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October 31, 1978

Director of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. A. Schwencer, Chief
Operating Reactors Branch 1
Division of Operating Reactors

Gentlemen:

INCREASED CAPACITY SPENT FUEL RACKS
NO. 1 UNIT
SALEM NUCLEAR GENERATING STATION
DOCKET NO. 50-272

Public Service Electric and Gas Company hereby submits additional information in support of its application to increase the spent fuel storage capacity at the Salem Nuclear Generating Station. This information is in response to discussions held with members of your staff.

This submittal consists of forty copies.

Should you have any questions regarding this application, please do not hesitate to contact us.

Very truly yours,

F. P. Librizzi
General Manager -
Electric Production

Attachment

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TEST REPORT

NEUTRON ABSORBER SPENT FUEL CELL

CORROSION SWELLING EFFECTS

SALEM NUCLEAR GENERATING STATION

ABSTRACT

This document reports the results of a test conducted by the Exxon Nuclear Company at the Horn Rapids plant in Richland, Washington on October 20, 1978. The purpose of the test was to evaluate the response of a poison spent fuel storage cell to internal pressurization caused by corrosion.

INTRODUCTION

The fuel cells for the Salem spent fuel storage racks are nominally 8.97 inch (I.D.) square hollow tubes with a .207 inch wall thickness. The cell walls are of a sandwich construction; consisting of a Boral core encased in two stainless steel shrouds. When installed in racks in a spent fuel pool, the cells are oriented with their long axis in a vertical position. It is a design intention that the Boral core material be installed in the cell in a clean, dry condition; and that the cell sandwich closure welds result in a leak tight seal while the cell assembly is immersed in the fuel storage pool.

There is small probability that a cell could have a water leak in a weld or other defect sufficient to permit leakage at the time of installation or develop a leak after some time in service. The worst location for such a leak would be at the bottom of the cell. Two possible cases could occur.

Case I - An empty cell develops a leak at the bottom. Water leaks into the void space between shrouds and compresses the air at the top of the cell until an equilibrium pressure is reached between the external head of water and the air pressure. This may or may not deform the inner shroud. At this point the aluminum face sheets on the Boral start to corrode and evolve hydrogen gas. This gas increases the pressure in the gap between shrouds pushing the water level down until bubbles escape at the elevation of the crack. This limiting pressure will cause the thin inner shroud to bend and move towards the center of the cell. Subsequent venting by drilling a hole at the top of the cell would relieve the pressure and might allow the inner shroud to return to some position closer to the original.

Case II - A cell containing a fuel bundle develops a leak in-service. Water enters the void space between shrouds until pressure equilibrium is reached. Corrosion starts and evolves gas. As the pressure rises, the inner shroud bulges toward the fuel bundle and contacts the rods and spacer grids. Further pressure increase loads the fuel bundle. Hydrogen evolution continues and the pressure increases until pressure equilibrium is reached when gas bubbles from the crack. Drilling a hole near the top of the cell would relieve the pressure and allow the inner shroud to spring back elastically toward the initial position.

SUMMARY AND CONCLUSIONS

The results of the test performed demonstrated that:

A. Should water leak into the Boral space of a sealed spent fuel storage cell, with the cell empty, hydrogen gas evolution due to corrosion would cause the inner stainless steel shroud to deform inward plastically. This deformation would be of such extent that, even if subsequently vented, no space would be available for fuel assembly storage.

B. Should water leak into the Boral space in a sealed spent fuel storage cell, with a fuel assembly in place, hydrogen gas generation would cause the inner stainless steel shroud to bulge into contact with the fuel assembly. The measured friction force, with the cell pressurized, suggests that withdrawal of the assembly might be possible (but not advisable - the cell might then be damaged by further irreversible inward bulging). After venting the hydrogen gas pressure, the inner stainless steel shroud sprung back elastically such that the fuel assembly was freed. The cell was usable for fuel assembly storage, even though some residual inner shroud deformation existed.

C. During the Case II test with the fuel assembly in place, the force of the inner shroud on the fuel assembly caused some of the outer row of fuel pins to deform inward a maximum of 0.19 inch. Translating this deformation from the prototype fuel configuration used in the Salem fuel design, the pin would experience a maximum stress of 20 ksi. This is substantially below the yield stress of 30 ksi for unirradiated Zircaloy-4 tubing. No damage to the fuel assembly would be anticipated.

TEST PROCEDURE AND RESULTS

An experiment was set up as shown in Figure 1. A production fuel storage cell was mounted on a base plate, supported in a vertical position. The void space containing the Boral was vented to the inside of the cell at the bottom closure weld, and was connected to an instrument manifold at the top closure weld. The instrument manifold consisted of a 30" mercury manometer for pressure measurement, three needle valves for pressurizing gas flow control, and a 0-30 psi pressure regulator. A dummy fuel assembly was suspended in the fuel storage cell, hung from an overhead 2 ton crane with a 2000 lb. spring scale to allow measurement of friction withdrawal loads. The fuel bundle was instrumented with five (5) strain gauges at the midspan of the second and third grids of the fuel bundle. The gauges were intended to measure deformations between opposite sides and across one face of the bundle.

In order to simulate the first part of Case I, the valve at the top of the void space was closed, and the cell was filled with water. The internal pressure was measured at water heads of 6', 9', and a full condition. The maximum internal pressure generated was 1.8 psi in the void space. This pressure produced slight inward deformation of the inner shroud. Upon venting the void space, the inner shroud returned to the original position. The conclusion is that a cell with a leak at the lower closure weld will not have the inner shroud collapse due simply to filling the spent fuel pool with water.

The test for the second part of Case I, executed after completing the Case II test, started with the void space between shrouds at equilibrium with the water inside the cell. The instrument manifold was used to slowly pressurize the void space to a maximum value of 5.6 psi. At the maximum pressure, gas bubbled from the holes at the bottom closure weld in a manner similar to that which would occur in the spent fuel pool. Between the pressures of 3 and 5 psi the inner shroud underwent large plastic deformations. After release from a maximum pressure of 5.6 psi, the throat dimension of the inner shroud was 3.2" at a distance of 3' from the upper end of the cell. It is concluded that a fuel cell that has been fully pressurized by corrosion offgassing in an empty condition will be unusable for fuel storage.

For simulation of Case II, a prototype 15 x 15 PWR fuel assembly with the same overall dimensions as the Salem design was instrumented with strain gages and placed in the fuel storage cell. After filling the cell with water, the void space between shrouds was pressurized in steps to a maximum pressure of 5.6 psi.

At a pressure between 2.5 and 3 psi the inner shroud bulged inward to contact the fuel bundle. As further pressure was applied, the bundle withdrawal forces increased. At the maximum pressure of 5.6 psi the measured friction force between the inner shroud and bundle was 1200 lbs. After venting the void space the permanent inner shroud inward deformation was measured to be 0.4 inch, allowing the bundle to be withdrawn without friction force loading from the fuel cell. It is concluded that, after relieving the inner shroud pressure, the cell would be usable for storage of a fuel assembly. The maximum fuel rod deformation measured using strain gages during Case II, was 0.19". Extrapolating the prototype 15 x 15 fuel to the 17 x 17 Salem configuration, a maximum stress of 20 ksi was conservatively calculated in the most highly stressed fuel pin wall. This is substantially below the yield stress of 30 ksi for unirradiated Zircaloy-4 tubing. No damage to the fuel assembly would be anticipated.

FUEL CELL SWELLING TEST - ARRANGEMENT

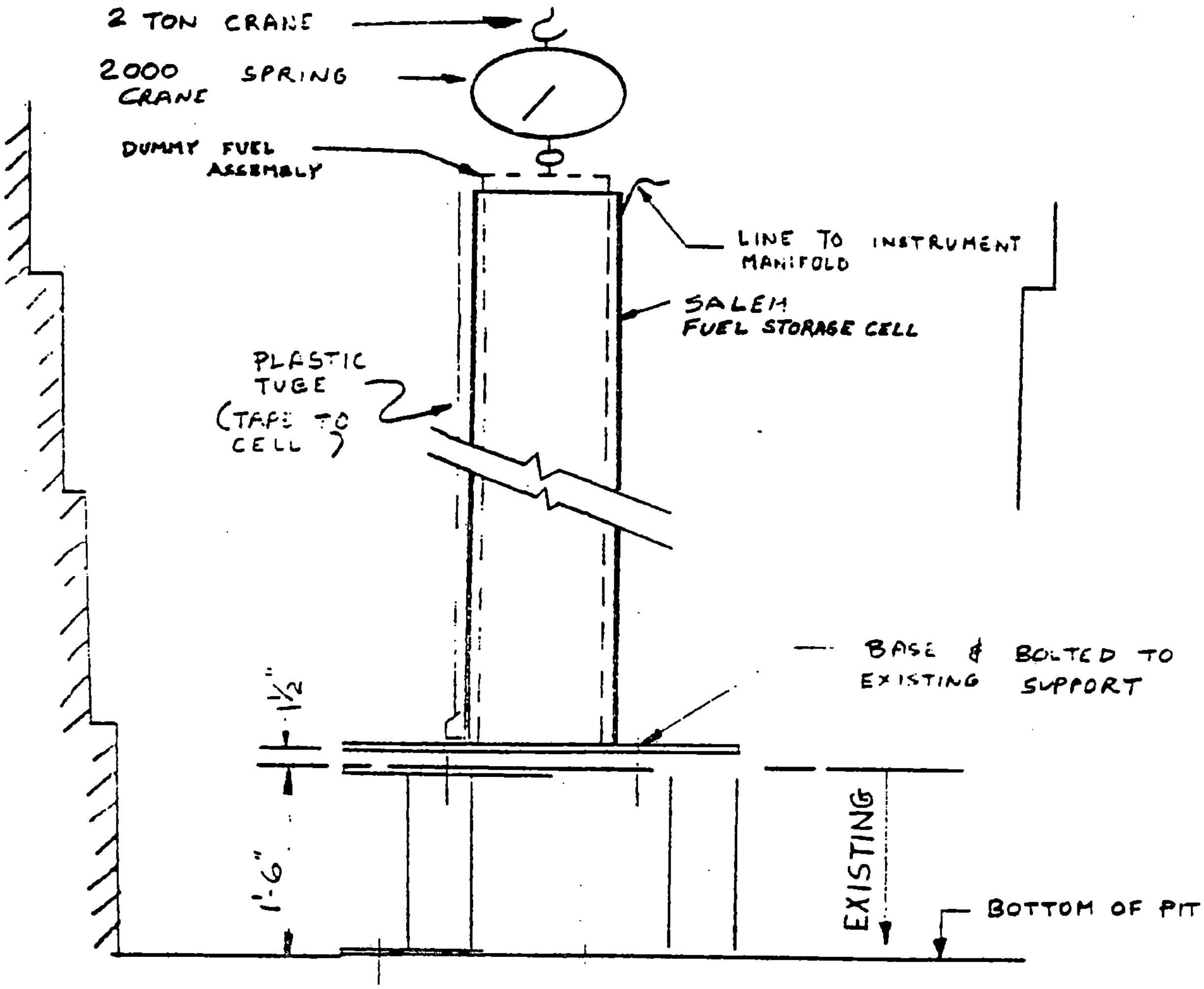

FIGURE 1

PUBLIC SERVICE ELECTRIC AND GAS COMPANY
SALEM NUCLEAR GENERATING STATION

Fuel Bundle Recovery From Bulged Fuel Cell

In the unlikely event that a leak exists in a fuel storage cell after installation in the water filled storage pool and before fuel is inserted, the worst consequence would be failure to be able to insert the fuel. In such an event, the affected storage position would be lost from service.

If a leak develops in a fuel storage cell during the operating lifetime of the storage pool, and fuel is already in place, the most severe result would be that the fuel could not be withdrawn within the normal fuel withdrawal force limits of the fuel handling machine. In this event, semi-remote tooling would be utilized to provide vent holes in the top of the storage cell annulus to relieve the pressure on the fuel assembly and permit routine removal. Based on results of tests performed, it was shown that a fuel bundle can easily be removed from a bulged cell upon venting the annulus at the top of the fuel storage cell, as the inner stainless steel shroud sprung back elastically, freeing the fuel assembly for routine removal.

Two (2) feasible alternatives have been identified for venting a pressurized annulus at the top of a fuel storage cell.

Alternate 1 - Fuel Assembly Without Control Rod Assembly in Place

Sufficient clearance exists between the minimum cross-section dimensions at the top of the fuel storage cell and the maximum cross-section dimension of the fuel assembly to install a semi-remote operated fixture over the tie plate of the fuel assembly and extend a drill or piercing tool into the resultant annulus to place one or more vent holes through the fuel storage cell inner cell at the top end of the internal Boral plate.

Successful venting of the fuel storage cell annulus would be verified by escape of vented gas into the water of the fuel storage pool, or normal withdrawal forces when the fuel assembly was withdrawn.

Alternate II - Fuel Assembly with Control Rod Assembly in Place

Based on the results of the Exxon Nuclear Company experiment, there is no reason to believe that the RCCA would not be readily removable, since the maximum deflection of an RCCA guide tube would be less than 0.1 inch. Nevertheless, if for some unrelated reason, the RCCA could not be removed, venting could be accomplished by drilling a vent hole in the bulged fuel storage cell annulus utilizing remotely operated tooling positioned in one of the four (4) adjacent fuel storage positions. This approach may require that fuel assemblies be removed from one or more adjacent storage positions prior to initiation of venting operations.

Based on the unlikely event that fuel storage cell swelling will occur, no hypothetical position has been identified that would prevent fuel cell venting by either Alternate I or II above.

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QUESTION

Provide a description of the procedures used to insure that the fuel storage racks are leak tight.

ANSWER

The fuel storage cell is fabricated from two concentric square stainless steel shrouds which are seal welded together at both ends such that the annulus between the shrouds is leak tight. The only leakage that could result would be from incomplete or defective welds. A high confidence level that leak tight fuel storage cells are being produced is achieved by careful control of the manufacturing processes and by application of nondestructive testing methods.

The manufacturing processes involved in fabrication of the fuel storage cells are forming and welding. Welding is performed in accordance with ASME Section III Subsection NF, "Component Supports". Welding procedures, welding operations and welders are qualified in accordance with the requirements of ASME Section IX. Welding activities are supervised by the responsible manufacturing engineer and the welding foreman. In-process examination of the automatic welding process is performed by metallographic examination of representative weld samples at predetermined intervals. The forming processes are controlled through non-destructive testing of both welds and stress points to assure that no damage has been done by the hydroforming process.

Non-destructive Examination (NDE) is applied to verify that the manufacturing processes have produced high integrity leak tight fuel storage cells. All NDE of welds is performed in accordance with ASME Section V and all weld NDE personnel are qualified in accordance within ASME Section III, Subsection NF and SN-TC-1A. NDE activities are supervised by the Manager - Quality Control and QC Lead Inspector. All welds receive a visual inspection in accordance with Subsection NF for Class 3 supports. In addition to the ASME Code requirements, all automatic welds are required to be liquid penetrant examined (LPE) on a statistical sampling basis and all manual seal welds are required to be liquid penetrant examined.

The combination of process control and NDE outlined above provide a high confidence level that the fuel storage cells are leak tight. However, to provide additional assurance that cells are leak tight, helium leak testing is performed on finished cells on a sampling basis.

The helium leak test is performed using a sampling plan which on its own results in a 95/95 tolerance limit, (i.e., there is a 95% probability that a lot with 5% defects will be detected and rejected). The plan is a multiple sampling plan which allows three stages of sampling to demonstrate acceptability of each sublot. If the sublot is shown to be unacceptable, the entire sublot must be leak tested. The method used is a helium mass spectrometer test (by the hood method). It is capable of detecting very small pin holes which would not be significant in the fuel storage cell service environment. It is, therefore, more severe than would be warranted by the expected service environment of the fuel storage cell.

The manufacturing and examination program used in producing the fuel storage cells provides a high level of confidence that the cells are leak tight. The leak test alone provides a 95/95 tolerance limit. The actual tolerance limit relative to the cell service environment is substantially greater than 95/95, considering the severity of the leak test and the process control and other NDE which is performed to assure cell weld integrity.

In the unlikely event that a leak exists in a fuel storage cell after installation in the water filled storage pool and before fuel is inserted, the worst consequence would be failure to be able to insert the fuel. In such an event the affected cell would be lost from service.

A procedure will be used to determine if fuel storage cell swelling exists in any fuel storage position before fuel is inserted.

If a leak develops in a fuel storage cell during the operating lifetime of the storage pool, and fuel is already in place, the most severe result would be that the fuel could not be withdrawn with the normal fuel withdrawal force limits of the fuel handling machine. In this event, semi-remote tooling will be utilized to provide vent holes in the top of the storage cell annulus to relieve the pressure on the fuel assembly and permit routine removal.

PUBLIC SERVICE ELECTRIC AND GAS COMPANY
SALEM NUCLEAR GENERATING STATION
SPENT FUEL STORAGE RACKS

Handling, Shipping & Receiving Inspection

To ensure that the rack modules arrive at the site with the same configuration as witnessed and verified by Quality Control during the spent fuel storage rack fabrication and final inspection at the fabricator's shop, all subsequent handling, packaging and shipping will be in compliance with the following:

A. <u>Handling</u>

1. All rack lifting (whether horizontal or vertical) will be done at designated points which have been designed to withstand the load without distorting or overstressing the rack module.

2. Vertical lifting of the rack modules will be done only with a lifting fixture specifically designed for this operation.

3. Upending of the rack modules will be accomplished using the rack module rotating fixture only.

B. <u>Packaging</u>

1. Immediately after the completed racks have been cleaned and inspected, the racks will be wrapped in halogen free polyethylene.

2. The racks will be secured to a shipping skid to assure that the rack is adequately supported to prevent shipping damage during truck transport.

3. A heavy canvas tarpaulin will be used as an outer cover and securely fastened around the rack module.

C. <u>Shipping</u>

1. The shipment of all rack modules will be exclusively by truck. Conventional air ride flatbed trailers, 40-45 feet in length will be used to transport the racks. All equipment will be prepared for shipment as outlined above to prevent physical damage to the racks during shipment to the site.

2. The necessary shipping papers, packing list and handling instructions will be included with each shipment.

3. Each rack module will be adequately secured to the flat bed trailers to prevent displacement and loading concentrations.

D. Receiving Inspection

1. The rack module will be visually inspected for damage to shipping cover and support skid upon arrival at site and prior to removal of rack module from the trailer.

2. The rack module will be visually inspected for shipping damage, distortion, and cleanliness prior to installation in fuel storage pool.

Public Service Electric and Gas Company
Salem Nuclear Generating Station
Spent Fuel Storage Racks
In-Plant Testing Program

The In-Plant Testing Program for the Salem Nuclear Generating Station Spent Fuel Storage Racks consists of two (2) separate and distinct phases. These phases are:

1. Pre-Operational Testing

   a. Neutron Attenuation Testing
   b. Indexing and Drag Testing

2. Long-Term Surveillance

Phase 1.b. and 2 are discussed below. Phase 1.a Neutron Attenuation Testing, has been previously discussed and was submitted to you on May 17, 1978:

1. Pre-Operational Testing

   a. Neutron Attenuation Testing - Please refer to Answer 14 in our May 17, 1978 submittal.

   b. Indexing and Drag Testing

   The spent fuel storage cells shall be indexed and drag tested prior to receiving fuel. Indexing of the spent fuel storage cells is performed to assure that the fuel handling crane can be accurately positioned over any cell to within aceptable limits. Drag testing is performed concurrently with indexing to assure that the loads generated as the fuel assembly is inserted in and removed from the storage cell is in compliance with the fuel manufacturer's recommendations. The intent of both the indexing and drag tests is to assure that the spent fuel storage cells are square, plumb and free of rough surfaces, sharp edges or protrusions that could mar or snag any part of a fuel assembly. The spent fuel storage cells shall permit fuel insertion and removal of the fuel without binding or snagging at any point along the storage cell.

   A random sample population of spent fuel storage cells is chosen for the indexing and drag tests in such a manner as to provide statistical assurance that the spent fuel storage cells are acceptable for the storage of fuel. A detailed procedure will be prepared prior to the indexing and drag testing and this procedure will enumerate the storage locations chosen for this testing.

The testing consists of the insertion of a dummy fuel assembly into each storage location of the chosen sample population. The dummy fuel assembly will be free to travel along the entire length of insertion. Storage locations which do not permit freedom of travel from the top to the bottom of the storage cell will be considered unacceptable for fuel storage until they are repaired or modified. Should any storage cell be determined to be unsatisfactory, additional storage locations will be tested to provide statistical assurance that the racks are acceptable for fuel storage. Quality Assurance procedures are in use at Salem Nuclear Generating Station which provide the guidelines for choosing the number of additional spaces. If more than five storage locations are found to be unacceptable for fuel storage, all 1170 storage locations will be tested.

As further assurance that the spent fuel storage locations are acceptable for fuel storage, at each refueling, those storage locations chosen for storage of fuel will be drag-tested with a dummy assembly prior to receipt of fuel. This test will be performed under water. Should any storage location be determined to be unacceptable for storage of fuel, it will be temporarily abandoned and an alternate location designated. The unacceptable storage location will then be evaluated for possible repair or modification.

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2. LONG TERM FUEL STORAGE CELL SURVEILLANCE PROGRAM NO. 1 & 2 UNITS SALEM NUCLEAR GENERATING STATION

The long-term fuel storage surveillance program serves to verify that the spent fuel storage cell retains the material stability and mechanical integrity over the life of the spent fuel storage racks under actual spent fuel pool service conditions. Sample flat plate sandwich coupons and short fuel storage cell sections are provided for periodic surveillance and testing. The short fuel storage cell sections and flat plate sandwich coupons can be disassembled for examination when required. The short fuel storage cell sections are prototypic of the actual fuel storage cells and thus provide reasonable assurance that the periodic surveillance will yield characteristics that are prototypic of the fuel cells.

The samples are of the same materials and are produced using the same manufacturing and QA/QC procedures specified for the fuel storage cells. All samples will be numbered on the outside. All Boral plates will be weighed after oven drying and numbered prior to sample assembly in order to provide a reference for any possible subsequent corrosion analysis based on weight gain or loss. The entire test section will be weighed after fabrication to establish a reference weight for detecting water ingress without resorting to destruction of the assembly.

The samples will be placed in an empty fuel storage cell in the racks as shown on Figure 1. The test sections will be positioned in a stainless steel fixture such that plane of the Boral plates is in the vertical direction. After examination, they will be moved to an empty fuel storage cell position near the most recent off-loaded fuel.

For examination, all samples will be removed from the pool at the end of each prescribed exposure. Visual examination will be made of all samples. Samples will be weighed. If any samples are found, as a result of visual or weight examination to have evidence of corrosion, weld cracking, or leaks of any type, further examination will be made. This could include selecting one of the suspect samples for further external visual and microscopic analysis. This sample may also be disassembled to verify the condition of the internal poison material. Remaining samples will be returned to the pool for further exposure.

The following is the sample examination program and frequency:

1. Place five short fuel storage cell section samples and five flat plate sections in the spent fuel pool.

2. Remove all samples from the pool for visual and weight analysis after one year. Any sample suspect of presenting a future problem will be retained for further examination. The remaining samples will be returned to the pool.

3. Repeat Step 2 every two years thereafter.

Should destructive examination of five samples be required, examination of the spent fuel racks would follow.

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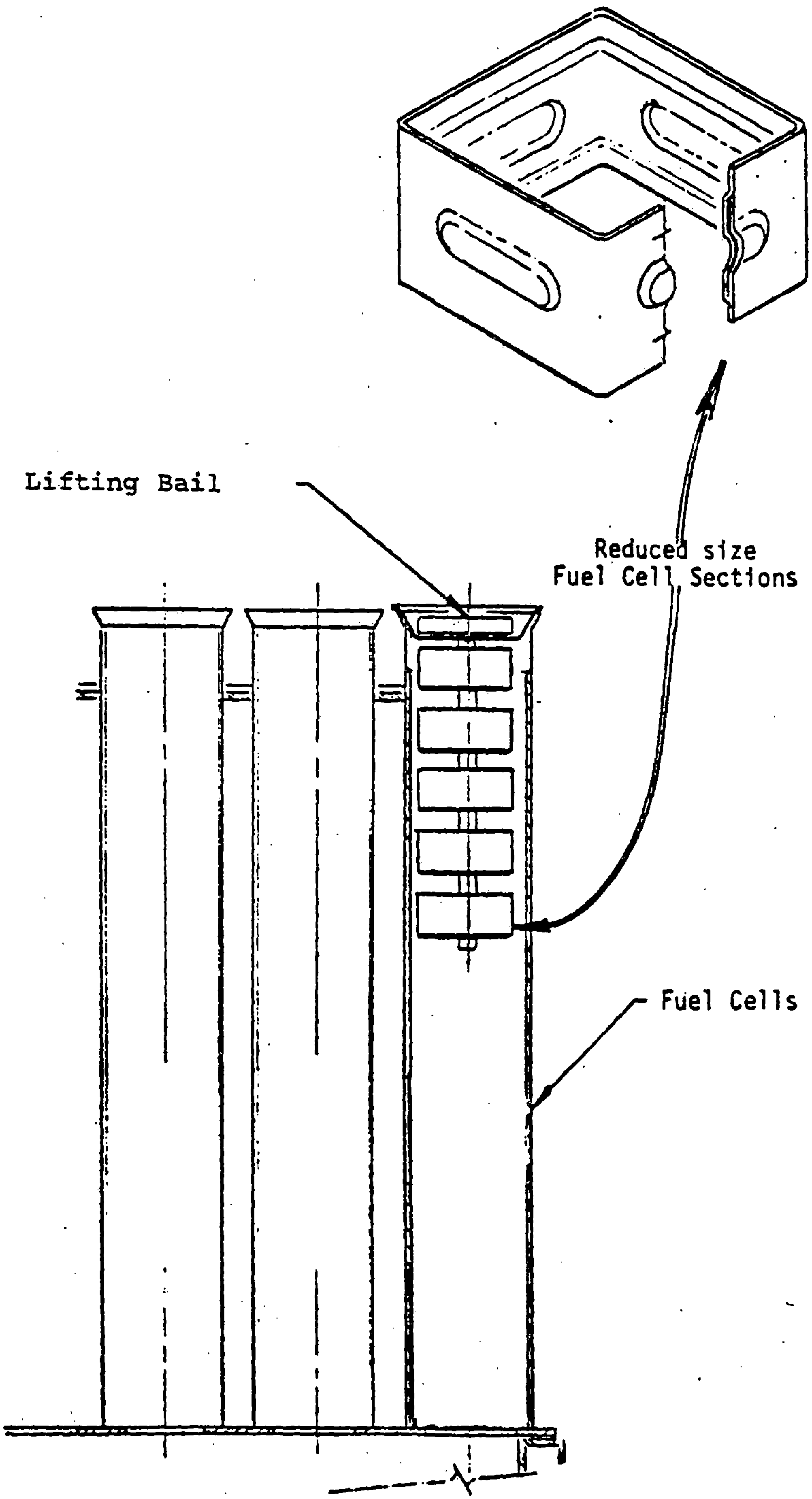

Figure 1. Surveillance Program Samples Positioned In High Density Storage Rack.

QUESTION

Verify that the racks will withstand the drop from the maximum transport height of any of the items which will be carried over the racks when impacting the racks both horizontally and vertically without violating the appropriate acceptance criteria. In addition, discuss the effects of the total rack structure flexibility on the reults of the postulated drop analysis.

ANSWER

See the response to Question 4 of our May 17, 1978 submittal for a list of tools carried over the Spent Fuel Pool. The possibility of these tools falling over the spent fuel racks is highly improbable. These tools are handled by the fuel handling crane whose hook has a safety with latch to prevent the inadvertant separation of the tools from the crane hook. These tools are also connected to the crane hook in the transfer pool and not in the SFP which further eliminates the possibility of a drop accident. However to provide yet another redundant safety feature, a safety cable will be attached to the tools.

With respect to the derivation of the equivalent static load of a fuel assembly drop, and the deformation of the top 7" of the fuel cell, we feel that these questions were adequately answered in our May 17, 1978 submittal where it is shown clearly that the results of the fuel drop accident analysis were emperically derived.

QUESTION 25

Provide detailed justification that the 2.0S linear elastic limit for the faulted condition is in accordance with F-1370 of ASME Section III, Appendix F.

ANSWER

The Salem fuel storage rack design is in accordance with all requirements of subsection F-1370 of the ASME Section III, Appendix F.

In the specific case of tensile stresses, the allowable stress of 2.0S is derived from F-1370 of ASME Section III, Appendix F as follows:

> Per Appendix XVII, Paragraph XVII - 2211(a), the tensile stress allowable is $F_t=0.60Sy$.
>
> Per Appendix F-1370(a), the allowable stresses may be increased by a factor of 1.2 (Sy/F_t).
>
> Combining these two equations results in a faulted condition stress increase factor of 1.2 (Sy/0.6 Sy) = 2.0

In summary, the rack design is in accordance with all of the requirements of F-1370 of ASME Section III, Appendix F.

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SALEM STORAGE RACK - FUEL ASSEMBLY LOAD ANALYSIS

An analysis was performed to calculate the component stresses on a fuel assembly stored in the spent fuel racks during a seismic event.

The fuel assembly was assumed to be positioned in the storage racks such that it was initially in contact with one of the storage cell walls. Based on that assumption, the maximum attainable fuel assembly deflection at any location was 0.60 inches. Static loads were applied to the fuel assembly grids to simulate the fuel assembly inertial forces.

The fuel assembly deflected shape resulting from the calculated load distribution is presented in Figure 1, and indicates that the fuel assembly experiences grid to cell wall contact at the third and higher grid elevations. The fuel assembly component maximum stresses obtained from the analysis were compared to the established allowable limit and are presented in Table 1.

TABLE 1
RATIO OF ALLOWABLE STRESSES TO FUEL ASSEMBLY COMPONENT MAXIMUM STRESSES

COMPONENT	ALLOWABLE STRESS LIMIT (P_M) / UNIFORM STRESS (M)	ALLOWABLE STRESS LIMIT (P_M P_B) / COMBINED STRESS (M + B)
Thimble	4.7	1.75
Fuel Rod	133.	26

For the seismically induced fuel assembly impact forces, it can be concluded based on a fuel assembly deflected shape that the stress margins for the various fuel assembly components are acceptable. It can also be concluded that the minimum experimental grid strength was substantially greater than the estimated grid maximum impact force of 540 lbs.

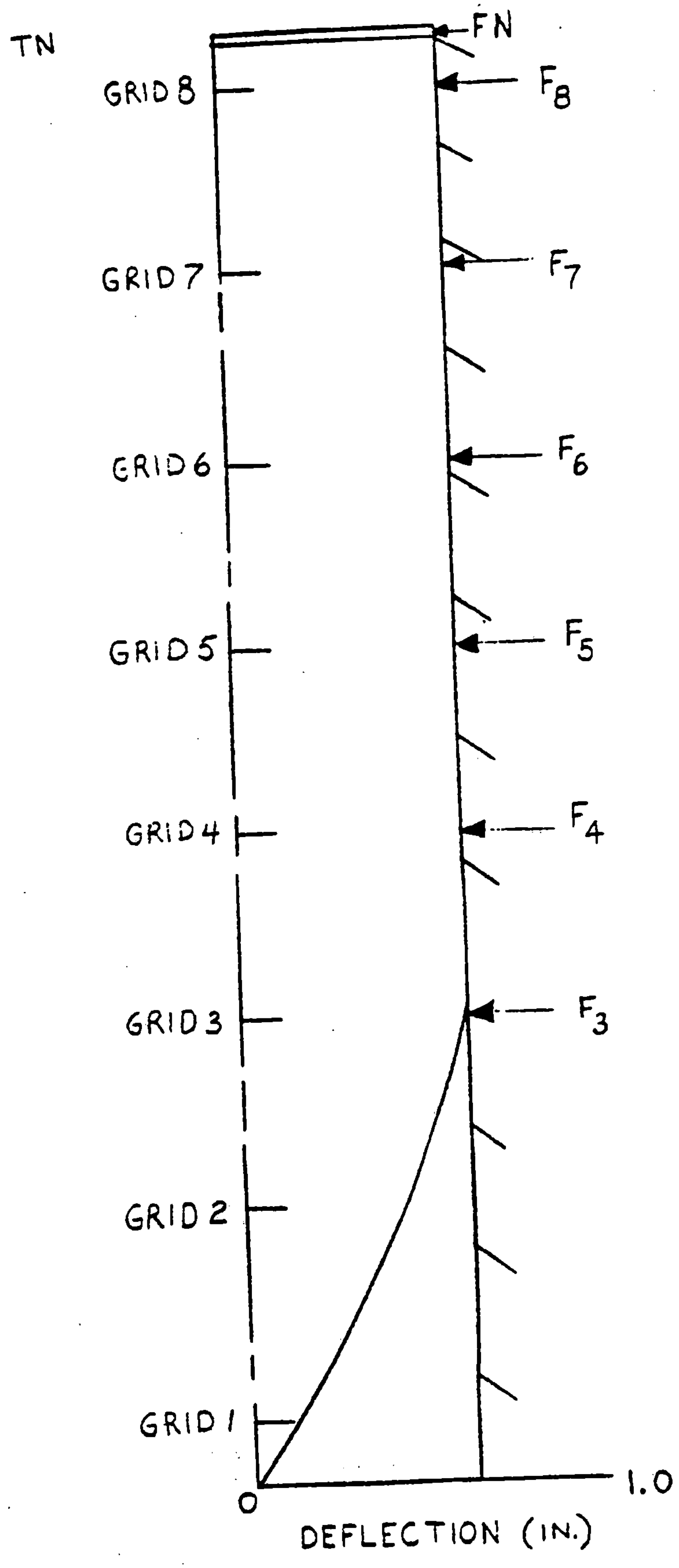

FIG. 1 FUEL ASSEMBLY DEFLECTED SHAPE FOR STATICALLY APPLIED SEISMIC LOADS

PUBLIC SERVICE ELECTRIC AND GAS COMPANY
SALEM NUCLEAR GENERATING STATION
EFFECT ON SPENT FUEL POOL LINER DUE TO
SPENT FUEL RACK MOVEMENT

An analysis has been performed to determine whether damage to the spent fuel pool liner can occur due to the movement of the spent fuel storage rack modules. From Question 17 of our July 31, 1978 submittal, it was concluded that the coefficient of friction can be expected to be .45 with the static coefficient of friction to be even higher. Empirical results conclude that the coefficient of friction may be as high as .8. Assuming a coefficient of friction of .45, the frictional force between the spent fuel storage rack module feet is so much greater than the resulting seismic force that movement of the racks relative to the liner plate is not possible. Furthermore, due to the head of water above the liner plate and the coefficient of friction between the stainless steel on the concrete, the friction force between the concrete and the pool liner is great enough to prevent movement of the liner relative to the concrete base. Since no relative motion is possible between the rack module feet, liner plate and the concrete, no wear to the spent fuel pool liner can occur. A further analysis was performed to determine whether the maximum forces imposed by the spent fuel rack module feet on the liner plate could cause the spent fuel pool liner to tear. This analysis concludes that tearing is not possible since the stresses generated on the liner plate by the module feet are much smaller than the yield stresses of the material.

For the purpose of analysis, the conservative case where the coefficient of friction is equal to .3 was analyzed. With this lower coefficient of friction, movement of the spent fuel storage rack modules along the pool floor would occur. However, data is available which concludes that due to the small displacement and the short time duration of the seismic event, insignificant damage would be expected.