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CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

INDIAN POINT NUCLEAR GENERATING UNIT NO. 2

THIRD SUPPLEMENT TO: PRELIMINARY SAFETY ANALYSIS REPORT

1748

INTRODUCTION

The information contained herein is supplied pursuant to oral requests of the AEC Regulatory Staff on June 3, 1966 and June 13, 1966.

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

INDIAN POINT NUCLEAR GENERATING UNIT NO. 2

ADDITIONAL INFORMATION REQUIRED

1. Discuss method of attaching liner and relate to leakage potential. Provide results of tests or indicate the test program which will be carried out to show that the studs will not pull out when concrete is under tension or fail due to fatigue. What is the inspection program to be used during installation of studs and liner? What percentage of all welds including the studs will be inspected or radiographed?

2. Provide the detailed method of analyzing penetrations to assess their capability to remain leak-tight under all accident conditions. Discuss how cracking of the concrete will be taken into account for all penetrations.

3. Placement of rebars and general design drawings should be provided for the large openings.

4. Discuss the design of the crane to resist earthquake loadings and what would be the effect should the crane fail while it is being used for some operation (one area to consider is during refueling).

5. Provide information which indicates that the crushed rock backfill will not increase the earthquake loading on the structure.

6. Provide deformation criteria or limits for all components which must meet the "no loss of function" criteria.

7. Are there any loading combinations which the concrete cannot carry in tension; i,e, lift credit allowed for lateral shear under various loads.

8. List the percentage of lateral shear carried in diagonal or other rebars and in concrete. What role does the liner have in this regard? Describe under what conditions credit is taken for compression and diagonal rebars?

9. Provide a discussion of the adequacy and reliability of the emergency core cooling system.

Question: (1A)

Discuss method of attaching liner and relate to leakage potential. Provide results of tests or indicate the test program which will be carried out to show that the studs will not pull out when concrete is under tension or fail due to fatigue.

Answer:

The liner will be attached to the concrete by means of welded stud anchors. Extensive testing of the fatigue life of plates with stud shear connectors has been done at the University of Illinois under the sponsorship of Gregory Industries Inc. The results of these tests are reported in a paper in Highway Research Record No. 76 -"Fatigue Tests of Plates and Beams with Stud Shear Connectors" by J. E. Stellmeyer and W. H. Munse, professors of Civil Engineering, University of Illinois, and E. A. Selby, University of Toronto. The object of the tests was to study the effect of shear connectors on the fatigue life of the parent material and to study the influence of material on this behavior.

Of particular interest is the rather extensive series of tests on flat plate type specimens.

Flat-plate fatigue tests were conducted on stress cycles of complete reversal, zero to tension and partial tension to tension. The test materials were A-7 steel and A-441 steel. The plate thickness in all cases was 1/2". Stud diameter was 3/4".

Failure was defined as having occurred when the specimen could no longer withstand prescribed load without yielding.

Stress range causing failure @ 2,000,000 cycles were:

8.0 ksi compression to 8.0 ksi tension
0 to 16.0 ksi tension
14.0 ksi tension to 28.0 ksi tension

It should be noted that the stress range remained almost constant (16.0 ksi) as the stress cycle changed.

Test results also showed that:

a) For 20.0 ksi compression to 20.0 ksi tension a fatigue life of 180,000 cycles.

b) For 10.0 ksi compression to 10.0 ksi tension a fatigue life of 960,000 cycles.

c) For 8.5 ksi compression to 8.5 ksi tension a fatigue life of 1,700,000 cycles.

There was no significant difference in the test results on A-7 steel and A-441 steel. Also, variations in welding procedures produced no significant difference.

The presence of the studs did not in any way influence the yield point or ultimate strength of the base material.

The results of these tests indicate that the application of attaching the liner to the concrete will present no problems. Since the liner face is at all times at a higher temperature than the exterior face of the concrete the liner is always in a compressive state. Ambient temperature changes will only vary the compressive stresses in the liner. Neither the stress levels nor the number of cycles are as severe as those reported in the test results. The maximum liner stress under operating conditions is about 10,000 psi compression. Conservatively assuming a cycle a day would result in only 15,000 cycles over the life of the plant. For these reasons, no further testing is proposed.

In order to ensure that anchorage of the liner to the concrete is maintained when the concrete is under tension, the stud detail has been changed as follows:

The stud will be "L" shaped so that the stud will be hooked around the reinforcing to give positive anchorage. Because bond to concrete is not counted on, no testing program is proposed to determine pull out capacity of studs when the concrete is in tension.

The 3/8" plate thickness is much greater than minimum plate thickness requirements for electric arc welding. In Welding Engineer July, 1963, an article entitled "The Growth of Stud Welding" by Robert C. Singleton lists minimum plate thickness for electric-arc welding as listed below:

Stud Base Diameter Inches	Min. Steel Plate Thickness In.
.250	.0478
.312	.0598
.375	.0707
.437	.0897
.500	.1196

It can be seen by a comparison of the required thicknesses, that the 3/8" plate thickness is many times that required for full strength welds, in the range of stud sizes to be used.

1B. What is the inspection program to be used during installation of studs and liner? What percentage of all welds including the studs will be inspected or radiographed?

Answer

United Engineers and Constructors, which is designing and constructing the containment building, is subcontracting the fabrication and erection of the liner and attachments to a qualified and experienced vendor. The liner specification calls for the studs to be attached to the liner plate by an automatic arc welding machine according to the stud manufacturer's recommended procedures. Plate to plate attachment will be by double V butt welds and plate to penetration sleeve attachment by full penetration bevel fillet welds.

During construction of the liner, before the day's work begins, each welder will perform weldment of at least one test stud which will be tested by bending the stud over approximately 45° toward the plate to demonstrate the integrity of the plate to stud weldment. In addition, 50% of all stud welds will be visually inspected by a qualified quality control inspector responsible directly to United Engineers and Constructors.

Quality control, inspection and testing of the liner welds will be as follows:

The installation and inspection of the bottom liner plate will follow the procedure whereby the liner plate will be full butt welded using an automatic welding machine with the submerged arc process with additional full penetration of the butt welded to the embedded steel. The intention of using automatic submerged arc welding is to reduce the human element and error that may result from manual welding. At the end of each plate weld, a coupon of the plate material will be attached and will be welded and the weld run will incorporate this coupon. The coupon will then be cut out, radiographed, bent and Charpy tested. The plate welds will then be wire brushed and 100% vacuumed boxed tested. The pressurization channels will then be attached over all the plate welds to be followed by a 100% pressure soap bubble test and a 100% pressure halide test. The bottom plate welds including the pressure channels will then be subjected to a 54 psig, 2 hour weld pressure test to insure essentially zero leakage of the bottom plate and pressurization system.

The walls and the dome liner plate work will have the first ten feet of liner to liner weld of each welder or welding operator radiographed and a 12 inch photograph will be taken every 50 feet thereafter. If a weld is found to be defective per the definition of the ASME Code Section 8, two adjacent areas will be radiographed. If either of these weld areas if found to be faulty, 100% radiographing of the responsible welder or welding operators welds will be performed until the end of the defect is found as outlined in the ASME Code, Section 8. The defective weld will be removed and joined rewelded and spot tested as outlined above. The channels will then be attached over the seams and a 54 psig air pressure test performed followed by a pressurized halide air leak test with 100% leak inspection.

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During construction of the liner, before the day's work begins, each welder will perform weldment of at least one test stud which will be tested by bending the stud over approximately 45° toward the plate to demonstrate the integrity of the plate to stud weldment. In addition, 50% of all stud welds will be visually inspected by a qualified quality control inspector responsible directly to United Engineers and Constructors.

Quality control, inspection and testing of the liner welds will be as follows:

The installation and inspection of the bottom liner plate will follow the procedure whereby the liner plate will be full butt welded using an automatic welding machine with the submerged arc process with additional full penetration of the butt welded to the embedded steel. The intention of using automatic submerged arc welding is to reduce the human element and error that may result from manual welding. At the end of each plate weld, a coupon of the plate material will be attached and will be welded and the weld run will incorporate this coupon. The coupon will then be cut out, radiographed, bent and Charpy tested. The plate welds will then be wire brushed and 100% vacuumed boxed tested. The pressurization channels will then be attached over all the plate welds to be followed by a 100% pressure soap bubble test and a 100% pressure halide test. The bottom plate welds including the pressure channels will then be subjected to a 54 psig, 2 hour weld pressure test to insure essentially zero leakage of the bottom plate and pressurization system.

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Question (2)

Provide the detailed method of analyzing penetrations to assess their capability to remain leak-tight under all accident conditions. Discuss how cracking of the concrete will be taken into account for all penetrations.

Answer:

The answer to Question No. 2 is in three parts as follows:

A. Liner Stresses at Penetrations

B. Design of Sleeves and End Plates

C. Design of Large Openings

A. Liner Stresses at Penetrations

The liner is basically not a load-carrying member and because of its integral relationship with the reinforced concrete is subjected to the strains which the reinforced concrete imposes upon it. Therefore, the criterion at penetrations is one of consistent deformations rather than transfer of load. Nevertheless, the liner will be reinforced at each penetration according to the rules set forth in the ASME Unfired Pressure Vessel Code, Section VIII UG-36. An additional conservatism is that the reinforcing requirements set forth in the ASME Code are based on unequal bi-axial stresses, whereas the liner principal stresses, being dependent on reinforcing bar strains, are essentially equal. For the penetrations the maximum stress at the opening is essentially the same as the average nominal stress of the liner.

The weldments of liner to penetration sleeve will be of sufficient strength to accommodate the stress raisers around the openings. These welds shall adhere strictly to ASME Section VIII requirements for both type and strength. In addition, each weld shall have a pressurized channel placed over it which will add strength and stiffness to the welded area and assist in reducing stress in the weld and liner plate.

B. Design of Sleeves and End Plates

The penetration sleeves and end plates are designed to accommodate all loads imposed on them. The sleeve and end plate loads include the effects of internal pressure; concentrated loads imposed by the sleeve anchors to the concrete as the anchors strain in conjunction with wall movement under both operating and accident conditions; thermal effects due to both gradient and thermal reactions of the particular item passing through the sleeve; shear, bending, and compression due to accident end pressures; and shear and bending due to seismic movements of the particular item passing through the penetration. The sleeve and expansion joint are designed to remain within ASME Code Section VIII stress limitations with small strains under all or any combinations of loadings mentioned above.

C. Design of Large Openings

Recent experiments indicate that concrete under tension is insensitive to stress concentration effects as reported by W. Wright and J. G. Byrne in "Stress Concentrations in Concrete" in Nature Vol. 203, 26th September, 1964. Should concentrations develop, however, the concrete would crack and the liner would have to span over the cracks. Although the liner has sufficient ductility to span relatively large cracks, reinforcing steel will be used to control cracking and to accommodate stress concentrations should they arise. Making an analogy to a homogeneous, isotropic elastic material subjected to equal bi-axial strains (since strain is a function of reinforcing bar stresses) the classical stress concentration factors as set forth by S. Timoshenko give a magnification factor of 2 as the maximum stress occurring at the penetration. This concentration effect dampens quickly such that within a diameter of the edge of the opening, the stress is virtually the same as the unmagnified stress.

To accommodate these wall stresses, the main reinforcing bars are uninterrupted by bending the reinforcing bars around the penetration. In addition, reinforcing steel equal in area to the area of reinforcing bent around the penetration will be supplied. This approach is a conservatism because:

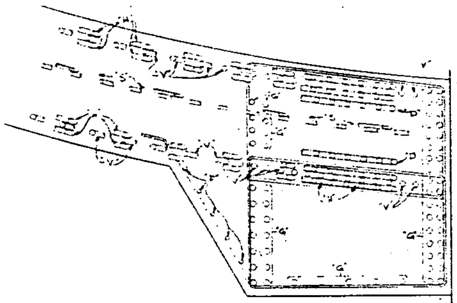
1) Experiments indicate very small stress raisers in concrete
2) Additional reinforcing is provided to resist stress raiser factors of two although this factor occurs only at the edge of the opening.
3) The liner has sufficient strength and ductility to span any cracks in the concrete.

The pressure forces on the penetration result in moments and shears on the wall at the edge of the opening. This effect will be damped out by the restraint of the horizontal bars on local deformations. Bars radial to the opening are provided to resist these effects.

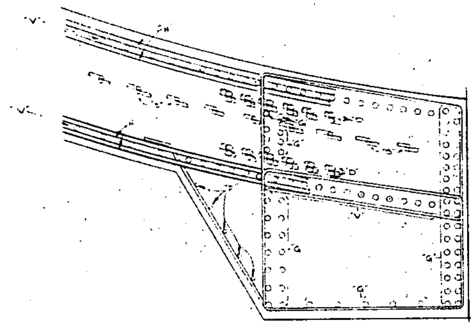
3. Placement of rebars and general design drawings should be provided for the large openings.

Answer

The attached sketch details the placement of reinforcing around the equipment access opening.



SECTION 3-3



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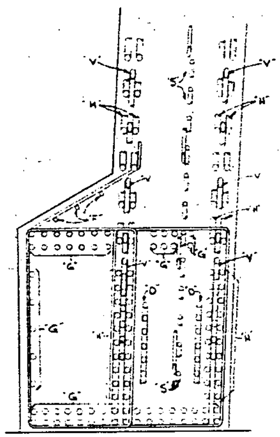

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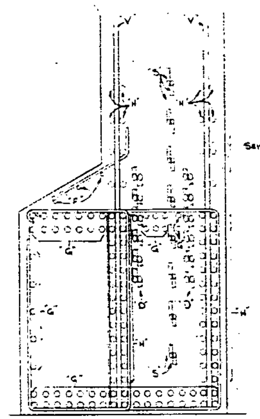

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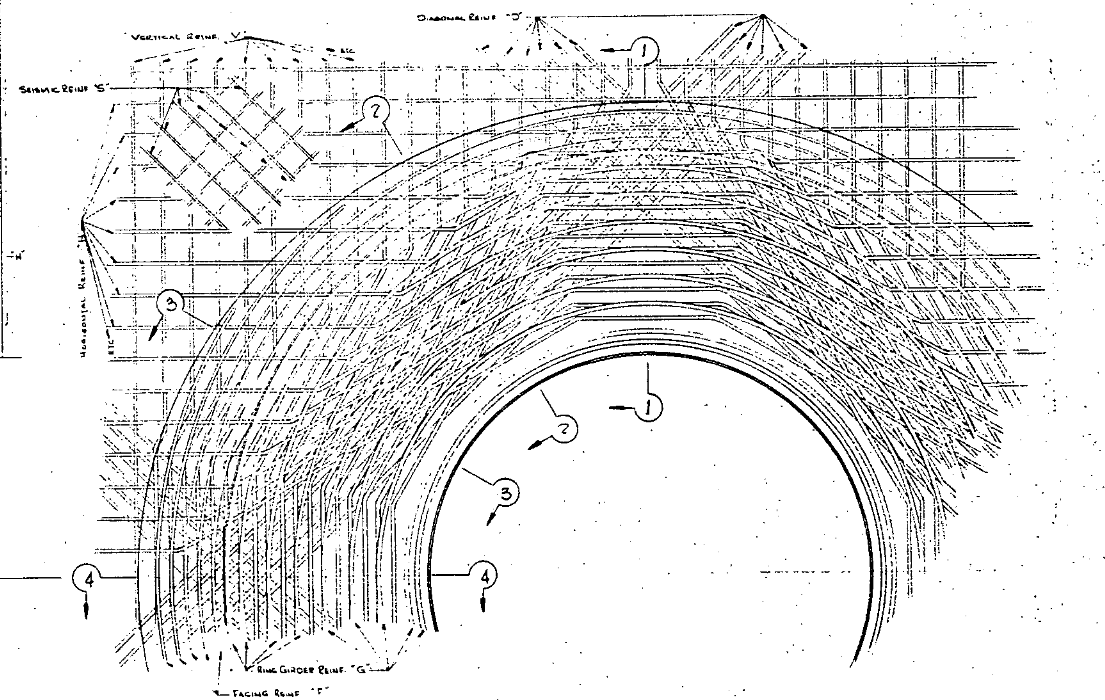

REINFORCEMENT DETAIL AT EQUIPMENT HATCH.

PRELIMINARY 6-15-66

UNITED ENGINEERS & CONSTRUCTORS INC
3321-SK-HD101

4. Discuss the design of the crane to resist earthquake loadings and what would be the effect should the crane fail while it is being used for some operation (one area to consider is during refueling).

Answer

The Polar Crane is designed to remain elastic under lifting and seismic loading conditions. Under maximum operating lifting loads, the structure has a factor of safety of about three based on the yield point. Superposing effects of design earthquake lifting loads gives a factor of safety of approximately 1.5 based on yield with the maximum design lifting load of 175 tons. The seismic design also precludes tipping of the crane under the action of seismic loads.

Under seismic motion, the amplification factor is based on the response spectra contained in Second Supplement to the Preliminary Safety Analysis Report. The forces imposed on the crane structure from the load swinging under its own response to the seismic motion is accounted for in the design.

When the crane is not in operation, the rails will be blocked by rail clamps.

The most serious effect of failure of the polar crane during its use would be physical damage to equipment. The primary function of the crane is the movement of heavy pieces of equipment, during shutdown and refueling periods. The pieces of equipment most frequently handled by the crane are the missile shield over the control rod drive mechanisms, the reactor vessel head and the upper internals package.

During the refueling operation, the CRDM missile shield is the first major piece of equipment to be moved. The worst consequence of failure of the crane during the removal of this missile shield would be dropping of the missile shield on the reactor vessel head and possibly causing damage to equipment on the head.

The most serious damage would be deformation of some control rod mechanism housings. Even if, in the extreme, a control rod drive mechanism housing were sheared off as a result of this accident, there would be no danger of the release of fission products to the environment. Forthis operation, the reactor coolant system is cold and depressurized to essentially 1 atmosphere and borated to refueling concentration ($k_{eff} \lessapprox .90$) so that there would be no reactivity excursion or core heat up if such an accident were to occur.

Damage to the CRDM housings would require that special procedures be taken if reactor head removal were required to repair or replace the damaged housings because a damaged housing might cause the control rod drive shaft to be joined in the mechanism and cause the RCC assembly to be withdrawn from the core when the head is lifted. The refueling boron concentration is sufficiently high so that no reactivity excursion could occur even if all RCC assemblies were withdrawn from the core because of damaged mechanisms and joined drive shafts.

The next major piece of equipment handled by the crane in the refueling procedure is the reactor vessel head. Following the removal of the CRDM missile shield, insulation and instrumentation connections and the head bolts, the head is lifted vertically by the crane until the bottom of the head flange can clear the upper internals package and the control rod drive shafts. The head is kept in vertical alignment by guide pins installed in 3 of the head stud holes. The water level in the reactor vessel cavity and refueling canal is maintained at the level of the head flange as the head is raised. Failure of the crane during the lifting operation would result in the head falling back onto the reactor vessel. The result of such an accident would probably be some damage to the mating surfaces of the head and vessel flanges and possibly some damage to the upper internals package and the control rod drive shafts. The extent of damage to the latter components would depend on the degree of alignment maintained during the fall of the head. As before, this accident will not result in a reactivity excursion or release of fission products from the core.

Should a crane failure occur after the vertical lift of the head but before it is moved clear of the vessel, the fall of the head could be other than vertical. Even in this case, the results of the accident would be limited to damage of the head and vessel flanges and the upper internals components although the damage would probably be more extensive than for the vertical fall case described above.

The third major component handled by the crane is the upper internals package. This upper internals package is removed after the control rod drive shafts are disconnected from the RCC spider assemblies. Failure of the crane during the vertical lift of the upper internals would cause them to fall back into the reactor vessel. If the fall were exactly vertical so that there were no contact between the upper core support plate and the core barrel (there is only about 1/2 inch diametral clearance between these two items out of a diameter of about 148 inches) the upper internals would fall back on the fuel assemblies. No significant damage to the fuel assemblies is expected as the dashpot action of the core barrel would slow the fall of the upper internals. The amount of damage would also depend upon the alignment as the upper internals fell. Failure of the crane after the upper internals are moved laterally away from above the core would cause them to strike the edge of the reactor vessel and tilt so that they would not fall back into the vessel. The resulting damage in this case would be limited to the upper internals and the vessel flange. As before, there would not be a reactivity transient or release of fission products from the core.

Question (5)

Provide information which indicates that the crushed rock backfill will not increase the earthquake loading on the structure.

Answer:

The seismic design of the containment structure takes into account the effects of the backfill by imposing forces on the containment necessary to cause a shear failure of the backfill material. The total force necessary to cause a shear failure in a cohesionless soil can be represented by the equation

$$P= \frac{1}{2} q H^2 K$$

Where q is the unit weight of the soil material

H is the height of soil

K is a factor depending on the soil characteristics and the intergranular relationship of the soil particles.

The K value for well compacted cohesionless soil is about 0.8. This value of K can change if the entire mass of soil is given the opportunity to either expand or be compressed in a horizontal direction. The two extreme points referred to as states of active and passive plastic equilibrium occur when the soil expands freely or is compressed fully, respectively. The K values for these two points for the backfill material selected are 0.33 and 3.0. Partial satisfaction of the plastic conditions result in K values intermediate between the extremes 0.33 and 3.0.

In the analysis of the effects of the backfill on the containment under seismic motion the following two conditions can exist:

1. The inertial forces of the structure acting opposite to the soil forces, i.e. the structure deflecting into the soil. Here a worst soil condition exists and a full state of passive plastic equilibrium exists and K=3.0.

2. The inertial forces of the structure act in the same direction as the soil forces. In this case the soil is allowed to expand and a state of active plastic equilibrium exists and K-0.33.

The above shear failure planes will then be assumed to be subjected to ground acceleration and the dynamic loads will be added to those forces necessary to cause the failure planes.

6. Provide deformation criteria or limits for all components which must meet the "no loss of function" criteria.

Answer

For the no loss of function earthquake condition as defined in answer to Question 9-d of the Second Supplement to the PSAR (as distinguished from the design earthquake), the criterion is that there shall be no loss of function for components that are necessary to bring the plant to a safe shutdown condition. No loss of function implies that rotating equipment will not freeze, pressure vessels will not rupture, supports will not collapse under the load, systems required to be leak tight will remain leak tight and components required to respond actively (such as valves and relays) will respond actively.

To satisfy the criteria (1) in steel supports and reinforced concrete supports, stresses will not exceed the yield stresses; (2) in pressure vessels and piping systems, there will be regions of local bending where the strains will be equivalent to twice the yield, representing a strain of 0.4%; (3) in piping systems, the hangers will be installed to limit deflection for proper drainage so that the combined membrane stresses are maintained within the allowable stress limits set forth in the piping code rules; (4) on rotating equipment, the stresses associated with the seismic load are an insignificant item inasmuch as moving parts are deflection limited rather than stress limited. The seismic load manifests itself as a temporary bearing overload that is well below the normal design margins in bearings.

7. Are there any loading combinations which the concrete cannot carry in tension; i.e., list credit allowed for internal shear under various loads.

Answer

Under the combination of design accident pressure and earthquake loads, the concrete may not be able to carry the diagonal tension load. For this reason, diagonal reinforcing is used in the design of the structure.

As stated in the First Supplement to the Preliminary Safety Analysis Report, the moments and shears resulting from the restraint at the base of the cylindrical wall are analyzed on the basis of an uncracked section. As horizontal cracking occurs, the stiffness of the vertical wall is reduced. This conservatism insures that the actual moments and shears will be much less than those calculated.

The participation of the concrete in resisting these calculated shears will be based on the ACI Standard Building Code requirements for reinforced concrete (ACI 318-63) Part 17-B Structural Analysis and Proportioning of Members-Ultimate Strength Design-Section 1701-Ultimate Shear Strength, paragraph (e).

Where the calculated shear stress exceeds the allowable shear stress given by the Code, no credit whatsoever will be taken for the concrete to resist shear.

8. List the percentage of lateral shear carried in diagonal or other rebars and in concrete. What role does the liner have in this regard? Describe under what conditions credit is taken for compression in diagonal rebars.

Answer

The seismic loading results in shear flow with the maximum shear flow occurring tangential to the direction of seismic motion.

In discussing the various structural elements resisting shear forces, seismic shears and discontinuity shears at the base joint will be discussed separately.

Since, under the combination of seismic forces with those from the design accident the concrete will be cracked, horizontal and vertical crack planes are assumed to form. The function of the diagonal seismic bars is to prevent relative deformation at these planes.

The required capacity of the diagonal bars will be determined such that the horizontal component per foot of the diagonals will be equal to the maximum value of shear flow. Although, in the cylinder the liner has some capacity available to resist the seismic shears, no credit is taken for the liner. Only in the upper area of the dome (beyond about 30° above the spring line), where the seismic shears are small will the liner be counted on to resist shear. For all of the cylinder and for the lower areas of the dome, the diagonal reinforcing is designed to accommodate all seismic shears. No credit is taken for the dowel action of the vertical and horizontal bars in resisting seismic shear.

In the design of the diagonal reinforcing, the initial tensile stresses due to pressure loadings are taken into account. With the superposing of seismic shears, one direction of diagonals will have its tensile stresses increased, while the bars normal to the first direction will have the tensile stresses reduced. The design criteria are that the stresses in the first mentioned bars shall not exceed ninety-five percent of yield and that no further credit is taken in the second set of bars beyond a zero resultant stress condition.

9. Provide a discussion of the adequacy and reliability of the emergency core cooling system.

Answer

The Safety Injection System consists of three high head, low flow pumps and two high flow, low head pumps delivering borated water from the refueling water storage tank. The low head pumps are the residual heat removal pumps of the residual heat removal system. The high head Safety Injection pumps inject into each reactor coolant loop cold leg, while the low head residual heat removal pumps deluge the core by nozzles that are connected to each reactor coolant hot leg. In addition, the charging pumps of the Checmial and Volume Control System will normally augment the flow of the Safety Injection System. For long-term recirculation cooling of spilled Safety Injection water and reactor coolant, a separate recirculation loop with redundant pumps within the reactor containment can deliver water from a sump through the residual heat exchangers to the reactor coolant loops for core cooling. In addition, the residual heat removal pumps located outside the containment can be used for this recirculation function.

Safety injection (emergency core cooling) is actuated by a coincidence of low pressurizer pressure and low pressurizer water level. This signal opens the safety injection isolation valves at each reactor coolant loop hot leg and cold leg pipe (eight parallel injection paths in all). Reliability of the actuation circuitry is obtained by redundancy, in which each channel (primary sensing element, relaying, etc.) is separate. A two-out-of-three coincidence circuit is used, in which failure of one channel to operate when required will not negate the safety action. In general, each channel is designed so that trip occurs when the circuit is de-energeized; an open circuit or loss of channel power therefore would cause the system to go into its safety state. Individual channel testing can easily be carried out at anytime, since tripping of the channel will put the actuation circuit in the half-tripped mode.

Although the safety injection equipment is arranged to operate from electrical buses supplied from normal outside AC power which should not fail as a result of reactor trip, reliable on-site emergency power is provided should normal AC power be lost concurrent with a loss-of-coolant accident. Three diesel generator sets, any two of which are capable of powering the required engineered safeguards loads, are provided. In the event that any diesel fails to start immediately, any of the engineered safeguards equipment normally supplied by that diesel is automatically transferred, if required, to one of the other two diesel-supplied buses. Automatic starting of each diesel is initiated by an undervoltage relay on the 480 volt bus to which the diesel is connected. The undervoltage scheme will de-energize to actuate, so that loss of 480 volt power will not prevent the relay scheme from functioning properly. The sensing and control equipment is redundant.

The Safety Injection System and associated auxiliaries, including structures, are classified as Seismic Class I. The environment accompanying the situation in which the various components are required to function will not interfere with that function.

The effectiveness of the Safety Injection System in providing emergency core cooling following a loss-of-coolant accident is not dependent upon maintaining the integrity of any safety injection components within the reactor vessel, since there are none. Injection of cooling water is accomplished by delivery of water to the reactor coolant loops (deluge to each of the four hot legs and high pressure injection to each of the four cold legs). The supports for the reactor vessel and the other main reactor coolant piping will be designed to accept the blowdown thrust loading without causing rupture or failure to deliver of any safety injection line not connected to the pipe assumed to rupture. Thus, the delivery capability of the Safety Injection System will not be impaired. The system is designed to provide adequate cooling with the possible spilling from one loop.

Approximately 20% of the installed deluge flow capability will prevent the core from melting through the reactor vessel. This represents approximately 15% of total Safety Injection System delivery capability.

During blowdown of the reactor coolant system, differential pressure forces higher than normal will exist across core components. These forces will result from both frictional resistance to flow and from sonic effects. While it does not appear that the differential pressure across the core barrel will reach 1000 psi, a force of this magnitude was examined as part of the investigation of shock waves reported in the Appendix to the Second Supplement of the Preliminary Safety Analysis Report. While the natural period of the barrel is of greater duration than that of the shock wave, such a differential (1000 psi) is within the capability of the barrel to withstand on a sustained basis without blocking the coolant nozzles. Should a break occur in a loop cold leg, water in the downcomer between the reactor vessel wall and the barrel will redistribute to reduce the magnitude of the flow reversal and pressure oscillation. A break in the hot leg would not produce as great a pressure differential across the barrel.

Even assuming that yielding of the barrel occurred to the point of blocking the nozzle in the leg of the loop assumed to rupture, at least seven nozzles would still be in communication with the reactor vessel. Since previous analyses have assumed spilling of safety injection from the affected loop (and also failure of a valve to open or at least one pump to start), the delivery effectiveness of the Safety Injection System would not be affected by blocking the loop nozzle.

The maximum coolant flow through the core during blowdown will be approximately three to four times normal flow. The pressure waves will be primarily longitudinal, also resulting in an axial loading on the fuel assemblies. The shock waves will be of a duration considerably less than the natural period of the assemblies, and therefore is not a sustained load.

The high flow associated with the initial coolant blowdown will be approximately 200 milliseconds duration. Flow decreases rapidly thereafter. The pressure drop across the core associated with maximum flow is of the order of 500 psi or less. The forces associated with this condition will not cause any significant distoration of the fuel assemblies or distort the upper internals sufficiently to prevent core cooling by blocking of coolant nozzles.

In summary, the Westinghouse Pressurized Water Reactor is designed to exacting quality standards, and the reactor system components thereof are fabricated using quality materials with extreme care going into Quality Control and inspection. Consequently, a massive failure of reactor system components or connecting reactor coolant piping is considered to be an extremely unlikely event. Even if such a hypothetical event were to occur, the plant has emergency core cooling systems which have reliable and redundant components. Extensive studies of modes of failure have been done in order to provide completely reliable emergency cooling systems and these studies have been factored into the design. Furthermore, the same exacting quality control standards have been applied to the cooling system components as to the reactor system components. Therefore, it is considered that these systems will surely perform their intended function if ever called upon.

While these facts show that a means of coping with the core meltdown accident is not necessary, the cavity below the reactor vessel will have the capability of preventing breaching of the containment by the molten core through the use of the water in the cavity.