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

SAFETY EVALUATION REPORT BY THE OFFICE OF NUCLEAR REACTOR REGULATION OF THE EXPANSION GAP FIRE ON JANUARY 20, 1986 AT DRESDEN STATION UNIT 3

LICENSE NO. DPR. 25

COMMONWEALTH EDISON

DOCKET NO. 50-249

1.0 INTRODUCTION

Polyurethane foam was installed on the outer surface of the steel drywell containment vessel (fabricated of carbon steel plate approximately 1-1/8 inch thick) at Dresden Station, Unit 3, to provide an expansion gap between the vessel and the surrounding concrete shield. Piping and instrumentation penetrations into the containment vessel were made prior to pouring the concrete shield. A sleeve installed around each penetration provides an annulus space of approximately two inches around the penetration. The sleeve extends from the outer surface of the concrete shield to the outer surface of the polyurethane foam; (it does not attach to the surface of the containment vessel). The penetration enters the containment vessel at an upward angle of about 45° from the vertical.

At about 8:30 a.m., on the morning of January 20, 1986, with the reactor shut down and fuel removed, workers were removing one of the guard plates for the reactor water cleanup penetration from outside the shield wall by means of an air-arc cutting process. This process melts metal through a combination of pressurized air and high electric current. While cutting, hot slag dropped down the annulus and ignited the polyurethane foam expansion gap filler material. Smoke was noticed about 9:00 a.m. A fire watch in the vicinity discharged a dry chemical extinguisher into the annular space. About 10:00 a.m. smoke was again reported, and at 10:04 a.m. the reactor building ventilation system was turned on to facilitate smoke removal. All personnel were removed from the drywell and the torus area due to the potential of airborne radioactivity.

About 11:20 a.m. workers returned to the drywell and the torus. At 11:30 a.m. workers discovered a hot spot on the inside of the steel drywell containment in the vicinity of the affected penetration. Station personnel were again evacuated from inside containment at 11:55 a.m. because of excessive heat radiating from the drywell wall.

Between 12:30 and 1:15 p.m. two separate actions were taken.

1. Temperature readings on the inside of the drywell by means of a general purpose pyrometer were obtained. The highest readings recorded were 440 - 445°F.

2. Demineralized water was applied to the affected penetration. Also, hose streams supplied from the fire water system were used to introduce water into four other penetration sleeves in the vicinity.

With the application of water to the five penetration sleeves, the temperature of the steel containment vessel began to drop. At about 1:30 p.m. the licensee started to monitor the drywell temperature with a pyrometer. Local temperatures at three locations had fallen to 140, 110 and 90°F by 5:00 p.m. The fire was considered to be extinguished at 5:30 p.m. Water flow was continued until 9:00 p.m. when temperature inside the drywell was found to be normal. Paint damage was observed in scattered locations inside the drywell in two principal areas about 10 ft. in diameter and 10 ft. apart.

Region III conducted an investigation of this fire on January 28, 29, and February 7 and 13, 1986. Their inspection report No. 50-249/86006 (DRSS), dated February 26, 1986, identified 13 open items to which the licensee was asked to respond. In addition, Region III submitted to NRR a memo detailing four separate concerns related to this fire in a memo from Paperiello to Holahan, dated August 11, 1986. These four concerns are essentially elaborations of specific open items in the inspection report, questioning the adequacy of the licensee's responses.

2.0 EVALUATION

This evaluation will consider the first 12 open items identified by Region III and the licensee response thereto, dated May 6, 1986. The items will be considered in the same sequence that they are listed in Section 3 of the Inspection Report. The four concerns listed in the Region III August 11, 1986, memo will also be addressed.

a. Detailed Chronology of the Fire Event

The chronology of the fire as reported by the licensee is generally consistent with that in the Region III Inspection Report. We agree with the licensee's decision that off-site fire department assistance was not needed. The cause of the fire and the source of combustible material (the polyurethane foam expansion gap filler material) were determined early in the course of the fire. Fire brigade response was prompt as was the fire marshall's decision to apply water to the burning material. The fire brigade response was not limited by lack of personnel. Response by an off-site fire department would not have enhanced any of the fire fighting actions by the licensee. Based on that information, open item 3.a from the Region III Inspection Report dated February 26, 1986, is considered closed.

b. Duration and Intensity of the Fire

This open item asks for several different pieces of information. They can be summarized as follows:

1) Duration, physical extent and intensity of the fire including highest temperature reached by the steel drywell liner and concrete shield wall.

2) Lacking specific data taken during the fire, use available calorific heat values for free burning polyurethane foam for a fire of this duration to estimate temperatures reached by both steel and concrete.

3) Estimate material property changes due to temperatures experienced by the steel drywell liner, the concrete shield wall, and mechanical and electrical penetrations in the vicinity of the fire.

There is general agreement regarding the extent and intensity of the fire. There is one area of uncertainty, however. The licensee described damage to paint on the inside of the drywell by stating, "Post fire examination of the steel containment indicated that the coating had discolored or flaked away in several scattered areas inside containment," (p.17). The Region III report indicates what may be more extensive damage by stating, "At the time of the inspection the licensee had not determined the extent of damage resulting from the fire. In two principal areas inside the drywell (approximately 10 feet in diameter and 10 feet apart), charred, discolored, blistered, or burned away paint was visible on the drywell liner." Three NRR staff members and a fire protection consultant to the staff also visited Dresden Unit 3 shortly after the fire. The three NRR staff members recall damage as being slight based upon discoloration of the paint on the inside of the drywell. In addition, photographs do not indicate such severe damage to the paint on the affected area inside the drywell. We do, however, recognize that localized temperatures in excess of 500°F may have occurred on the fire side of the steel containment drywell liner. But, we do not believe any temperature approached 850°F, the minimum temperature at which this steel begins to lose tensile strength. This is based upon the visual indications of damage to the paint on the inside of the drywell, and comparison of damage done to paint samples on steel plates heated to 500°F. In those tests paint was totally charred, a condition not seen by any NRR representative who visited the site following the fire.

As mentioned above, the staff believes that while spot temperatures on the fire side of the drywell liner may have exceeded 500°F, it is not likely that there were temperatures that approached 850°F, the minimum temperature at which steel begins to lose its tensile strength. In addition, the Steel Design Manual, published by United States Steel in July 1968, states the following on page 15.

> "There are a considerable number of metallurgical phenomena that may affect the mechanical properties of steel at high temperatures, such as precipitation hardening or aging, temper embrittlement, and carbide instability. For the structural steels these phenomena are not usually important for most applications involving temperatures below approximately 1000 F."

Observable damage to paint on the inside surface of the drywell liner was confined to two areas, each about 10 feet in diameter and each consisting of several hot spots. This indicates a fire was burning and progressing slowly; not a free burning fire, but one that was oxygen limited. This would account for temperatures more in the 500°F range, rather than the 2000 plus °F one would expect from free burning polyurethane foam. It is also the only explanation for a fire involving about 30 cu. ft. of two-inch-thick polythurethane foam lasting for somewhere between two and six hours, rather than 10 or 15 minutes that one would expect with a free burning fire.

The portion of the licensee's response that is open to question is their conclusion that, based upon lack of substantial damage to paint on the inside of the steel drywell liner, the primer on the fire side of the drywell was undamaged. The potential consequences of damage (if any) to the primer on the fire side will be discussed in 3c below.

In view of the above discussion, there is no reason to believe that temperatures approached 850°F in the expansion gap. Therefore, we agree with the licensee's analysis that the steel drywell liner, the concrete shield wall and the various electrical and mechanical penetrations have not been adversely affected by the fire. Based on the above discussion, open item 3.b from the Region III Inspection Report, dated February 26, 1986, is closed.

c. Corrosive Species Introduced Into the Drywell Expansion Gap

The licensee was asked to determine the type and amount of corrosives that were introduced into the expansion gap as a result of the fire, and to determine the short and long term effects of these corrosives on the various components of the steel containment vessel and the surrounding concrete shield. The licensee's method of identifying the type and quantity of corrosives present was to analyze samples obtained at two drainline locations of water used to extinguish the fire. This analysis indicated the following:

Chlorides	28	and	24 ppm
PH	8.09	and	7.92
Sulfite	3	and	1 ppm
Sulfate	0.902	and	7.086 ppm

Elsewhere in their report the licensee estimated a total amount of water used to extinguish the fire at between 30,000 and 34,000 gallons. This would result in considerable dilution and may be considerably less than the concentration of corrosives actually experienced by the various components. The licensee states that the polyurethane foam fire was probably smoldering, rather than vigorous burning (pages 26-27), and that various residues would be left, some in direct contact with the concrete. By inference, one could conclude that some of this material would also cling to

the steel surface of the containment vessel itself as well as the penetration. Such residues would probably contain higher concentrations of corrosives than were measured in the collected water samples.

The licensee has assumed in their response to the second portion of this open item that the primer on the fire side of the steel containment vessel was undamaged and, therefore, none of the corrosives came in contact with the steel. The pH of the water samples collected were shown to be slightly basic rather than acidic, which reduces the corrosion rate. Any chlorides that might be present in the unburned residue of the polyurethane foam could do only limited corrosive damage to the steel, and would then become chemically tied up in the resultant corrosion film and be unavailable for further damage. Therefore, based on this chemical data, even if the primer was destroyed in part or all of the fire area, we conclude that the adverse consequences of potential corrosion to be slight. Open item 3.C from the Region III Inspection Report dated February 26, 1986, is, therefore, considered closed.

d. Effects of Spalling Concrete and Polyurethane Residue Remaining Inside the Drywell Expansion Gap

The staff finds the licensee's response regarding spalling concrete and polyurethane residue acceptable based on the reasons outlined above. Temperatures of the concrete would have been no higher than the steel temperature which has already been stated to have not approached 850°F. Concrete spalling does not occur at temperatures below 1000°F. Chloride intergranular stress corrosion cracking also is not of concern for the same reason it does not pose a concern for corrosion of the carbon steel liner. Based on that information, open item 3.d from the Region III inspection report dated February 26, 1986, is, therefore, considered closed.

e. Amount of Water Applied to the Drywell Expansion Gap to Extinguish the Fire

This item consists of three major parts:

1) Thermal shock that may have occurred to the steel containment vessel from the water used to extinguish the fire.

2) Total amount of water used in the fire extinguishing operation, amount recovered, and amount unaccounted for.

3) Actions taken to remove residual moisture from the expansion gap.

Staff comments on the licensee's response to each of these issues follow:

1) Based on the temperatures involved, the staff concludes that thermal shock resulting from applying water to either steel or concrete at the estimated temperatures in the expansion gap is not a problem.

2) Based on a review of the data involved, the staff finds that the estimates of 240,000 gallons of water used to extinguish the

fire is likely an over estimate. (Inspection Report page 5.) This estimate is based upon an assumption of 500 gallons per minute (GPM) for 8 hours. We agree with the time, but question the rate of 500 GPM. Water was applied to five penetrations using a 1-1/4 inch (3/4"ID) black rubber industrial hose (inspection report, page 4) and thin wall conduit (page 75) to get the water into the annular spaces of the penetrations. That averages out to 100 GPM/penetration which is a high estimate for a 3/4" hose. In addition, the licensee stated (pages 75-76) that the volume of water processed by the radwaste system was 30,000 to 35,000 gallons and the volume calculated as actually used for fire extinguishment was 34,000 gallons. This leaves approximately 1,000 gallons unaccounted for, rather than 205,000 gallons. It is unlikely that it is possible to lose as much as 200,000 gallons of water in the containment. It is likely that any excess amount of water would be drained from the drywell gap. The most important point is that moisture was introduced.

3) We agree with the licensee evaluation that any moisture remaining in the expansion gap can eventually escape by evaporation through the several penetrations in the concrete shield wall.

Based on the above discussion, open item 3.e in the Region III Report dated February 26, 1986, is, therefore, considered closed.

f. Basic Drywell Liner and Structural and Shielding Concrete Design Functions

This item asks that the licensee determine the extent of degradation, if any, to the steel containment vessel, to electrical and pipe penetrations, and to the concrete shield. The staff believes these questions are closely related to open items b. and c. above and, therefore, have already been addressed. Thus open item 3.f from the Region III Inspection Report, dated February 26, 1986, is considered closed.

g. Compliance with the Safe Shutdown Requirements of Appendix R to 10 CFR Part 50

This item asks the licensee to explain how electrical cables and circuits of normal safe shutdown systems are in compliance with Section III.G requirements of Appendix R where they pass through the expansion gap in both Dresden Units 2 and 3.

By letter dated June 5, 1986, the licensee responded to the NRC letter dated February 25, 1986, which requested the licensee to address the matter of compliance with Appendix R to 10 CFR Part 50. In that response the licensee provided a fire hazards analysis which demonstrated that the existing and proposed fire protection features at Dresden Station assure that safe shutdown can be achieved and maintained in the event of fire in the expansion gap. The analysis showed that a fire in the two inch gap cannot spread to the drywell because the drywell is normally inerted. The fire is not likely to escape into the reactor building but should it do so it would be contained in one fire area of any one unit and therefore an

independent safe shutdown path would be available. The fire in the gap is not likely to effect the penetration but the licensee analysis shows that even if it did, impairment of the safe shutdown capability of either unit would not result.

The June 5, 1986 submittal also requested an exemption from the automatic detection and fixed fire suppression requirement of Appendix R. The exemption is under review and the staff will respond in a separate action. Based on the above discussion open item 3.g from the Region III Inspection Report, dated February 26, will be resolved by the staff action on the exemption request.

h. Potential Repairs Needed

The licensee was asked to determine the need for any repairs to the steel containment vessel, concrete shield, or penetrations. The staff has agreed with the licensee in the consideration of open Items 3.b, 3.c, 3.d, and 3.f, that no significant damage has been done to the steel drywell liner, the concrete shield wall or the penetrations. Based on our review of those areas we conclude that no repairs are required, and open item 3.h from the Region III Inspection Report, dated February 26, 1986, is, therefore, considered closed.

i. Results of Water and Polyurethane Residue Samples

The licensee was asked to, "Provide the results of any and all extinguishing water and fire residue samples collected as a result of the fire for NRC review." The staff discussed this concern and it has been resolved under items 3.c and 3.d above. Therefore open item 3.i from the Region III Inspection Report, dated February 26, 1986, is closed.

j. Corrective Actions Taken to Prevent Reoccurrence

The licensee was asked to "describe in detail the corrective actions that will be taken to prevent fires involving polyurethane material in the drywell expansion gap, including interim measures currently in place."

The licensee has responded that procedures have been reviewed and revised as necessary to assure that all openings are stuffed with fire retardant sheeting prior to any cutting or welding being done in an area to prevent hot slag from entering. The importance of this precaution, and the need for a posted fire watch whenever cutting and welding is done, has been stressed with Dresden Station construction and maintenance personnel. In addition, the station prefire plans are to be enhanced to address this type of event. The staff believes these efforts will be adequate with the reminder that hot slag should be prevented from entering any opening (floor, ceiling, walls or any type of concealed space) when cutting or welding operations are in progress. If that policy is followed one need not be concerned with establishing whether a given opening is safe or unsafe with respect to fire and all openings will be protected. Based on the above discussion and the commitment by the licensee in its May 6, 1986 submittal the staff considers open item 3.j from the Region III Inspection Report, dated February 26, 1986, closed.

k. The licensee was asked to, "Provide an assessment of the extent and results of the radiolytic and thermal decomposition of materials in the drywell expansion gap in Unit 2 and an estimate of the effects of such decomposition in fire potential and containment structural integrity."

The licensee has supplied adequate independent data to show there is no unacceptable risk over the 40-year plant life. Calculated radiation exposure for the polyurethane foam located on the outside of the steel containment vessel based on 40 full years of reactor operation are 2.5×10^7 RADS. Radiation tests on samples of material similar to that used in the expansion gap resulted in no detectable change in resilience, and by inference fire characteristics, below 10^8 RADS, confirming the published data. With respect to thermal degradation, the polyurethane foam used in the expansion gap has a temperature rating of 280°F while normal in-service temperature will be only 135°F. The staff agrees with the licensee that these two operating parameters pose no unacceptable risk and considers open item 3.k from the Region III Inspection Report, dated February 26, 1986, closed.

l. The licensee was asked to, "Provide a list of other plant locations where polyurethane or other combustible foam materials are installed in concealed spaces. Identify where these materials were explicitly addressed as part of our (sic) fire hazards analysis."

The licensee has responded that polyurethane and polyethylene have been used as filler at the top of block walls and to seal penetrations. None of the block walls are rated fire barriers. Where polyurethane foam has been installed as a penetration seal, the wall is either not a rated fire barrier or the polyurethane material has been removed and replaced with a fire rated or noncombustible material. The licensee also provided a listing of 21 locations where polyurethane or polyethylene filler material has been used at the top of block walls. Quantity of material used ranges from 0.9 to 18.7 cubic feet, and the increase in fire loading ranges from 0.001 to 3.4 per cent. The increase in fire loading for the area having 18.7 cubic feet of material was only 0.8%. The staff considers this response adequate. Open item 3.l from the Region III Inspection Report, dated February 26, 1986, is therefore, considered closed.

Region III Concerns Contained in August 11, 1986 Memo

Three of the four Region III concerns contained in the August 11, 1986 internal NRC memo from Paperiello to Holahan have been explicitly addressed above.

Concern No. 1 has to do with possible underestimating by the licensee of the peak temperature experienced by the steel containment vessel and the method used to arrive at this conclusions. These concerns are addressed in our evaluation of the licensee's response to Region III open item 3.b.

Concern No. 2 has to do with whether or not the primer on the fire side of the steel containment vessel was damaged during the fire. These concerns are addressed in our evaluation of the licensee's response to Region III open item 3.b and 3.c.

Concern No. 3 has to do with whether or not the expansion gap fire affected any electrical penetrations. These concerns are addressed in our evaluation of the licensee's response to Region III open item Nos. 3.b, 3.c and 3.g.

Concern No. 4 states that, "The fire altered the physical characteristics of the polyurethane foam. It is the inspector's concern that the decomposed material may be subject to spontaneous combustion or experience lower ignition temperature at normal elevated temperatures during operation." This concern was not explicitly addressed by the licensee in their response to the Region III Inspection Report. Without test data to support a conclusion one way or another, the staff is not able to resolve this issue. Therefore, the Region III inspector's concern No. 4 remains open and the licensee should be requested to respond to that concern.

3.0 CONCLUSION

Based upon the above evaluation we conclude that the licensee's response of May 6, 1986 to the open items contained in the Region III Inspection Report dated February 26, 1986, and the four specific concerns raised by a Region III inspector that are contained in a memo from Paperiello to Holahan, dated August 11, 1986, are generally sufficient. The licensee has shown that:

A. Temperature of the steel drywell liner probably did not exceed 500°F and in any case did not approach 850°F, the minimum temperature at which the steel begins to lose its tensile strength. In addition, the Steel Design Manual published by United States Steel in July, 1968, indicates temperatures below 1000°F are not of concern. We are, therefore, confident in stating that the steel drywell liner sustained no structural damage as a result of burning of the polyurethane foam expansion gap filler material.

B. The primer on the fire side of the steel drywell was probably not damaged. However, even if the primer was damaged, the concentration of corrosive species produced by the fire was so diluted as to pose no problem to steel over the life of the plant.

C. In a similar manner, the combination of heat and corrosive by-products generated by the fire were shown to present no deleterious effects on the containment penetrations or the concrete shield wall.

D. Water used in fire extinguishing efforts did not damage any of the components it contacted. Residual moisture remaining in the expansion gap will evaporate under normal operating temperatures and vent through the many penetration openings through the shield wall. Such residual moisture, will, therefore, cause no future problems.

E. Residue from the burning expansion gap filler material poses no problems to the steel drywell either by way of providing a source of corrosive products or by limiting expansion of the drywell liner because of hard spots.

The licensee has responded adequately to the first 12 of 13 open items (3.a - 3.l) in the Region III Inspection Report, dated February 26, 1986.

Item 3g will be resolved by the staff action on the licensee's June 5, 1986 exemption request, which is currently under review. The staff action on that exemption will be reported in a separate document.

Open item 3.m in the Region III Inspection Report has to do with Emergency Preparedness. The licensee has committed to respond separately to this open item.

With respect to the internal NRC memo of August 11, 1986 (memo Paperiello to Holahan), detailing four concerns of the Region III inspector with the licensee's response of May 6, 1986, we believe that concerns Nos. 1, 2 and 3 have been satisfactorily resolved. Concern No. 4 has to do with whether or not residue left from the burning polyurethane foam material and remaining in the expansion gap is now subject to spontaneous combustion or ignition at the normal operating temperature of the drywell (about 135°F) which is substantially lower than the temperature rating of 280°F for new material. This concern was not addressed by the licensee in their May 6, 1986, reference. We recommend that the licensee be requested to respond to this concern No. 4.

The staff concludes that resolution of issues 3.g and 3.m, and concern No. 4 from NRC memo Paperiello to Holahan, dated August 11, 1986, should not preclude resumption of operation of Dresden Station, Unit 3.

The staff has reviewed this event to determine whether it has generic implications. Based on that review we conclude that there are no generic implications resulting from this fire that will require modifications at other nuclear power plants.

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