence implies that the turbine does not have to be placed on turning gear for several days, and that the lube oil system can be shut off after rundown without major damage to the turbine.

This is not the case. Experience has shown that steam turbine shafts can be bowed after even short periods off turning gear. Such bowing can be permanent, and the risk of such damage should not be incurred, particularly since, as will be noted below, the implied procedure does little to avoid very major damage during a lube or control oil fire, and there is an effective alternative procedure to prevention of such a fire.

Even with the vacuum breaker, a large steam turbine could not be decelerated in less than 25-30 minutes. This would permit ample time for extensive property damage in the event of an oil spray fire. There are numerous examples to support this statement, but the most telling may be the case of a fire in a large utility where 18,000 sq ft of roof collapsed 26 minutes after such a fire broke out.

The added paragraph recommends consideration of excess-flow check valves in lube and hydraulic oil lines to shut off the flow of oil instantly subsequent to line break or separation. The valves would be installed throughout the lube system to isolate each branch line in the even to of a break in that line. There would be no fire, and the turbine could be shut down and placed on turning gear with no damage, other than to the bearing fed by the line that separated (which damage would occur in any event). It is expected that this damage would be far less than that might be sustained by the bearings and shaft if all bearings were suddenly starved of oil, even at low speed.
COMMITTEE ACTION: Hold for Further Study.
COMMITTEE STATEMENT: This public comment introduces a concept that has not had public review and is being held for further study according to section 11-10 of the NFPA Regulations Governing Committee Projects. Further information on this subject from turbine manufacturers is considered important and time is required for these concerns to be pursued.

(Log # 7)

850- 7 - (5-7.4.1): Reject
SUBMITTER: Daniel J. Sheridan, Black & Veatch
COMMENT ON PROPOSAL NO.: 850-39 and 850-46
RECOMMENDATION: Return to the original wording of 5-7.4.1 and delete the following text:

"0.30 gpm per sq ft (0.20 L/sec per m^2) over an application of 3,000 sq ft (279 m^2) and"

SUBSTANTIATION: This comment presents a compromise between the existing dual densities and the TCR comments No. 39 and 46, which as indicated in Mr. T. C. Clayton's negative ballot may have been voted on improperly. The 0.20 gpm per sq ft over 10,000 sq ft density would remain in effect. This single density provides a simple, clear, and conservative recommendation, and is supported by EPRI Report NP-4144 "Turbine Generator Fire Protection by Sprinklers" and Mr. Clayton's memo of 10/90.

A major concern is the system's ability to control a large fire. A large fire could result from extensive pooling of oil prior to ignition. Once ignited, it would take a large area of opened sprinklers to control the fire. 0.2 gpm per sq ft over 10,000 ft would provide the large distribution of water required in this case.

The following is an excerpt from Mr. Clayton's memo of 10/90:

In response to the continuing concern of fire protection for turbine-generators, the objective is to address the following:

1. Which hazards to protect.
2. Design criteria for protection systems.

1. Which Hazards to Protect

For the purpose of this discussion, in determining which areas to protect, reference will be made to the EPRI T-G fire protection report.

(a) Turbine-Generator Bearings

Table 2-3 of the EPRI report is a summary of fires involving oil by location. In reviewing this table the bearings were the highest frequency of fires. This is misleading to some degree, because in some cases bearing fires also include the underfloor area, as may be expected, because of oil flowing down from the shaft seal area.

In one incident, the bearings were protected by a dry chemical system and had full underfloor protection. The turbine experienced vibration and oil leaked from the bearings and spread to the underfloor. The source of ignition for the oil fire was at the bearings. The dry chemical system exhausted its supply including the reserve, and the oil reignited. The underfloor system controlled the fire to some degree; however, the burning oil continued feeding the fire below the operating floor. The consequence of this fire was $1,600,000 and 180 days of plant downtime for a 730 megawatt unit. If the bearing system would have been water based, and if the underfloor system would have had a higher density, it is my opinion that damage would have been significantly less.

In the Seminole fire the fire was basically located below the operating floor. The bearings had an automatic preaction spray system. It was stated in the fire report that the bearing system operated and mitigated damage in the bearing seal area.

(b) Turbine-Generator Lube Oil Piping
Table 2-3 of the EPRI report lists other areas in the turbine building or pieces of equipment that involve oil fires including insulation, pipe, valves, motor control centers, lube oil reservoirs, etc. By in large, they involved the failure of bearings, lubricating oil piping component failure, or hydraulic oil leaks. The oil then spread to other areas under the turbine.

(c) Summary
There are four areas that should be protected based on the fire records and recent experience.

(1) Turbine bearings.
(2) Oil piping under the lagging but above the operating floor, because this is where most of the connections for pressure gages, pressure switches, etc., are located.
(3) The turbine underfloor area where oil may collect.
(4) Lube oil reservoirs and boiler feed pump turbines, which are discussed in the EPRI report.

2. Design Criteria for Protection Systems

It is assumed that for all cases, water is the primary extinguishing agent because limited supply agents are not suited for time of duration or volume considerations.

(a) Turbine-Generator Bearings — Several scenarios will be described to explain coverage of this hazard. (1) Oil leaks from bearings in small quantities, impinge the gland steam casing and ignite almost immediately. In this case the fire can be described as localized; however, the oil will impinge on the surface of the casing (hot end) because of the rotation of the shaft. In addition, some run down of oil may be expected. (2) Oil is released in large amounts that cover front of casing and bearing housing. Large quantities of oil may be expected to flow beneath the turbine. Ignition may occur instantaneously from friction of bearings or from oil coming in contact with hot gland steam casing (hot end). Ignition may not occur for an extended period of time and oil may run down to areas below the turbine. This generally occurs at the cold end of the turbine-generator.
The design criteria for the bearing area should be as follows.

- Coverage area should include shaft, seal area, face of bearing housing where oil is escaping and the face of the casing where oil is thrown due to the rotation of the shaft.
- The density should be 0.25 gpm per square foot based on NFPA 15 for similar hazards (combustible liquid) like transformers.

(b) Oil Piping Under the Turbine Lagging — Again, several scenarios will be described. (1) A leak from a pressure gage develops because of improper installation. Ignition may not occur for some time because the oil is not directly impinging on ignition sources like hot parts of the bearing area. The oil would flow on to the operating floor but within the enclosure area, and run down the floor opening of the casings. The amount of oil that escapes would depend on pressure and orifice size, but could result in very large amounts. (2) A leak from a bearing could run into the turbine lagging enclosure. Limited access during a fire would make manual fire fighting efforts difficult, and fixed fire protection coverage is warranted.
The design criteria for the turbine lagging area should be as follows.

- Coverage area should include the floor area under the lagging (concealed area).
- The density should be 0.2 gpm based on the Finnish report. The area beneath the lagging is considered a pool fire because it is about 2 1/2 feet from top of lagging to operating floor.

(c) Turbine Underfloor — The turbine underfloor represents the area most likely to collect oil in the event of a lube oil component failure. This does not necessarily mean that the majority of losses will occur there, as in the case of a failed roof system, smoke damage to computer systems located in the boiler area, etc.
The design criteria of an underfloor protection system must take into account the type of fire, extent of fire derived from actual fire records, and actual fire tests performed in the past. Therefore, there are two basic design criteria that one must address. They are:

- Coverage area.
- Design Density(ies).

There are three types of oil fires that may occur; (1) oil pool fires, (2) oil spray fires, and (3) three-dimensional oil fires. The fire records indicate that all three can occur simultaneously, not to mention other fires like hydrogen, cable, etc.
The most common type of oil fire, as indicated by fire records, is the three-dimensional fire and pool fire that occur as one. A typical event occurs as a release of oil from bearing or bearing seal area. The oil then flows downward, following the path of pipe, and cascades onto other equipment such as bus ducts,motor control centers, switchgears, lube oil tanks, and finally pools on the lower level floor. Once ignited, three-dimensional fire (cascading oil) and pool fire (oil collected on the floor) occurs.
The question now becomes: With two types of fires occurring, what should the density and coverage area of the sprinkler system be?

Coverage Area
In the event of a three-dimensional fire, the oil would flow from a failed generator bearing, down the outside of the oil return line to the oil reservoir. On a medium-sized turbine this would involve approximately 75 feet of piping. Oil would follow the pipe and drop along the length of the path, involving the mezzanine level. This would be an area of 20' x 95' on each level, which is 3,600 square feet of three-dimensional fire. Assuming a three-dimensional spread of 10 feet on either side of the oil return line, this could be a much larger area on larger units.
In the event of a pool fire, it is difficult to determine the extent of oil pooling. However, for a medium sized unit, the pooling would occur on the lowest level and on the mezzanine level where solid floor is provided. This could be determined on an individual basis. However, assuming that pooling can occur 20 feet on either side of the oil return line results in an area 40' x 115' x 2 levels, which is 9,200 square feet for a medium size unit, this pooling effect would more than likely be a larger area because there are no drains or curbs on the mezzanine level. Typically, there are no curbs on the lower level, nor would they be of any significant benefit because the oil would be falling from long runs of pipe and cable trays which would traverse the curbs from above. Curbs around lube oil tanks would be of benefit in the event of small leaks from the tank but certainly not from cascading oil from above.
In the event of an oil spray fire, oil can spray as much as 60 feet. This has occurred based on incidents in the EPRI report and events occurring after the EPRI report.
Based on the EPRI report and major fires occurring after the EPRI report, a fire can spread to any part of the turbine building. Therefore, full underfloor protection should be provided.

Density Criteria
The density criteria for oil pool fires has been documented by the Finnish report as 0.2 gpm per square foot. I believe that this varies based on film or pool thickness of oil. One of the biggest problems at power plants in the application of this density over a uniform area. In many cases, the direct application of water cannot be achieved because of obstruction of the sprinkler pattern caused by cable trays, ducts and pipes. Therefore, the 0.2 gpm measurement is an extreme minimum and would control the fire somewhat and may prevent major structural steel damage.

In the Seminole fire where full underfloor coverage was provided, except for the bus duct area, 91 head fused. This represents an area of approximately 10,000 square feet based what head spacing was installed.

The density criteria for three-dimensional fires is extremely difficult because no practical test would be of particular benefit. That is to say, how three-dimensional should "three-dimensional" be for test purposes; or put another way, how many pipes, cable trays, etc., should be considered to satisfy everyone. The answer is infinite. 0.3 gpm certainly seems very small as compared to density requirements in the flammable liquids codes (NFPA 30) of 0.5 for combustible liquid container storage with no obstructions.

The design criteria for oil spray fires has been documented somewhat in the Finnish report. However, trying to determine the location and pattern of spray is infinite and will not be considered as practical.

NFPA 13, paragraph 1-7.4.1, defines extra hazard occupancies or portions of occupancies where quantity and combustibility of contents is very high and combustible liquids are present introducing the probability of rapidly developing fires with high rates of heat release.

In addition, paragraph 1-7.4.2 further defines group 2 as occupancies with moderate to substantial amounts of combustible liquids or where shielding of combustibles is extensive. See attachment, Page 13 of the Automatic Sprinkler Handbook.

Based on Figure 2-2.1.1(b), the requirement of density would be 0.3 gpm over 5,000 square feet.

Other conditions exist, such as (1) 1,000 gpm for hose stream water supply, (2) fully sprinkler occupancy, (3) increase of operating area by 30% where dry pipe sprinkler system is used, and (4) reduction of operating area by 25% where high temperature sprinklers are used.

One area that has not been discussed in the EPRI or NFPA report is the turbine room roof. I do feel that even under full underfloor coverage and bearing protection, partial roof damage, or in some cases severe damage could occur. An example of this would be where extremely large openings in the operating floor exist and venting of hot gases could occur.

3. Summary

(a) Turbine-generator bearing protection is required based on the highest frequency of fires associated with turbine lube oil systems. In addition, fire experience has demonstrated that water based bearing protection has mitigated damage at the bearing/seal area even though no fire existed at the bearings.

The design criteria for turbine bearing protection is based on fire experience and existing NFPA standards.

(b) Oil pooling under the turbine-generator lagging is required based on fire experience of component failures like pressure gages, switches, etc.

The design criteria for the oil piping under the lagging is based on the Finnish report.

(c) The type of oil fires that occur under the operating floor are pool, three-dimensional and spray fires. Based on fire experience, these fires can occur anywhere below the operating floor and damage occurs above the operating floor as well as below the operating floor.

Fire experience has shown that full underfloor protection can control a fire from a major turbine vibration while the exclusion of one relatively small area from full coverage can result in a 40 million dollar loss.

The specific design density of the underfloor area should be designed to control a combination of three-dimensional and pool fires simultaneously because this is the most common type of fire, based on fire records.

The design density of 0.3 gpm over the most remote 3,000 square feet for a three-dimensional fire may not be enough. The 10,000 square foot area to which 0.2 gpm would be applied, has been shown to be appropriate based on the Seminole fire (91 heads operating). In some cases 1.0 gpm per square foot would not be adequate to extinguish a fire due to sprinkler pattern obstruction by numerous large pipes, cable trays and equipment. However, the integrity of the steel structure, concrete turbine pedestal and other pieces of equipment could be protected.

NFPA 13 describes a 0.30 gpm per square foot over 5,000 square feet with the addition of 1,000 gpm.

(d) Other individual pieces of equipment, such as elevated turbine lube oil reservoirs and boiler feed pump turbines, should be individually protected as described in the EPRI report.

(e) The NFPA 850 committee should strongly consider recommending protection of the turbine room roof structure where large access areas exist at the operating floor and where sprinkler coverage cannot cover pooling of oil at the lower levels. The intense heat may cause roof collapse.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: The use of a design area of operation of 10,000 ft^2 is not supported by loss data for facilities protected in accordance with the recommendations contained in this document. The use of .3 gpm/ft^2 over 5000 ft^2 has shown to be effective in controlling or extinguishing fires involving substantial quantities of combustible liquids or where combustibles are shielded (see NFPA 13). Both of these conditions could occur in a typical turbine building.

The Technical Committee continues to stress the importance of correctly applying the recommended density (.3/5000) in all areas where oil can spread or accumulate. This coverage normally includes all areas beneath the operating floor in the turbine building.

(Log # 11)

850- 8 - (5-7.4.1): Reject

SUBMITTER: Paul H. Dobson, FMRC

COMMENT ON PROPOSAL NO.: 850-39

RECOMMENDATION: Revise 5-7.4.1 (850-39) so that recommended density is 0.20 gpm/sq ft over 10,000 sq ft.

SUBSTANTIATION: The basis for making the change from 0.3 over 3,000 and 0.2 over 10,000 sq ft was the use of the NFPA 13 Extra Hazard Group 2 category involving high hazard occupancies. The following operations are listed as typical of Group 2: asphalt saturating, flammable liquid spraying, flow coating, solvent cleaning, varnish and paint dipping. The examples cited are either combustible liquid pool fires such as asphalt saturating and oil quenching or are flammable liquids where one of the protection features includes either automatic shutoff on fire detection (paint spray or flow coating) or drainage to a safe area (large dip tank).

There has not been enough loss experience with fully protected turbine buildings to say for sure what the design basis should be. Turbine oil fires can be expected to burn for a minimum of 30 and possibly 60 min. We should plan for a large area to open.

We reviewed Factory Mutual loss experience involving hydraulic oil fires. There were 17 fires during the period reviewed. In 9 of the fires the time of oil pump shutdown was recorded. For the six fires where the pump was shutdown immediately the number of sprinklers opened was 12, 15, 15, 16, 18, and 26.

For the three fires where oil pumps operated for extended periods the number of sprinklers opening was substantially greater. In one loss 72 operated and from 800 to 1,000 gal of a 1,400 gal oil tank was consumed. In a second loss 87 automatic sprinklers operated. The reservoir was 165 gal capacity. There was no sprinkler protection for two 4 x 8 ft hoods which was an additional contributing factor in this loss. A third loss resulted in 120 sprinklers opening. The oil pump was shutoff 30 min after ignition, approximately 1,000 gal of oil was consumed. All the above were wet pipe systems with 165 F rated sprinklers. The area affected were in the 9,000 to 10,000 sq ft range.

At this time I do not think we have enough loss experience to change the protection criteria.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: Refer to action on 850-7 (Log #7).

(Log # 4)

850- 9 - (6-5.3.2): Accept in Principle

SUBMITTER: W. D. Phillips, CIBA-Geigy Additives

COMMENT ON PROPOSAL NO.: 850-57

RECOMMENDATION: Revise paragraph to read:

6-5.3.2 In many units the lubricating oil is used both for lubrication and hydraulic control Where possible a listed fire resistant fluid should be used in both systems. If this is not possible the turbine should be protected as described in Section 6-5.4.

SUBSTANTIATION: Placement of mineral oil in the hydraulic system does not remove the hazard associated with the use of mineral oil.

There are 130-140 gas turbines in Canada/USA using a phosphate ester fire-resistant hydraulic fluid and lubricant. Over thirty years experience in a range of designs has accumulated with no known fires. There are, therefore, commercially available alternatives to mineral oil which greatly reduce the fire hazard. Such products provide protection throughout their use at all parts of the system. The protection offered is not dependent on good maintenance of fluid/equipment and in the event of leakage does not normally require emergency attention.

COMMITTEE ACTION: Accept in Principle.

Revise 6-5.3.2 as follows:

"In many units the lubricating oil is used for both lubrication and hydraulic control. A listed fire resistive fluid should be considered for use in both systems. If separate systems are used, the hydraulic control system should use a listed fire resistive hydraulic fluid."

COMMITTEE STATEMENT: This incorporates the submitter's recommendations to use fire resistive fluids. Extensive Committee deliberations based on personal Committee member experience indicates that listed fire resistive fluids will burn, and thus their use does not necessarily justify the lack of fire suppression systems. The criteria of section 6-5.3 are preventive measures (as indicated by the title of 6-5.3) and does not preclude nor require the use of fire suppression systems. The need for fire suppression systems for the combustion turbines requires consideration of many different factors, as stated in 6-5.4.1. Even if a fire resistive fluid is used in the lubrication oil system, consideration should be given to the volume and pressure of the fluid, whether or not the facility is constantly manned, operating experience and fire experience with the fluid, etc.

(Log # 6)

850- 10 - (6-5.4.2(c)): Hold for Further Study

SUBMITTER: Daniel J. Sheridan, Black & Veatch

COMMENT ON PROPOSAL NO.: 850-???

RECOMMENDATION: Replace part (c) with the following:

"(c) Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas may be protected by shields and encasing insulation with metal covers."

SUBSTANTIATION: The existing wording implies that water should not be used. This impairs the protection of non-enclosed units because water is one of the few practical means for protection in non-enclosed units. The suggested wording above is used successfully in Section 5-7.4.2.

COMMITTEE ACTION: Hold for Further Study.

COMMITTEE STATEMENT: This presents new material that has not been subjected to public review, and is being held for further study based on section 11-10 of the NFPA Regulations Governing Committee Projects.

(Log # 1)

850- 11 - (7-2): Reject

SUBMITTER: S. N. Dmitrovich, ASCOA Fire Systems

COMMENT ON PROPOSAL NO.: 850-60

RECOMMENDATION: Add to new Chapter 7 the following paragraphs to Para 7-2:

"Generator.

Hydrogen systems should comply with recommendations in paragraphs 5-7.1 and 5-7.4.6.

Fire protection should be provided in accordance with 6-5.4.1, 6-5.4.2, 6-5.4.3, or 6-5.4.4.

Air cooled generators should be tightly sealed against the ingress of moisture in the event of discharge (accidental or otherwise) of a water spray system. Sealing must be positive, such as by a gasket or grouting, all around the generator housing."

SUBSTANTIATION: The generator of a plant using alternative fuels is usually the same size range as that used in combustion turbine plants. Since this Standard addresses protection of the generator when driven by a combustion turbine it should be addressed in the alternative fuels plant configuration.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: The revised Chapter 7 (as shown on pages 106 & 107 of the A92 TCR) addresses the concerns of the submitter. By reference to Chapter 5, which addresses this in Section 5-7, protection for generators is sufficiently covered.

(Log # 3)

850- 12 - (7-3.4.4, 7-4.4.6, 7-4.4.7, 7-5.4.4): Reject

SUBMITTER: Loren Keltner, National Fire Suppression, Inc.

COMMENT ON PROPOSAL NO.: 850-60

RECOMMENDATION: Revise paragraphs to read:

"Systems should be designed for a minimum of 0.25 GPM/ft^2 over the most remote 3,000 ft^2 (increase by 30 percent for dry pipe systems) of floor area with the protection area per sprinkler not to exceed 100 ft^2."

SUBSTANTIATION: By requiring a minimum of 0.25 GPM/ft^2, these areas fall into an extra hazard occupancy, maximum density for ordinary hazard is 0.20 GPM/ft^2. See NFPA 13-1991, fig. 5-2.3 and table 4-2.2 Note 5: for extra hazard occupancies: 2) The protection area per sprinkler for hydraulically designed systems with densities below 0.25 GPM/ft^2 may exceed 100 sq ft, but shall not exceed 130 sq ft.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: The unique hazard of these applications were evaluated by the Alternative Fuels Subcommittee and the densities and square footage criteria were determined to be adequate. The Committee does not intend these applications to be classified as extra hazard.

PART II

(Log # 1)

851- 1 - (4-7.1): Accept
SUBMITTER: Lee Warnick, Virginia Power
COMMENT ON PROPOSAL NO.: 851-17
RECOMMENDATION: Revise as follows:
a. Section 4-7.1 - Replace the last sentence with the following:
"Fixed suppression systems should be designed in accordance with the following codes and standards unless specifically noted otherwise:
NFPA 11, Standard for ...
NFPA 11A, Standard for ...
NFPA 12, Standard on ...
NFPA 12A, Standard on ...
NFPA 13, Standard for ...
NFPA 15, Standard for
NFPA 16, Standard on ...
NFPA 231, Standard for ...
NFPA 231C, Standard for ...."
Modify the references in the following sections as follows:
b. Section 5-4.3 (as reworded by proposal no. 851-27). - Delete "designed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems" in the first sentence, and delete "designed in accordance with the applicable NPFA documents" in the second sentence.
c. Section 5-5.2 (not affected by proposal no 851-30). - Delete last sentence, referring to NFPA 11, 11A, 12, 12A, 13, and 15.
d. Section 5-6.1 - Delete "designed in accordance with NFPA 11, Standard for Low Expansion Foam and Combined Agent Systems; ...; or NFPA 16, Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems."
e. Section 5-7.1 (as re-worded by proposal no. 851-32) - Delete "(See NFPA 15, NFPA 16, or NFPA 11)."
f. Section 5-8.1 - Delete "in accordance with NFPA 11, Standard for Low Expansion Foam and Combined Agent Systems; ...; and NFPA 16, Standard on the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems."
g. Section 5-12.1 (not affected by proposal no. 851-34) - Delete second sentence, referring to NFPA 13.
h. Section 5-13.1 (not affected by proposal no. 851-35) - Delete third sentence, referring to NFPA 13.
i. Section 5-15.1 (not affected by proposal no. 851-37) - Delete second sentence, referring to NFPA 13, 231, and 231C.
j. Section 5-16.1 - Delete last sentence, referring to NFPA 13, 231, and 231C.
k. Section 6-4.8.2 - Delete parenthetical references to NFPA 13, 231, and 231C.
SUBSTANTIATION: The change is submitted to ensure that references to standards addressing fire protection systems are given in a consistent manner in all paragraphs.
COMMITTEE ACTION: Accept.

Editorial Corrections

The Technical Committee on Electric Generating Plants wishes to note the following editorial change to NFPA 851. In 3-2.3(c), change "unusual" to "special." This editorial change is being made for consistency and to coordinate with the action taken on NFPA 850 by public comment 850-4 (Log #5).