UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:)	
SOUTH CAROLINA ELECTRIC & GAS COMPANY, et al.)	Docket No. 50-395-OL
(Virgil C. Summer Nuclear Station, Unit 1))	
COUNTY OF BERKS) COMMONWEALTH OF PENNSYLVANIA) ss.	

1. My name is James F. Fulton, and I am the Supervisor of Concrete Containments for the Structural Department of Gilbert Associates, Inc. My current business address is P. O. Box 1498, Reading, Pennsylvania 19603.

2. I hold both a B.S. and a M.S. in Civil Engineering, North Carolina State University, where I was trained as a structural engineer, and I have approximately 15 years of experience as a structural engineer. I am also registered as a professional engineer in the Commonwealth of Pennsylvania. A more detailed resume of my experience is attached as Appendix "A" to this Affidavit and is incorporated by reference as if set forth in full text.

3. I have been associated with the Virgil C. Summer Nuclear Station project since 1971. Although I have had other assignments, I have continued to work on this project until the present date.

4. I have reviewed an undated document entitled "Affidavit in Support of Intervenor's Motion to Reopen Hearings", which is apparently signed by Harold L. Jennings who identifies himself as a former Cadwelder on the Virgil C. Summer Nuclear Station. Mr. Jennings alleges that a number of Cadwelds on vertical reinforcing bars in the containment building for the Virgil C. Summer Nuclear Station were improperly performed and therefore, in his view, defective. I see nothing in Mr. Jennings' Affidavit which indicates he has the engineering qualifications necessary to judge whether such splices have structural or safety significance. As to improper performance, it is not my purpose to address the truth of the allegations. Rather, I have been asked to assess the significance of the conditions which would exist if the allegations were true. Thus, the purpose of this Affidavit is to address the structural significance of assumed

numerous defects in Cadwelds joining vertical reinforcing bars within the containment wall at the Virgil C. Summer Nuclear Station.

5. Containment for the Virgil C. Summer Nuclear Station is provided by the containment structure, a prestressed (post tensioned), reinforced concrete structure comprised of a flat foundation mat, cylindrical wall, steel liner and shallow dome roof. The foundation mat, cylindrical wall, and dome are reinforced with conventional steel reinforcing bars. The cylindrical wall is prestressed in the vertical and horizontal directions by vertical and hoop tendons. The shallow dome roof is prestressed by a three-way tendon system. The inside surface of the reactor building is lined with a carbon steel liner to insure a high degree of leak tightness under operating and accident conditions. (FSAR sections 1.1.3 and 3.8.1.1)

6. Attached hereto, as Appendix "B", and incorporated by reference as if set forth in full text, is a report of an investigation of reactor containment capacity made by Gilbert Associates, Inc. at the request of the Licensees related to the allegations of Cadweld defects. That investigation and report were made and prepared under my supervision and direction.[1/] The discussion in paragraph 7 below summarizes the significant parts of the report.

7. The report addresses two main aspects of containment function when subjected to various load combinations: resistance to membrane forces and resistance to tangential shear forces.

A. The extreme assumption was made that none of the Cadwelds on the vertical reinforcing bars was effective, and it was calculated that the vertical tendons alone have sufficient capacity to resist the membrane and tangential shear forces which result from the design load combinations.

B. However, since the original design criteria considered only reinforcing bars to be effective in resisting the tangential shear force portion of the design loads, the amount of vertical reinforcing bars required to resist the tangential shear forces was also calculated. The calculation indicated that in the worst case (El. 480 ft.), 50% of the existing vertical reinforcing bars would be required to resist the tangential shear forces.

C. Many of the vertical reinforcing bars in the containment wall are #14 and #18 bars, and the current concrete design codes consider only mechanically spliced, e.g. Cadwelded, bars of this size to be

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1/ I am advised that the report has been filed with the NRC Staff under cover of a letter dated September 3, 1982 from O. W. Dixon to H. R. Denton.

effective. Accordingly for the worst case, and again making the conservative assumption that the tendons are not effective in resisting tangential shear, 50% of the Cadwelds on the vertical reinforcing bars would have to be effective to satisfy the code requirements.

D. Nevertheless, in a realistic assessment of the ability of the vertical reinforcing bars to resist the tangential shear forces, calculations indicate that these bars would be able to resist these forces even if the Cadwelds were assumed to be ineffective. This occurs because the vertical reinforcing bars have a development (embedment) capacity due to the general stagger of the Cadwelds and resulting overlap of the bars. This is explained further in the report.

E. In conclusion, based on the discussion above and the evaluation in the report, it is our opinion that the containment would have sufficient capacity to resist the design loads even if the extreme assumption were made that all the Cadwelds on the vertical reinforcing bars were not effective.

8. One other matter should be discussed. I have carefully read the paragraphs addressing the Structural Acceptance Test which appear on pages 8 and 9 of the Affidavit of D. A. Nauman dated September 9, 1982. I am quite familiar with the information set forth in those paragraphs since I was the Lead Structural Engineer in conducting the Structural Acceptance Test. I performed the evaluation of the results of this Test, and I prepared the report (GAI Report No. 2778 dated March 18, 1981) referenced in the Affidavit. To the best of my knowledge and understanding, the information set forth on pages 8 and 9 of the Affidavit regarding the Structural Acceptance Test is true and accurate.

James F. Fulton

James F. Fulton

SWORN to before me this _____ day of ______________, 1982.

______________________________ (L.S.)

Notary Public for Pennsylvania

My Commission Expires: ______________________

APPENDIX A

JAMES F. FULTON
Structural Engineer

Experience in structural engineering and stress analysis involving solid propellant rocket motors, filament wound pressure vessels, plastic structures and nuclear power plant buildings. Concrete Design Specialist, Concrete Containment Specialist, and Post Tensioning Systems Specialist.

EXPERIENCE: 1971 to Present

GILBERT/COMMONWEALTH since 1971

Structural Engineer - Responsible for design and analysis of reactor building containment, including post tensioning system and foundation, and intermediate building and caisson foundation for South Carolina Electric & Gas Company's V. C. Summer Nuclear Station, Unit 1, 900 MW. Also, Responsible Engineer for post tensioning system specifications on V. C. Summer.

Lead Engineer on structural evaluation of delaminated dome for Florida Power Corporation's Crystal River Unit 3 concrete containment.

Specialist in areas of reinforced concrete design, concrete containment design, and post tensioning system materials and design. Projects included:

Lead Engineer responsible for developing structural acceptance criteria for SAT's on V. C. Summer, Unit 1, and Crystal River, Unit 3.

Lead Engineer on Rochester Gas and Electric Corporation's R. E. Ginna tendon evaluation.

Lead Engineer on Crystal River, Unit 3, Metropolitan Edison Company's Three Mile Island, Unit 1, and V. C. Summer, Unit 1, tendon surveillances to adapt these programs to latest NRC Reg Guides.

Lead Engineer on V. C. Summer, Three Mile Island 1, and Perry projects to evaluate hydrogen detnonation effects on containments.

Member of ACI 349 Committee on Nuclear Concrete Structures. As member of the Design Working Group, co-authored a report on designing reinforced concrete structures for thermal effects, which was published by ACI.

Member of Working Group on Concrete Pressure Components of the ASME Subcommittee on Nuclear Inservice Inspection of ASME Code Section XI. Responsible for drafting lift-off force acceptance criteria for post-tensioned containments.

Participant on Design Subgroup of ACI359/ASME Containment Code.

(Continued)

1970-71 Rohm & Haas Company, Bristol, Pennsylvania
Applications Engineer - Design and test of small plastic structures including tanks, signs, and rail covering.

1967-70 Rohm & Haas Company, Huntsville, Alabama
Engineer - Scientist - Involved in stress analysis of solid propellant rocket motors and filament wound pressure vessels.

EDUCATION: B.S.C.E., North Carolina State University, 1965
M.S.C.E., North Carolina State University, 1967 Graduate courses in Solid Mechanics, University of Alabama at Huntsville, 1967-70 Composite Materials, UCLA, 1970 Earthquake Engineering, University of California at Berkeley, 1972 Finite Element Analysis, Engineer's Club of Philadelphia, 1979

REGISTRATION: Professional Engineer - Pennsylvania (1973)

SOCIETIES: American Society of Civil Engineers, Member
American Concrete Institute Member ACI 349 Committee American Academy of Mechanics National Society of Professional Engineers

PUBLICATIONS: "Reinforced Concrete Design For Thermal Effects On Nuclear Power Plant Structures," ACI Journal, Nov.-Dec. 1980.

Tendon Surveillance Requirements - Average Tendon Force. Presented at SMIRT 6, August 1981.

R. E. Ginna Nuclear Power Station, Containment Building Tendon Investigation, GAI Report 2347, February 1982.

V. C. Summer Unit 1 Nuclear Station, Reactor Containment Building, Structural Acceptance Test, GAI Report 2278, March 1981.

APPENDIX B

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 pronorted 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 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.

Conduct Further Hearings, dated August 26, 1982, and apparently

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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 it is believed that the reinforcement will 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 them 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 predicted 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

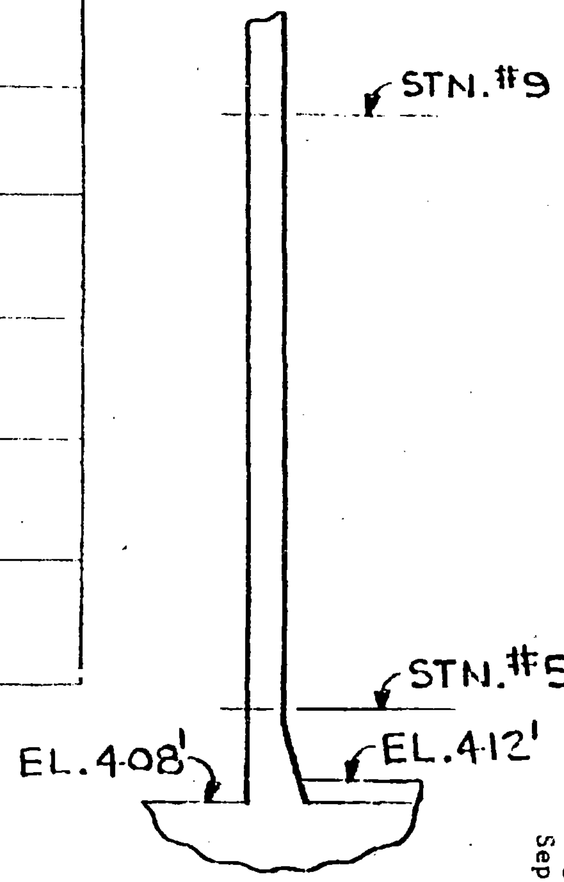

TABLE 1

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