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MEMORANDUM FOR: Zoltan R. Rosztoczy, Acting Chief
Advanced Reactor and Generic Issues Branch
Office of Nuclear Regulatory Research

FROM: S. Singh Bajwa, Section Chief
Generic Activities Integration Section
Policy Development and Technical Support Branch
Program Management, Policy Development and Analysis Staff
Office of Nuclear Reactor Regulation

SUBJECT: GENERIC ISSUE 148: SMOKE CONTROL AND MANUAL FIRE FIGHTING EFFECTIVENESS

GENERIC ISSUE 149: ADEQUACY OF FIRE BARRIERS

On December 11, 1990 representatives of ARGIB (R. FRAHM and W. Milstead) met with NRR personnel to discuss our concerns with the prioritization of Generic Issue 147: Fire Induced Alternate Shutdown/Control Room Panel Interactions. At that meeting RES also stated that Generic Issues 148 and 149, subjects as above, were planned for prioritization. Conrad McCracken, Chief, Plant System Branch (SPLB), NRR agreed to provide RES with an analysis of why we believe these two generic issues should be prioritized as LOW or DROP. Enclosed for your information is the SPLB analysis.

S. Singh Bajwa, Section Chief
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Policy Development and Technical Support Branch
Program Management, Policy Development
and Analysis Staff
Office of Nuclear Reactor Regulation

Enclosure:
As stated

cc: F. Gillespie
W. Russell
C. McCracken

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

March 22, 1991

NOTE FOR: Walter S. Schwink, Section Chief
Generic Activities Integration Section
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THRU: Gary M. Holahan, Deputy Director
Division of System Technology
Office of Nuclear Reactor Regulation

FROM: Conrad E. McCracken, Chief
Plant Systems Branch
Division of System Technology
Office of Nuclear Reactor Regulation

SUBJECT: GENERIC ISSUE 148: SMOKE CONTROL AND MANUAL FIRE FIGHTING EFFECTIVENESS

GENERIC ISSUE 149: ADEQUACY OF FIRE BARRIERS

In response to your request of December 11, 1990, we have reviewed the subject Generic Issues. Based on our review of these issues, we have determined that factors such as the current fire protection guidance provided to the industry, the conservative approach which was taken in the implementation of fire protection, the low fire loading and the lack of combustible materials which are easily ignited, give prudence to these issues being dropped or assigned as "LOW PRIORITY ISSUES." The following is our technical justification for determining that these issues do not warrant addition research funding:

I. EVALUATION OF GENERIC ISSUE (GI)-148: SMOKE CONTROL AND MANUAL FIRE FIGHTING EFFECTIVENESS

GI-148 references the Chernobyl event and the "Chernobyl Follow-Up Research Plan." The expressed concern in this plan regard GI-148 is smoke propagation from one unit to an adjacent unit. This reference is misleading and the implication made implies that United States (US) facilities do not consider smoke impact from internal and external events. The level of fixed fire protection features, the limits imposed on material combustibility, and the implementation of strict fire preventive administrative controls at US facilities are significantly more conservative than those applied to Soviet facilities.

In addition, GI-148 identifies that lubricating oils and cable insulation are the primary fire sources found in nuclear power plants and represent the most prolific sources of smoke. In principle we agree that the burning of petroleum based oils and/or cable insulation do produce smoke. However, these fuel sources are not readily ignitable and are provided with various mitigating fire protection features. The most significant source of petroleum oil (i.e., lube and fuel) is located in the diesel generator rooms. The following is an overview of Standard Review Plan (SRP) 9.5.1, "Fire Protection Program", guidance provided for the diesel generator and the fuel oil storage areas:

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- The diesel generator cells are required to be separated from each other and the other areas of the plant by fire barriers having a fire-resistive rating of 3-hours.

- Each diesel generator cell is required to be provided with an automatic fire suppression system designed to combat lubricating oil fires.

- Automatic fire detection system, which is annunciated and alarmed both locally and in the control room, is required to be provided in each diesel generator cell.

- Manual fire suppression capability in the form of hose stations and portable extinguishers is required to be provided and accessible to all areas in the diesel generator cell.

- Drainage for fire fighting water and a means for local manual venting of smoke is required to be provided for each diesel generator cell.

- The diesel fuel day tank capacity in each diesel generator cell is limited to a maximum of 1,100 gallons providing that the day tank is located in a separate 3-hour fire resistive enclosure capable of containing the entire contents of the tank. In addition, the enclosure is require to be protected by an automatic fire suppression system. If the day tank is located inside the diesel generator room the tank should be located within a diked enclosure which has the capability to hold 110% of the contents of the tank.

- The bulk diesel fuel storage facility is required to be located outside a minimum of 50 feet away from the nearest exposed structure. Above ground tanks should be appropriately diked and provided with automatic suppression capability.

In reviewing the flammability of these petroleum fire sources, these sources are not considered in their enclosed system configurations (e.g., contained within closed tanks, closed bearing reservoirs on pumps, inside transfer piping systems, etc.) to be an in-situ combustible which is directly ignitable without experiencing an initiating failure first (e.g., non-pressurized tank or reservoir failure, piping failure, etc.). In addition, the flammability characteristics of these sources are considered to be low (i.e., ignition temperature - lube oil 700 F, diesel fuel 490 F).

With respect to electrical construction and cable flammability, SRP 9.5.1 provides the following guidance:

- Cable trays and conduits are required to be constructed from metallic materials.

- Cable construction, as a minimum is required to meet the flame test in IEEE 383.

- Plant areas containing high cable concentrations (e.g. cable spreading room) are protected by automatic fire suppression systems and are provided with early warning smoke detection capability.

- Areas containing safety-related cabling are provided with area smoke detection capability to provide prompt detection of a incipient fire/smoke condition. This capability is alarmed and annunciated in the control room.

- Cable and cable tray penetrations of fire barriers are sealed with fire-resistive material. This reduces the likelihood of smoke and fire propagation from one fire rated compartment to another.

The overall flammability of cable insulation is considered to be low and the ease of cable insulation ignition is very difficult under normal plant operating conditions. Cable insulation ignition and self-sustaining combustion requires a considerable degree of preheating by a sizable external heat source (i.e., 2,159,000 Btu/hr source burning over a 3 to 6 minute period with the base of the ignition source 6 inches away from the exposed target [ref.1]).

In a series of cable fire tests conducted at Factory Mutual Research by the Electric Power Research Institute (EPRI) [ref.1] the following was demonstrated: Ignition of and a self sustaining free burning fire involving IEEE 383 cabling was difficult when compared to non-qualified cables; Fire development in the 12 (IEEE 383) cable tray array was slow and localized; Peak plume and; Measured maximum radiation (kw) was significantly less. From this information, it can be concluded that smoke development will be minimized as a result of the burning characteristics of IEEE 383 cabling. In addition, damage to exposed components in the area of the fire is minimized as a result of the lower radiation heat flux. The effectiveness of the fire brigade to extinguish the fire at the point of origin is greatly enhanced as a result of the slow fire development and localized burning characteristics of IEEE 383 cabling.

As referenced by GI-148, experimental evidence indicates that the smoke by-products from the burning of cable insulation would obscure a typical power plant enclosure in about 10 minutes. It appears that this experimental evidence was determined or collected by fire testing under destructive and confined conditions not duplicating typical power plant ventilation and fire protection program response conditions. In addition, GI-148 references the smoke effects of the Browns Ferry fire and its impact on fire fighting effectiveness and equipment. It needs to be fully understood and recognized that the NRC guidelines are a result of the Browns Ferry fire. Therefore, the reference made to the Browns Ferry fire/smoke effects is not appropriate when considering the mitigating effects of a fire protection program meeting NRC guidelines.

EPRI, in a series of grouped cable tray fire tests [ref. 2], modeled congested tray configurations (i.e., 14 horizontal trays with 7 vertical risers) which were similar in representation to a cable spreading room. The tests were performed in a 40'x 40'x 20' specially constructed enclosure which had a set ventilation flow rate of 6 room changes per hour. The test room was provided with sprinklers (100 sq.ft. spacing) and smoke detection (250 sq.ft. spacing). This is a good representation of the level of fire protection which would be recommended by the SRP in a cable spreading area (except that non-IEEE 383 cable was used during these tests). These tests indicated the following; Smoke detection responds to the initial stages of a cable fire (30 - 60 seconds) and; Peak ceiling temperatures (300 - 450 F) are limited and quickly return to near room ambient shortly after sprinkler operation (approx. 40-60 seconds of sprinkler operation). From these tests it can be concluded that smoke detection provides early warning of a fire condition in congested cable tray arrays and that the sprinkler protection limited fire damage, propagation, and smoke generation under ventilated compartment conditions.

Under actual in-plant fire conditions, during normal full power operating conditions, the plant fire protection program (e.g., human element - administrative controls and fire brigade response) and fire protection features would be expected to react in the following manner:

Plant administrative controls would limit the transient fuel available for preheating of in-situ combustibles.

Plant administrative controls would control the sources available for ignition of in-situ and transient combustibles.

If a fire were to occur involving transient combustibles associated with a maintenance related operation, personnel involved with the operation would be present. Appropriate actions to assure that the fire is properly reported to the control room would be taken by these individuals, and if possible fire control and suppression measures would be taken. (NOTE - Plant maintenance and operations personnel are given fire protection training in the area of fire reporting and fire extinguisher operations.)

If the fire were to continue in a non-controlled condition, plant smoke detection capability would also react to the condition (expected response of smoke detector 25 to 80 seconds [ref. 2]). Smoke being produced in the area would be slightly visible and its propagation controlled through normal plant ventilation systems [ref.2].

Fire brigade response would be initiated by the control room and would be on the scene of the fire within 5 to 10 minutes after the time of discovery. Fire control would be accomplished and the fire extinguished prior to significant smoke development and actual fire propagation involving fixed in-situ combustibles. (Note - generally, in power plant design, cables are routed in trays and conduits 8 to 12 feet above the floor surface where the majority of the transient fuel sources are available to support an exposure fire). The fire brigade is trained to operate and perform fire fighting tasks under smoke obscured and high heat conditions.

With regard to safety significance of this issue, smoke has been considered in the SRP (review position C.5.f.) and in Section III.G of Appendix R. In response to smoke affecting the fire brigade and manual firefighting effectiveness and causing misdirected suppression efforts, it appears that there is a misunderstanding of the practical application of fire protection/prevention programs at nuclear power plants as applied by NRC guidelines. As previously stated, the fire brigade is trained to operate and perform fire fighting tasks under smoke-obscured and high heat conditions. In their training they are instructed on how to utilize water effectively and efficiently by applying water directly to the fire (i.e, flames not smoke) and the hot gas layer in the ceiling overhead of a compartment containing the fire. Manual interior fire fighting techniques generally use a combination attack. This method applies short water bursts in the ceiling overhead to create steam conversion (to limit thermal damage and cool elevated temperatures) along with a direct application of water (in short burst) to the burning material at the base of the fire.

Since the Browns Ferry fire and the implementation of NRC fire protection guidelines and regulations, plant fire brigades have demonstrated a high degree of efficiency and effectiveness in prompt control and extinguishment of fires in plant areas important to safety. Even though this high degree of efficiency and effectiveness has been demonstrated by plant fire brigades, licensees in addressing IPEEE will have to justify their assumptions associated with fire brigade effectiveness. Taking fire brigade training into consideration, past records of successfully achieving control and extinguishment of fires in the direct area of origin, and the fire protection features provided for safe shutdown functions under the provisions of Appendix R, there is a high level of assurance that fires which do develop will not propagate beyond the incipient stage.

The smoke developed from an incipient stage fire or even a localized free burning fire will not have an immediate affect on electronic equipment in the area of a fire. Therefore, cold shutdown conditions can be achieved within the time constraints imposed by plant-specific technical specifications and Appendix R. The corrosive affects of smoke damage on electronic equipment is considered to be long term and would have to be addressed as part of the licensee's recovery program.

With respect to a fire in the control room and smoke hampering the operators ability to safely shutdown the plant, this is addressed by Appendix R, Section III.L. Section III.L. requires that the control room be provided with alternative shutdown capability which is physically and electrically independent of the control room. In addition, plants have procedures to implement plant shutdown from outside the control room and contingency plans to address fire brigade actions in response to this condition. It should be noted that in response to the IPEEE licensees will have to consider smoke propagation to areas adjacent to the control room where manual operator actions are necessary to support shutdown from outside the control room.

In addition, the concern that smoke can actuate automatic fire suppression systems in areas away from the fire and cause damage to safety systems is not credible. Generally, only gaseous suppression systems (e.g., Halon and CO2 which are considered clean agents and have no impact on equipment operation) respond to smoke conditions. Actuation of water systems depends on elevated compartment temperatures. GI-57 should address this concern.

II. EVALUATION OF GENERIC ISSUE 149 - ADEQUACY OF FIRE BARRIERS

GI-149 references several Licensee Event Reports (LERs) where fire barrier penetration seals, doors, and dampers have been rendered inoperable. It appears by this reference that inspection and surveillance of these barriers and their fire-resistive components are being performed and corrective actions are being taken by licensees to assure fire separation continuity. In addition, it should be noted that plant technical specifications require compensatory measures to be taken in the event that a fire barrier is made inoperable. Generally, a fire watch is established for the affected barrier and for the areas which it provides fire separation. In addition, since the Browns Ferry Fire there has not been a case where a fire in a nuclear power plant has challenged the integrity of a fire barrier or has contributed to its failure as a result of a differential pressure concern. Licensees will have to justify their fire barrier maintenance programs in support of justifying the adequacy of their fire barriers in response to IPEEE.

The fire barrier design in nuclear power facilities is conservative. The barriers are fully capable of preventing fire propagation within a facility.

Fire tests on fire barrier components are performed in accordance with various testing standards (i.e. ASTM-E119 for fire barriers in general, NFPA-251 for walls and columns, NFPA-252 for doors and dampers), which all basically test to the same criteria.

Under these test criteria a gas fired furnace is used for the test. There are two types of furnaces used, a wall type or a floor type. The specimen (i.e. door, penetration seal, fire damper, electrical raceway fire barrier) is installed into a floor slab or a wall which has a known fire-resistive rating. This composite assembly becomes one boundary (i.e. wall, or ceiling) of the furnace. Generally, two specimens are tested. The first is subjected to the fire exposure for the full duration (i.e. 1hr fire rating - 1hr fire exposure). The second specimen is subjected to the fire exposed for a duration of 1/2 it's fire rating, then subjected to the hose stream test.

The test exposes the specimen to a standard fire exposure which is controlled to achieve specified temperatures throughout the specified time period.

The test specimen is installed into the furnace and exposed to direct fire impingment. The temperature in the furnace is controlled over time, generally in the following manner:

- 1000 F at 5 minutes
- 1300 F at 10 minutes
- 1550 F at 30 minutes
- 1700 F at 1 hour
- 1850 F at 2 hours
- 1925 F at 3 hours

The post fire structural integrity of the specimen is tested by the application of a specified standard fire hose water stream. This water stream is applied to the specimen from 20 feet away through a 1-1/8 inch fire nozzle at a pressure of 30 to 45 psi for a period of 1 to 6 minutes, depending on the fire rating for which the specimen is being tested.

The passage of flame during the fire exposure test and/or water during the hose stream test is considered a failure. In addition, if the temperature on the unexposed side of the test specimen exceeds 325°F for penetration seals and component enclosures or 650°F for doors/dampers, the test is considered a failure.

The standard time-temperature curve (summarized above) used for fire test furnace temperature control was developed by National Bureau of Standards (NBS). Through actual full-scale building fire testing and analysis of the data collected from these tests, NBS developed a relationship of fuel loading that will produce a fire exposure equivalent to the standard time-temperature curve. The following is a summary of this NBS relationship:

STANDARD TIME TEMP. CURVE	NBS FIRE LOADING RELATIONSHIP
1550 F at 30 minutes	Fire Loading (FL) = 5 psf = 40,000 btu/sf
1700 F at 1 hour	FL = 10 psf = 80,000 btu/sf
1850 F at 2 hours	FL = 20 psf = 160,000 btu/sf
1925 F at 3 hours	FL = 30 psf = 240,000 btu/sf

psf = pounds of combustibles per sq foot of floor space

The NBS relationship is based on ordinary combustibles with a califoric value of 8,000 btu/pound. Generally, within a nuclear power facility while at power, ordinary combustibles (e.g., cable insulation) is the major fuel load contributor in safe shutdown related plant areas. Looking at some specific plant areas the following fire loadings could be considered representative:

CABLE SPREADING ROOM FL = 20 - 30 psf
(major fuel contributor - cable insulation) Plant area with the the highest fire load

Fire prot. provided - 3 hr fire barriers, fire/smoke detection, automatic fixed fire suppression.

CHARGING PUMP ROOM FL = 1/4 - 2 1/2 psf
(major fuel contributors - cable insulation, oil)

Fire prot. provided - 3 hr fire barriers, fire/smoke detection

BATTERY ROOM FL = 1 - 5 1/2 psf
(major fuel contributors - cable insulation, battery casings)

Fire prot. provided - 3 hr fire barriers, fire/smoke detection, ventilation system to maintain hydrogen concentration below 2% by vol.

SWITCHGEAR ROOM FL = 2 - 4 psf
(major fuel contributor - cable insulation)

Fire prot. provided - 3 hr fire barriers, fire/smoke detection

DIESEL GENERATOR ROOMS FL = 8 - 17 psf
(major fuel contributors - cable insulation, oil)

Fire prot. provided - 3 hr fire barriers, fire detection, automatic fixed fire suppression, dike (110% of tank vol.) protection for the day tank, day tank size limited to 1100 gals

Increased pressures leading to barrier failure resulting from a fire within a compartment in a US nuclear power plant is highly unlikely and is not considered creditable. This conclusion is based on the fact that compartments in US facilities are sufficiently ventilated (not fully air tight), have low and not easily ignitable combustible contents, are provided with early warning fire/smoke detection capability, and in areas where fire hazards exist which could affect safe shutdown capability automatic suppression capability is provided.

III. CONCLUSION

Based on the above evaluation, fire/smoke development and measures to mitigate smoke damage and fire propagation are assured through the implementation of a comprehensive fire protection program at nuclear power plants. The current guidance provides a basis for mitigating the effects of fire and smoke through a combination of administrative controls, early warning detection, fire-resistive separation, combination of manual and automatic fire suppression capabilities, and assures that safe shutdown can be achieved and maintained.

If you should have any questions, please advise.

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REFERENCES

1. P. S. Sumitra, "Categorization of Cable Flammability, Part III: Intermediate Scale Fire Tests of Cable Tray Installations," EPRI Project RP 1165-1, EPRI Report NP-1881, August 1982.

2. J. S. Newman, "Fire Tests in Ventilated Rooms: Extinguishment of Fire In Grouped Cable Trays," EPRI Project 1165-1, EPRI NP-2660, December 1982.