



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

SAFETY EVALUATION OF THE PALISADES  
CONTAINMENT CONSTRUCTION OPENING AND RELATED  
ITEMS FROM INSPECTION REPORT 255/90017

INTRODUCTION

Consumers Power Company is in the process of replacing the two steam generators (SG) at the Palisades Nuclear Plant. The replacement is being accomplished by cutting a transfer opening in the containment, followed by rigging each SG as a whole unit. After the completion of the SG replacement, the opening will be closed and the containment will be restored to its original integrity. Consumers Power Company is performing the replacement under 10 CFR 50.59. The NRC staff has conducted inspections of the related 10 CFR 50.59 facility change packages associated with the SG replacement. This Safety Evaluation addresses open items from Inspection Report 255/90017.

Open Item 90017-01

The following concerns were noted regarding modifications to the Component Cooling Water (CCW) Surge Tank Room:

- The Safety Evaluation (SE) did not address the potential for the release of airborne radioactivity through construction openings in the room.
- Some potential for damage to the CCW surge tank and other components in this area exists while the de-tensioning process is in progress. The heat load on the CCW system during this period was not addressed in the SE. The SE noted that the surge tank was required only for "long term" CCW operation. The duration of "long term" or a description of heat loading during that period were not addressed. Further, no contingency action were identified if damage to the CCW system should occur.

The licensee addressed the above noted items in a later revision to the SE. The scope of the SE was broadened to include a small hole in the roof of the fuel pool building through which cables would pass to facilitate work in the CCW surge tank room. Proper precautions were taken in the SE to minimize new air leakage paths. These precautions, coupled with the negative pressure in the fuel pool area, will assure no air out-leakage from the room.

The SE was also expanded to incorporate further protective measures to prevent damage to the CCW surge tank. The staff reviewed the updated facility change package and inspected the CCW surge tank room during the modification process. The latest revision to the SE adequately addresses the staff's concerns. This item is considered closed.

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Open Item 90017-03, 04

The SE for the Auxiliary Building Modification for containment personnel access also failed to address the potential release of airborne radioactivity via the access opening. This SE was revised by expanding the section detailing ventilation flow paths and potential airborne radioactivity release. The staff reviewed the updated facility change package and inspected the containment access building. Precautions taken to ensure that the fuel building negative pressure is maintained are adequate. It was verified that the auxiliary building entry doors were guarded by security personnel when left open for personnel access. Item 90017-03 is considered closed.

Required Technical Specification changes have been submitted by the licensee. The facility change package revision which reflected the licensee's commitments to submit the changes was reviewed and found acceptable. Item 90017-04 is considered closed.

Open Item 90017-02

DESCRIPTION OF THE CONTAINMENT AND THE TEMPORARY ACCESS OPENING

The Palisades containment is a prestressed concrete six-buttress structure with a circular flat base slab, a 160 foot high vertical cylinder and a shallow dome. The inside diameter of the containment is 116 feet. The inside face of the containment is lined with a 1/4 inch steel plate. The dome is 3 feet thick and is prestressed with 165 tendons grouped in three sets. The cylinder is 3 feet 6 inches thick and is prestressed with 522 hoop tendons and 180 axial tendons. Each tendon is made of ninety (90)-1/4 inch diameter high strength wires. Initially the opening cut will be about 29 feet high and 26 feet wide and is to be enlarged to 32 feet high and 30 feet wide to meet the restoration construction requirement. The analysis is based on the larger opening. The lower edge of the opening is about 60 feet above the top of the base slab. Seventy-two of the vertical tendons and sixty of the hoop tendons will be de-tensioned. Fifteen of the de-tensioned vertical tendons and thirty-seven of the de-tensioned hoop tendons which pass through the opening will be removed and reused. The opening will be made by a wire cutting method. Except for two small concrete sections removed to facilitate construction of the transfer rail system, the cut-out block will be removed in one piece. After the completion of the transfer of the SGs the opening will be closed and the containment will be restored to its original configuration.

REGULATORY CONCERNS

The components which will be cut and replaced include concrete, reinforcing bars, tendon sheathing and steel liner. The tendons and grease will be removed before cutting. The tendons will be reused in the restoration. The concerns in such an operation, which were highlighted as open item 90017-02 in the staff's inspection of the related facility change packages, are as follows:

1. The behavior of the containment structure at the time when the opening is cut (with the vertical and hoop tendons around the opening being de-tensioned) resulting in a containment unsymmetrically prestressed.

2. The creep and shrinkage of the concrete used in closing the opening, which are expected to be larger than the surrounding concrete, resulting in higher compression in adjacent concrete and in more loss of prestress.
3. The behavior of the steel liner in the area of the opening (most likely it will be under higher compression due to creep and shrinkage of the new concrete).
4. The creep and relaxation of the reused tendons potentially resulting in larger prestress loss.
5. The location of cadweld splices for reinforcing bars at one section without staggering and the use of sister splices for quality control, both of which may result in reduction of the strength of the reinforcing bars.
6. The leaktightness of the connection of new tendon sheathing with the existing sheathing to prevent grease leakage into the concrete.
7. The effect of withdrawing and re-inserting the tendons may wear the corrugated sheathing and possibly cause leakage of grease.
8. The effect of a structural integrity test at 115% design pressure on the containment (due to loss of prestress in tendons).

The above concerns were conveyed to the licensee and its Architect/Engineer (A/E) during inspections at the Palisades site and the A/E's office.

#### RESOLUTION OF STAFF'S CONCERNS

In order to respond to concerns arising from cutting an opening in the containment, the licensee had its A/E, Bechtel Power Corporation, perform a detailed finite element analysis for the whole containment. The following summarizes the finite element analysis as performed by the licensee:

The containment cylinder together with the buttresses and the ring girder, and the dome are idealized into 1400 elements. The containment is assumed to be fixed at the foundation level. The loads considered are dead, prestress (which ranges from full, maximum detension and minimum detension), seismic, wind, and thermal. Eight basic load combinations are considered for the containment shell structure evaluation during the existence of the transfer opening. Eleven basic load combinations are used to study the containment shell structure behavior after the close-up of the transfer opening with two different moduli of elasticity for concrete.

The finite elements are mostly rectangular. The elements are considered as uniform thin plates with the four corners of each element as nodal points for interconnection between elements. The plate element as idealized may be said to have five degrees of freedom.

Basically the approach used is nearly the same as that used by others performing finite element computer analysis for such a structure. The results of the finite element analyses are in terms of stresses at the center of the element which are compared with the allowable values as specified in the FSAR. The ratio between the stress obtained and the

allowable is defined as the utilization factor (UF) which serves as criterion of acceptance. To be acceptable the UF should be equal to or less than one. For any UF greater than one in any element, a process of averaging the stresses among the adjacent elements is performed. Such a situation exists at points of discontinuity or concentrated loads.

The use of averaging the stresses of neighboring elements is justified by the licensee on the basis of the actual behavior of concrete structural elements. Actually it should be noted that the stress discontinuities between elements are a direct result of the stress patterns assumed in the elements. Each element is stressed independently of its neighbors, which actually is not the case. Therefore, averaging the stresses of neighboring elements should give a very reasonable approximation of stresses in the elements of the region.

The results of the finite element analyses were compared to those of the original FSAR analyses for the same conditions. The results generally are within reasonable agreement. At one location, the junction of the cylinder with the foundation mat where the present analyses give much higher bending and shear than the original analyses. The major reason for the higher values as explained by the licensee is that the present analyses consider the cylinder as fixed at the junction while the original analyses take the basemat flexibility into consideration. The licensee used the higher bending moments and shears to check the design of the containment at the location and found it to be adequate. The analyses do not indicate any abnormality in the overall behavior of the containment for all the conditions specified.

In a prestressed concrete structure, creep and shrinkage of concrete are causes of prestress loss. Shrinkage arises in newly placed concrete as a result of concrete drying. Creep is load related, that is, when concrete is under sustained load, there is plastic deformation in addition to the elastic strain. If the load is released, the elastic strain is fully recovered but creep is only partially recovered. In a newly cast concrete member the surface concrete undergoes shrinkage due to drying but is restrained from doing so by the interior concrete and the reinforcing bars or both. It is thus subjected to tensile stress until the occurrence of surface concrete cracks which relieve the tension. Creep and shrinkage are not independent phenomena to which the principle of superposition can be applied. However, for simplicity the common practice is to consider the two phenomena to be additive. For the Palisades concrete in the transfer opening, Bechtel considers the effect of shrinkage on concrete, reinforcing steel and the liner and finds it to be negligible. For creep, the effect is studied in the analysis by using a lower modulus of elasticity for concrete which is judged to be acceptable. The result of such an analysis does not indicate any adverse effect. It is assured by the licensee that the materials selected for the concrete mix will be such that it has high compressive strength with low creep and shrinkage so that the values used in the analyses are conservative.

The steel liner is not included in the finite element analysis model. Bechtel has performed an analysis of the liner plate through the assumption of strain-compatibility between the liner plate and concrete shell around the opening. The information on concrete stress and strain is from the finite element analysis. On the basis of this analysis, the licensee concluded that the liner

plate in the transfer opening is structurally adequate.

The finite element analyses also take into consideration the load condition which occur during a structural integrity test (SIT) with reduced prestressing tendon force. The results concluded that the containment can withstand pressures up to and above 115% of the design pressure.

In order to check this to be truly the case, structural displacement determination and concrete cracking size measurement during pressurization and depressurization of the containment will be performed especially in the area affected by the transfer opening. Transducers and invar wires to measure displacements of the containment cylinder wall will be installed at the transfer opening area and other locations throughout the containment cylinder wall. Concrete cracks will be mapped at the transfer opening area as well as other comparable areas. By making comparison of the displacement data and crack size data with their predicted values, a confirmation can be made that the containment does not sustain any structural damage as a result of the transfer opening operation as indicated by the analyses.

#### RESOLUTION OF OTHER CONCERNS

The remaining staff concerns comprise the areas of quality assurance and quality control. The licensee's responses to these concerns are summarized as follows:

**Cadweld Splices** - The structural integrity of Palisades containment depends primarily on prestressing tendons. The reinforcing steel is provided mainly to minimize shrinkage cracks. The cadweld splices together with the use of sister splices for quality control should ensure that the structural integrity of the reinforcing steel is maintained. The adequacy of such cadweld splices has been demonstrated by these same practices carried out in the closing of the original construction opening.

**Sheathing Joint** - A one foot coupling will be installed with six inch overlap on each side of the joint and will be sealed with epoxy or caulk and taped to provide a leak tight seal.

**Sheathing** - The withdrawing and re-inserting of the tendons removed from the opening area will not result in any damage to the sheathing greater than that of the original installation in view of the fact that the sheathing has been previously filled with grease resulting in less frictional force during tendon movement.

**Concreting** - In closing the transfer opening with new concrete, a concrete mix that is designed to develop a high early strength along with exhibiting acceptable creep and shrinkage characteristics will be used. The concrete will be placed in the forms in 24-inch layers at the rate of 4 feet per hour utilizing tremies and elephant trunks. Placement of the concrete will continue until it is approximately six inches from the top at the inside face of the wall. The top of the opening is sloped so that the thickness of the concrete layer varies from 6 inches at inside face to 14 inches at the outside face. "Master Patch 20" will be used for this top layer. It has the characteristics of high early strength with low shrinkage.

The replacement concrete will be essentially stress free prior to tendon retensioning and therefore there will be some difference in the state of stress between the new and adjacent existing concrete. The effect of this difference is evaluated in the finite element analysis and found to be of little significance.

Creep and Relaxation of Reused Tendon - In order to study creep and relaxation of the reused tendons three wires will be pulled from the removed tendons. Samples of the wires will be tested to support the engineering analysis.

#### EVALUATION OF LICENSEE'S RESPONSES

The staff has reviewed the licensee's responses to the above concerns, especially those amenable through the finite element analyses and found that:

- (1) The analyses are detailed and comprehensive. They included the whole containment shell and considered all applicable loads and load combinations. The results of the analyses do not indicate any abnormal behavior of the containment either locally or globally.
- (2) The technique of replacing the concrete in the opening and the procedure of evaluating shrinkage and the use of lower concrete modulus of elasticity to consider the effect of creep and shrinkage on containment appear to be reasonable and are acceptable.
- (3) The procedure of analyzing the steel liner in the opening area is acceptable and the results appear to be reasonable.

The staff's remaining concerns are related primarily to quality assurance and quality control. The staff has found the licensee's responses to these concerns to be acceptable. With regard to the manner in which cadweld splices will be used the licensee responded that the tendons are the principal strength resisting elements (the reinforcing bars are provided to control concrete cracking due to thermal loads and other forces arising from structural discontinuity). Furthermore, such cadweld splices were used in the closing of the original construction opening. Therefore the cadweld splices as used will not jeopardize the structural integrity of the containment. The reasoning is convincing and the concerns with respect to the cadweld splices are satisfactorily resolved.

#### CONCLUSION

On the basis of staff's review and site inspection of the finite element analyses performed and of the measures to be taken in quality assurance by the licensee, the staff concludes that the cutting and closing of the transfer opening in support of the steam generator replacement should not jeopardize the structural integrity of the containment. As such, inspection report open item 90017-02 is considered closed. However, final acceptability of the Palisades containment is subject to the staff review and acceptance of the structural integrity test report.

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REFERENCES

The evaluation and conclusion of this report is based on staff's discussion with the licensee and on inspection of documents at Palisades Plant Site and at licensee's A/E office. The documents inspected are:

1. Documentation on finite element analyses, Report Nos. C-025 to C-31 inclusive, C-035, C-036, C-038 to C-40.
2. Task plan summaries, Revision 0, May 15, 1990.
3. The adequacy of steel liner plate in the containment opening after the restoration, calculation No. C-069.
4. Effect of new concrete shrinkage on the containment shell, calculation No. C-032.
5. Primary reactor containment, structural integrity test procedure, Palisades Plant, CPC, Bechtel job no. 20557.
6. Letter to NRC from David P. Hoffman of Consumers Power Company dated September 20, 1990.
7. A faxed sheet from Consumers Power on containment construction opening concrete placement dated October 29, 1990.