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April 24, 1996
IPN-96-050

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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Subject : Indian Point No. 3 Nuclear Power Plant
Docket No. 50-286
License No. DPR-64
Response to Unresolved Item 50-286/93-24-03

Reference: NRC letter, C. L. Miller to J. H. Garrity, dated December 14, 1993, "NRC Region I Inspection 50-286/93-24."

Dear Sir:

The attachment to this letter provides the Authority's response to Unresolved Item No. 93-24-03 in the referenced letter. The URI is related to the Authority's verification of cable ignition temperatures of cables that pass through fire barrier penetration seals. Based on this response, we request that URI No. 50-286/93-24-03 be closed.

There are no new commitments associated with this letter.

If you have any questions regarding this letter, please contact Ms. C. D. Faison at (914) 681-6306.

Very truly yours,

William J. Cahill, Jr.
Chief Nuclear Officer

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Attachment
cc : See next page

IE01
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Attachment to IPN-96-050
Indian Point 3 Nuclear Power Plant
Docket No. 50-286
Response to Unresolved Item 50-286/93-24-03

Introduction

During NRC Inspection 50-286/93-24, which took place from September 27 to October 8, 1993, the NRC staff opened Unresolved Item (URI) 50-286/93-24-03. This URI is related to NYPA's verification of cable ignition temperatures of cables that pass through fire barrier penetration seals. The concern was that NYPA did not adequately demonstrate that the auto-ignition temperatures of cables used at IP3 are sufficiently above the maximum unexposed-side temperature recorded at the conclusion of the penetration seal's qualifying three-hour fire endurance tests. Therefore, there was not reasonable assurance that the cables would not auto-ignite on the non-fire side of the penetration seal.

In response to the URI, NYPA prepared an analysis that established piloted ignition temperatures of cables used at IP3. This analysis used data that was based on Factory Mutual Research Corporation (FMRC) testing of cables of similar construction and jacket material.

It was noted in the analysis that auto-ignition temperature is by definition, the minimum temperature to which a substance must be heated for ignition and self-sustained combustion to occur without a pilot; and that piloted ignition is by definition, the minimum temperature for ignition with the aid of a pilot and self sustained combustion to occur. Therefore, the auto-ignition temperature of any cable will always be equal to or greater than its piloted ignition temperature.

Following a review of NYPA's response, the staff further elaborated on their concerns in NRC Inspection Report 50-286/95-10. The second paragraph under Findings in Section 2.0, reads in part:

> "The inspector found analysis IP3-ANAL-FP-01392, Revision 1, and supporting documents, to be generally sufficient. However, the staff was concerned with the FMRC test results, which differed from the results of cable ignition temperature testing provided in NUREG/CR-5546, "An Investigation of the effects of Thermal Aging on the Fire Damageability of electric cables." Additionally, the staff questioned the methodology used in the FMRC testing, particularly, the correlations between critical heat flux with critical temperature, and whether a 15-minute test adequately represents cable ignition temperatures for cables installed in a 3-hour barrier. Based on these concerns and questions, Unresolved Item 93-24-03 remains open pending further evaluation by the licensee and subsequent NRC review."

NYPA has compared the technical details of the testing methodologies used by the FMRC and those used by Sandia National Laboratory (SNL) in the development of NUREG/CR-5546. There are some differences and, therefore, different results should be expected.

NYPA has also compared the underlying purpose of each test method and the end use of the individual test results. They are basically different, and therefore, do not permit results and conclusions of the two test methodologies to be interchanged. The several differences and their effect on this issue are discussed below.

The following information provides NYPA's response to the NRC concerns identified in IR 95-10.

<u>Technical Review of Staff Concerns</u>

1. <u>Concern</u>:

"...the staff was concerned with the FMRC test results, which differed from the results of cable ignition temperature testing provided in NUREG/CR-5546..."

<u>Response</u>:

The Factory Mutual Research Corporation (FMRC) tests and the Sandia National Laboratories (SNL) test (NUREG/CR-5546) were each performed for a different purpose. The FMRC tests were performed to determine the characteristics of fire propagation. These tests included an investigation of critical temperature. In the FMRC studies, Critical Temperature is defined as: "the temperature at or below which ignition will not occur." This compares with the SNL test which evaluated the effects of thermal aging on cable fire damageability. The SNL test included an investigation of Thermal Damage Threshold and the relative time to failure for exposure temperatures above the Thermal Damage Threshold. In the SNL study, Thermal Damage Threshold is defined as a derived temperature range where the upper limit of this temperature range is defined by "the lowest experimental exposure temperature at which electrical failure was observed following exposures of up to 80 minutes". The lower limit of this temperature range is defined by "the highest experimental exposure temperature for which no electrical failures were noted following exposures of no less than 80 minutes". Cable failure is defined and determined by: "the failure of a two-ampere fuse in any one of the three phase circuits".

The SNL methodology involved the introduction of energized cable samples into a test chamber where both the walls and air were maintained at a uniform steady-state temperature. Times to cable failure were recorded. As a by-product of their investigation, SNL reported "...that in virtually every case, the failure of the cables through conductor to conductor shorting resulted in the initiation of intense, sustained, open flaming of the cable samples." It was observed that "as the cables shorted, sparks ignited the gases evolving from the cables." Based on this observation, SNL concluded that "the failure temperatures...are clearly above the piloted ignition threshold of the cable samples". Piloted ignition temperatures were reported as equal to the temperature of the test chamber when ignition occurred. SNL did not quantify the contribution of the intensity of the sparks to the ignition temperature, or the contribution of the cable shorting on cable jacket temperature. It was also noted during the review that, "In no case was spontaneous ignition of the cables observed prior to electrical failure".

The majority of the FMRC Research consisted of the testing of non-energized cable. The FMRC methodology involved the application of an external, uniform heat flux. The heat flux was provided by four quartz heaters located every 90 degrees around the perimeter of the cable sample. The pilot flame was provided by a horizontal flame approximately 1 cm long located approximately 1 cm from the cable sample. Due to the relative size, intensity and distance from the sample being tested, FMRC assumed that the contribution of the flame pilot is negligible in its contribution to cable sample ignition. Times to ignition were recorded. Cable surface temperatures were determined by assuming convective heat losses as negligible and the measured external heat flux equals the reradiation losses at steady state.

Conclusion:

Based on the different test methodologies in which FMRC measured the applied external heat flux and SNL assumed that the temperature of the cable is equal to the temperature of the test chamber in a radiative and highly convective environment, we believe it is reasonable to expect differing test results of piloted ignition based on the method of exposure and relative differences in the intensity of the pilot. A high intensity pilot is expected to contribute to the ignition of a cable sample whereas, a low intensity pilot can be assumed to have negligible effect on the cable ignition temperature. In addition, in the SNL test, auto-ignition was cited as not being reached by any of the cables. The lower limits of auto-ignition were never determined.

2. Concern:

"...the staff questioned the methodology used in the FMRC testing, particularly the correlations between critical heat flux with critical temperatures, and whether a 15-minute test adequately represents cable ignition temperatures for cables installed in a 3-hour fire barrier."

Response:

The FMRC methodology involved the application of an external, uniform heat flux and measured times to ignition. FMRC determined cable surface temperatures using principles of heat transfer. The methodology assumes that the heat losses due to convection are negligible and the reradiation from the cable sample surface will increase until the core of the cable sample has reached steady state with the cable surface. When steady state is reached the reradiative heat flux equals the applied heat flux (assuming an absortivity of unity and disregarding cable sample end effects). Once reradiative heat flux is known, the cable surface temperature can be determined by applying the Stefan-Boltzmann Law (assuming emissivity of unity). This test methodology is well documented in the area of PMMA (polymethylmethacrylate) research and has rendered comparable results when compared to published values of ignition.

The Stefan-Boltzmann Law is fundamental to the principles of blackbody radiation which is based on the fact that a blackbody absorbs all radiation incident on its surface and its emitted radiation is completely determined by its surface temperature.

The duration of the applied heat flux is **separate and distinct** from the rating of a fire barrier. In the case of the FMRC ignition test, 15 minutes is the time at which steady-state between the core of a cable sample and its surface, is assumed to be reached and upon which subsequent determination of a material physical property (i.e., critical heat flux) is made. This differs from a 3-hour rating of a fire barrier which represents satisfactory behavior upon completion of a three-hour fire endurance test and subsequent hose stream test where the conditions are for acceptance and qualification, and are intended as a uniform method for evaluating limiting heat transmission capability of a test assembly and subsequent structural integrity.

The assumption that steady state is reached within a 15 minute test duration is supported by FMRC test data which shows that cable samples of similar construction and jacket material but varying in size render similar critical heat flux values. Since a higher critical heat flux value would be rendered if a test was prematurely terminated prior to the cable sample reaching steady state, and since critical heat flux as a material physical property should be similar for cable samples of similar construction and jacketing **independent** of size, the similarity of critical heat flux values between cable samples and similar construction and jacket material **varying** in size, suggests the 15 minute test duration is sufficiently long for the type of material being tested.

Conclusion:

The FMRC test methodology uses well founded principles of blackbody radiation in its interpretation of results. A 15 minute test duration is reasonable considering the uniform, multi-directional application of external heat flux by the four quartz heaters and the similarity of critical heat flux values between large and small diameter cable samples.

Summary Conclusion

As summarized above, the FMRC test methodology can be used to obtain data from which piloted ignition temperatures of the cables tested can be reasonably derived. As documented in analysis IP3-ANAL-FP-01392, Rev. 1, the derived piloted ignition temperatures were used by comparing IP3 cables to cables of similar construction and jacketing tested at FMRC. Since an auto-ignition temperature of a cable will always be equal to, or greater than, its pilot ignition temperature, a lower limit of auto-ignition was established at the minimum piloted ignition temperature. This lower limit, auto-ignition temperature was then compared to the maximum unexposed side temperature of penetration fire seals that were qualified by test.

As documented in analysis IP3-ANAL-FP-01392, Rev.1, by using the FMRC test data and FMRC's derived values, the minimum piloted ignition temperature of IP3 cables was evaluated to be 786 degrees F. A lower limit of auto-ignition of 786 degrees F was then established for IP3 cables. Analysis IP3-ANAL-FP-01392, Rev. 1, also identified that the maximum temperature permitted on the unexposed side of the penetration fire seals for qualification was 700 degrees F. This maximum unexposed side temperature of IP3 fire barrier penetration seals was measured at the interface of a silicone foam seal and a metallic penetration passing through the seal. For this seal arrangement, the temperature at the conclusion of the three hour fire endurance test was recorded to be 690 degrees F.

By this comparison, the minimum auto-ignition temperature of cables used at IP3 (786 degrees F) is demonstrated to be sufficiently above the maximum permitted unexposed side temperature (700 degrees F) such that they would not cause fire propagation. This provides reasonable assurance that the effects of fire will be limited to a discrete fire area or zone and that safe shutdown systems will remain available post fire.

In addition, other considerations also serve to strengthen this assurance. These considerations relate to the role of fire barriers in the overall fire protection program at IP3, the technical basis for three-hour barriers and other elements of the overall fire protection program.

These considerations are:

1. Penetration seals provide protection of openings in a fire barrier. Fire barriers are qualified by testing in accordance with ASTM E-119, "Fire Test of Building Construction and Materials" using an exposure fire with a time-temperature history commonly referred to as the Standard Time Temperature Curve. The Standard Time Temperature Curve is based on the fire loading equal to a severe fire exposure which far exceeds the fuel load present in most areas of IP3.

2. In all areas of IP3, fixed fire hazards have been assessed and the areas are provided with fire detection, automatic fire suppression, manual fire suppression, or all three as appropriate for the hazard.

3. IP3 employs administrative controls which serve to limit the potential of a significant transient fire hazard. These controls include in part: control of combustibles, control of ignition sources, handling of flammable and combustible liquids, and control of cutting and welding.

4. The combination of training for personnel, and of automatic and manual fire fighting capability, provided at IP3, preclude a postulated fire of long duration.

5. The principles of defense-in-depth as detailed in BTP 9.5-1, Appendix A (fire prevention, prompt detection and fire suppression, and assurance of protection of safe shutdown capability even if a fire should occur and detection and suppression efforts fail), together limit the potential of fires and mitigate against long durations should a fire occur.

Based upon this response, in conjunction with our previously submitted analysis, we request that URI 50-286/ 93-24-03 be closed.