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VICE PRESIDENT
NUCLEAR OPERATIONS

September 3, 1982

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Virgil C. Summer Nuclear Station
Docket No. 50/395
Operating License No. NPF-12
Cadweld Allegation

Dear Mr. Denton:

In response to NRC staff questions, South Carolina Electric and Gas Company (SCE&G) hereby provides a summary report concerning the structural significance of the vertical cadwelds in the reinforcing bar within the containment at the Virgil C. Summer Nuclear Station. Because this is a matter before the V. C. Summer Nuclear Station Atomic Safety and Licensing Board, copies of this document will also be sent to the service list in that proceeding.

If you have any quetions, please let us know.

Very truly yours,

O. W. Dixon, Jr.

NEC:OWL/fjc

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EVALUATION OF REACTOR CONTAINMENT CAPACITY RELATED TO ALLEGATIONS ON CADWELD RELIABILITY

1.0 INTRODUCTION

This report describes the results of an evaluation of the ability of the V. C. Summer Reactor Building containment structure to resist the load combinations which control the design of the containment. The capacity of a typical containment usually depends on the strength properties and quantity of the prestressing tendons and reinforcement within the containment. The evaluation described herein for the V. C. Summer containment determines the effect on the capacity of the containment of neglecting the capacity of the vertical reinforcement. This condition is evaluated as a worst case assumption which results from allegations that some of the Cadwelds used to splice the vertical reinforcement may not be reliable.

The evaluation does not determine the acceptance of the containment relative to the acceptance criteria specified in either the ASME Containment Code or the FSAR. This evaluation is performed as a realistic determination of the capability of the containment to resist the controlling design loads, and it is similar to the ultimate pressure capacity evaluations currently being performed in the industry for the Hydrogen Detonation condition.

2.0 ORIGINAL DESIGN CRITERIA

The original design criteria for the Reactor Building containment was established in 1972/1973, prior to availability of the ASME Section III, Division 2 Code (Containment Code). As a result, the structure was designed such that when tension stresses occur in the concrete due to membrane forces they are resisted by conventional reinforcement. Provisions of the Containment Code allow taking into account the additional capacity of the prestressing tendons up to 90% of their yield strength.

3.0 CURRENT EVALUATION

3.1 TENDON CAPACITY

The capacity of the vertical prestressing tendon system corresponding to its yield strength was accounted for in the current evaluation. The minimum tested yield strength (yield at 1% strain) of the actual production tendon wire supplied for V. C. Summer was used. The minimum tested yield strength corresponds to 90% of the guaranteed Ultimate Tensile Strength (GUTS) of 240 ksi.

Load Combinations

The load combinations which control the design of the containment are the following:

Abnormal $D + F + T_o + 1.5\ P_a + T_a$

Abnormal/Severe Environmental $D + F + T_o + 1.25\ P_a + T_a + 1.25E$

Abnormal/Extreme Environmental $D + F + T_o + P_a + E' + T_a$

where:

- D = Dead Load
- F = Prestress Force (0.9 GUTS)
- P_a = Design Accident Pressure (57 psi)
- E = Operating Basis Earthquake (OBE) (0.1g, 2% Damping)
- E' = Design Basis Earthquake (DBE) (0.15g, 2% Damping)
- T_o = Operating Temperature (Taken as Zero)
- T_a = Accident Temperature (Taken as Zero)

Secondary stresses due to discontinuities and thermal effects are not considered when evaluating the capacity of the containment. The secondary stresses have little or no influence on overall containment capacity. The operating and accident temperature loads are not included in the evaluation because the thermal forces due to these loads are self-equilibriating over the cross section of the containment wall and, therefore, do not affect the capacity of the containment.

Results

The vertical membrane forces that are produced by the load combinations identified above were obtained at two elevations in the containment wall. The locations selected are El. 420 ft. and El. 480 ft. which bound the region in which the Cadwelds are proported to be suspect. The net tensile forces predicted to occur are indicated in Table 1 along with the yield capacity of the vertical tendons. The capacity of the vertical reinforcement is neglected.

The net tensile forces shown in the table include the direct membrane forces produced by Dead Load and Design Accident Pressure. For the OBE and DBE, the forces include the direct membrane force due to overturning moment and also the indirect tangential shear forces. For purposes of comparison with tendon capacity the tangential shear forces are considered the same as a direct membrane force because the tendon is assumed to resist the shear through a shear friction mechanism with a friction coefficient of 1.0.

The results in Table 1 indicate that the tendons alone are capable of providing sufficient membrane tensile capacity to resist the controlling loading conditions, and vertical reinforcement is not required.

3.2 REINFORCEMENT REQUIREMENTS FOR TANGENTIAL SHEAR

The results of the capacity evaluation in Table 1 indicate that the tendons alone have sufficient capacity to resist the combined membrane and tangential shear forces occurring in the containment wall. In this evaluation the tendons are assumed to be effective in resisting the tangential shear through a shear friction mechanism with a friction coefficient of 1.0.

Shear friction as a method of resisting tangential shear was, in effect, specified as part of the design criteria for the V. C. Summer containment and was consistent with industry practice at the time [1]. However, in this criteria, reinforcement rather than tendons is required to provide the "clamping action" which permits shear friction to resist the tangential shear forces. Therefore, consistent with this criteria, a capacity evaluation was performed in which it is assumed that the tendons are effective in resisting only the membrane tension forces and that only the reinforcement is effective in resisting the tangential shear forces. The evaluation was performed at all typical Cadweld splice elevations between El. 420 ft. and El. 480 ft.

of the containment wall. The results are indicated in Table 2 only for the bounding elevations; however, it was determined that the results at El. 480 ft. control the reinforcement evaluation.

Membrane Tension

As the results in Table 2 indicate, the tendon capacity exceeds the required membrane tension capacity for all load combinations.

Tangential Shear

The largest tangential shear forces occur for the Abnormal/Extreme Environmental condition. The values are indicated in the table as 113 kips/ft. at El. 420' and 102 kips/ft. at El. 480'. The area of vertical reinforcement generally provided near El. 420' is 6.25 in.^{2}/ft. (El. 423-4') and near El. 480' is 3.81 in.^{2}/ft. (El. 482'). Based on the shear values of 113 kips/ft. and 102 kips/ft. and a permissible reinforcement stress of 54 ksi, the reinforcement area required is 2.09 in.^{2}/ft. at El. 420' and 1.89 in.^{2}/ft. at El. 480'.

The current Containment Code and the Building Code for Reinforced Concrete, ACI 318-77, require that mechanical connections such as Cadwelds be used to splice the #14 and #18 reinforcement in the containment. These requirements are intended to apply to all structural members, most of which are subjected to membrane and/or flexure forces. An example of this condition is the vertical membrane tension forces in the containment wall and the vertical reinforcement. However, as discussed above,

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[1] "Criteria for Reinforced Concrete Nuclear Power Containment Structures", Reported by ACI Committee 349, Title No. 69-2, ACI Journal, January, 1972.

these tension forces are able to be resisted by the vertical tendons. Therefore, the vertical reinforcement only has to be developed sufficiently to resist the tangential shear forces. In a realistic assessment of this condition the reinforcement should be able to resist the tangential shear forces even if the Cadwelds are assumed to be ineffective. The reinforcement has a development (embedment) capacity due to the stagger of the Cadwelds and resulting overlap of the bars. In this mechanism the tangential shear forces produce tension forces in the vertical reinforcement. These tension forces are limited by the development capacity of the reinforcement above and below the shear plane. Development strength can be achieved due to the physical confinement of the vertical reinforcement. The concrete clear cover on the vertical bars is 5 inches. Additional confinement is provided by the horizontal reinforcement on the outside face of the wall and by the liner on the inside face. The minimum developed vertical reinforcement was determined to be 4.50 in.^{2}/ft. for El. 420' and 2.45 in.^{2}/ft. for El. 480'. These values are noted as VERTICAL REINFORCEMENT AVAILABLE in Table 2. As indicated in the table, the available reinforcement exceeds that required to resist tangential shear.

Another mechanism of resisting tangential shear acts in conjunction with shear friction, but it is conservative to consider the two independently. This mechanism is the direct shear action (dowel action) of the reinforcement crossing the shear plane. Here the shear forces are equilibriated primarily by shear stresses in the bars, and the tension forces in the bars are considerably less than that calculated using the shear friction approach. Consequently, the requirement for tension resistance of the reinforcement, in the form of Cadwelds or development capacity, is much less than that calculated above. The results of testing performed over the years have confirmed that dowel action is a significant mechanism by which shear forces are transferred; however, the codes for reinforced concrete construction have not yet reflected this in their design provisions.

4.0 CONCLUSION

The vertical tendons have sufficient capacity to resist the net membrane tensile forces in the containment wall as well as the tangential shear forces without the need for vertical reinforcement. However, a conservative assumption can be made that the tendons do not have any effectiveness in resisting the tangential shear. If this assumption is made, then vertical reinforcement is required to resist the tangential shear forces. In a realistic evaluation of this condition, it is calculated that the tangential shear forces can be resisted by the vertical reinforcement without the need for Cadwelds. The method for this resistance is the development capacity of the vertical bars which exists because the embedment lengths of these bars are generally well staggered and confined within the containment wall. Dowel action is another mechanism available for the vertical reinforcement to resist the tangential shear forces without the need for Cadwelds.

LOAD COMBINATION	STN #	ELEV. (FT)	REQUIRED CAPACITY NET TENSILE FORCE FOR LOAD COMBIN.* (KIPS/FT)	TENDON CAPACITY F = (0.9 GUTS) (KIPS/FT)	TENDON CAPACITY EXCEEDS REQUIRED CAPACITY YES/NO
Abnormal D + 1.5 Pa	5	420	281 [0]	504	Yes
	9	480	317 [0]	504	Yes
Abnormal/ Severe Environmental D + 1.25 Pa + 1.25 E	5	420	501 [94]	504	Yes
	9	480	441 [85]	504	Yes
Abnormal/ Extreme Environmental D + Pa + E'	5	420	492 [113]	504	Yes
	9	480	413 [102]	504	Yes

*Membrane + Tangential Shear
[] = Tangential Shear

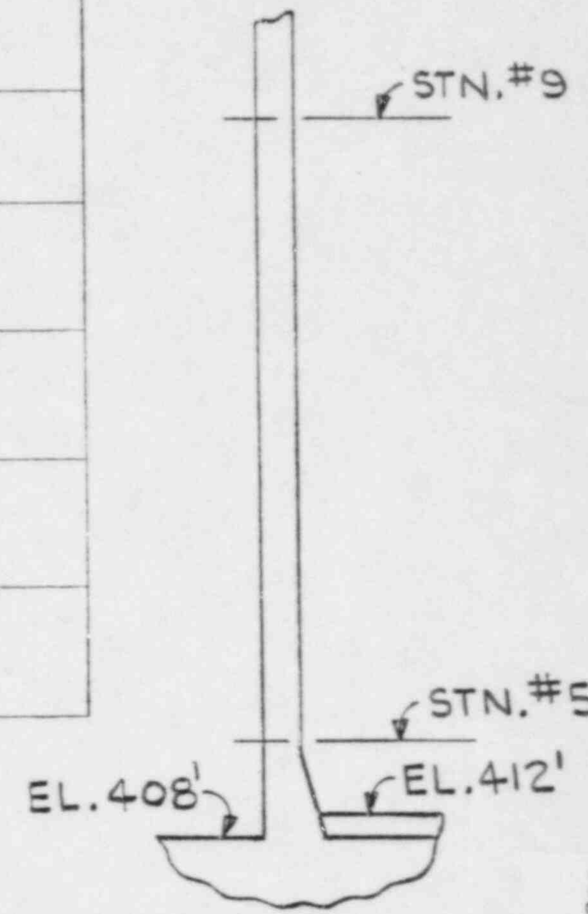

TABLE 1

CAPACITY COMPARISON IN VERTICAL DIRECTION OF WALL - REQUIRED VERSUS PROVIDED BY TENDONS

LOAD COMBINATION	STN #	ELEV. (FT)	MEMBRANE TENSION REQUIRED CAPACITY (KIPS/FT)	MEMBRANE TENSION TENDON CAPACITY (KIPS/FT)	MEMBRANE TENSION TENDON CAPACITY EXCEEDS REQUIRED YES/NO	TANGENTIAL SHEAR (T.S.) CALC. SHEAR (KIPS/FT)	TANGENTIAL SHEAR (T.S.) VERTICAL REINFORCEMENT REQUIRED FOR T.S. (IN^2/FT)	TANGENTIAL SHEAR (T.S.) VERTICAL* REINFORCEMENT AVAILABLE FOR T.S. (IN^2/FT)	TANGENTIAL SHEAR (T.S.) REINFORCEMENT AVAILABLE EXCEEDS REQUIRED YES/NO
Abnormal D + 1.5 Pa	5	420	281	504	Yes	0	0	4.50	Yes
	9	480	317	504	Yes	0	0	2.45	Yes
Abnormal/ Severe Environmental D + 1.25 Pa + 1.25 E	5	420	407	504	Yes	94	1.74	4.50	Yes
	9	480	356	504	Yes	85	1.57	2.45	Yes
Abnormal/ Extreme Environmental D + Pa + E'	5	420	379	504	Yes	113	2.09	4.50	Yes
	9	480	311	504	Yes	102	1.89	2.45	Yes

*Vertical reinforcement available for tangential shear is equal to the area of vertical reinforcement provided and reduced by the ratio of the Embedment Length (E.L.) to the Development Length (D.L.) for bars with E.L. less than D.L. All Cadwelds are assumed to be ineffective.

TABLE 2

CAPACITY COMPARISON IN VERTICAL DIRECTION OF WALL - VERTICAL REINFORCEMENT AVAILABLE FOR TANGENTIAL SHEAR