1.8 Tendons Not in Same Plane

Description:

Design calculations assume that the hoop and vertical tendons are located in the same radial plane. In practice, due to limitations in construction, that may not be the case. The potential for tendons to not be in the same radial plane leads to changed stress conditions that can damage the concrete and/or contribute to delamination initiation.

Another factor to consider is the possibility that the sleeves moved during concrete setting due to hoop forces applied on them from the buttresses. The delamination panel 34, together with the opposite panel 16, were the last two panels poured after the other four were already set. The sleeves are then possibly installed with both ends fixed and therefore the sleeves possibly cannot expand freely upon concrete pouring, particularly as the temperature rises due to cement hydration.

Data to be collected and Analyzed:

1. Gather evidence of out-of-plane tendons (FM 1.8 Exhibit 1);
2. Stress analysis of local stress with out-of-plane sleeve arrangements (FM 1.8 Exhibit 2 and FM 1.8 Exhibit 5);
3. Calculate elongation of sleeve due to temperature and outward movement generated when both ends are fixed (FM 1.8 Exhibit 3);
4. Sleeve installation documents (FM 1.8 Exhibit 4);

Verified Supporting Evidence:

a. Photographs show that some hoop tendons are out-of-plane (FM 1.8 Exhibit 1);

C/23

Verified Refuting Evidence:

a. With out-of-plane hoop tendon sleeves, the radial stress that tends to pull the outer layer apart is in fact decreasing with a larger radial loading area and this reduces the driving force to delaminate (FM 1.8 Exhibit 2 and FM 1.8 Exhibit 5);

b. Deviation in planar positioning by one inch to the inside increases the peak tensile stress by a factor of 1.1 only. This is not a major contributor to the overall failure scenario due to the small magnitude and isolated occurrence (FM 1.8 Exhibit 5);

c. Deviation in planar positioning to the outside reduce peak tensile stresses (FM 1.8 Exhibit 5);

d. Construction documents show that the ends of the sleeves, in the cylindrical walls at the buttresses, are not fixed very tight (FM 1.8 Exhibit 4);

Discussion:

The appearance of the sleeve/concrete interface on FM 1.8 Exhibit 1 can be explained in at least two ways:

1. Misalignment during installation of the sleeves before pouring of the concrete. Note that this was pointed out in the case of the vertical tendon sleeves in FM 2.8;

2. Movement of the sleeves during concrete pouring due to thermal expansion of a thick steel sleeve having both ends fixed;

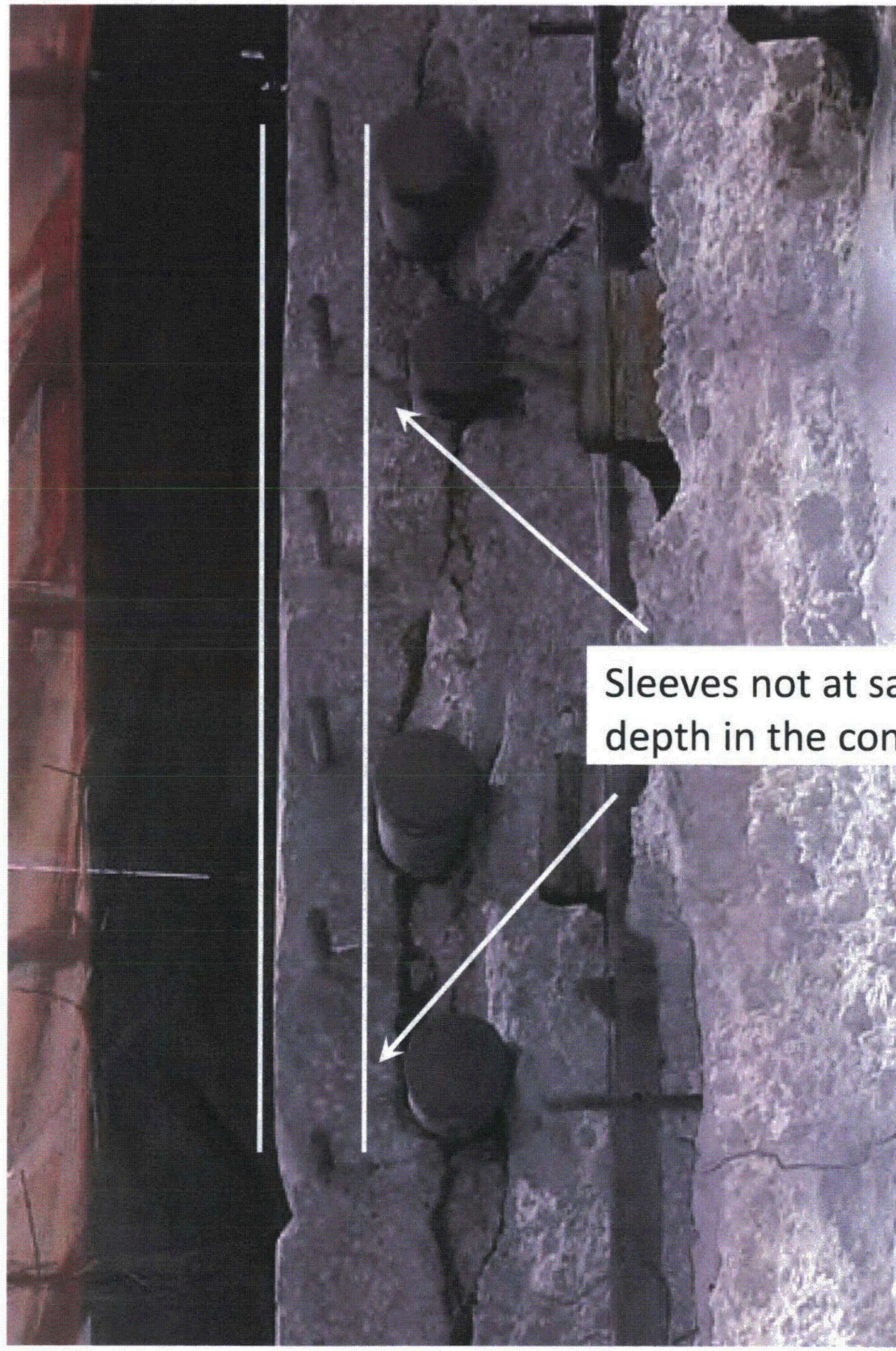
The latter possibility could potentially create very high stresses in the concrete early in the age of the containment.

Observation of construction documents shows that the tendon sleeves are not fixed enough to stay perfectly rigid. They will move and slide slightly, just enough to accommodate the thermal expansion of the sleeve.

Consideration of the changing peak tensile stresses as the hoop tendon sleeves radial position changes within the containment wall show that the increase is limited to 10% when the sleeve comes closer to the inside while all other factors decrease peak tensile stress.

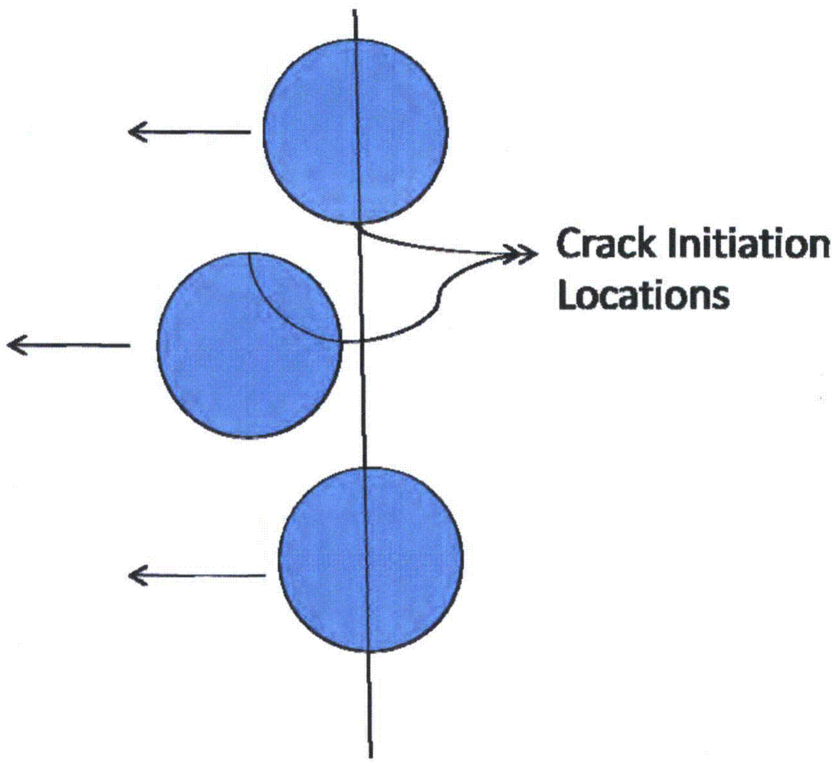
Conclusion:

The analysis shows that out-of-plane hoop tendon sleeves did not lead to the delamination.


Sleeves not at same depth in the concrete

Out-of-plane tendons

The area supporting the local radial tensile stresses is increased when the tendons are not in the same plane, as shown in the simple diagram below. This decreases the local tensile stress and is unfavorable to creating a delamination.



2/9/10 Outward bending from sleeve

(i) $L = 60\ ft$
$CTE = 6 \times 10^{-6}\ /°C = 4 \times 10^{-6}\ /°F$

However, ΔT is not large, and not positive $\Rightarrow$ movement of the sleeve is inward

Maximum $\Delta T = -25°F$

$\Rightarrow \Delta L = 60\ ft \times 4 \times 10^{-6}\ /°F \times -25°F$
$= 6 \times 10^{-3}\ ft$
$= 0.072\ in$ (very small)

(ii) If use $CTE = 6.5 \times 10^{-6}\ /°F$
and $\Delta T = 70°F$
$\Rightarrow \Delta L \sim 0.3\ in$

(iii) Assume the tendon remains a semicircle,
$\frac{\Delta r}{r} = \frac{\Delta L}{L} \Rightarrow \Delta r = 812\ in \times \frac{0.3\ in}{60 \times 12\ in}$

$\Delta r = 0.34\ in$ (from $L = 2\frac{\pi r}{6}$)

(that's a lot)

The Tendon sleeves (also referred to as conduits) have different material specifications and installation requirements depending in whether they are located in the Dome or the six cylindrical sections of the containment. The sleeve material and installation specifications are contained in FM 1.8 Exhibits 4a and 4b. The Dome tendon sleeve sections are joined together using couplings and are welded to the couplings (FM 1.8 Exhibit 4a paragraphs 3:08, 3:08.7; FM 1.8 Exhibits 4c and 4d, DRWs SC-421-046 and SC-421-41 respectively).

There is no similar requirement for connecting the tendon sleeves located in the six cylindrical sections of the containment; especially the sleeve connection between end of the sleeve and the trunk, which are located within the buttresses (FM 1.8 Exhibit 4b paragraphs 4:07.1 and 4:07.3). Although the precise attachment mechanism for the tendon sleeves in the six cylindrical sections is unknown, the recent SGR hole cut provided and example of the type of connection used in the containment wall (FM 1.8 Exhibits 4e and 4f). It is noted that the bracket found in the removed sleeve connection does not appear in any of the drawings where the ends of the sleeves attach to the trunks within the buttresses. (FM 1.8 Exhibits 4g, 4h, and 4i)

FLORIDA POWER CORPORATION
POWER ENGINEERING & CONSTRUCTION DEPT.
CRYSTAL RIVER - UNIT 3
APPROVED BY:
Engineer [signature] Date 11/24/71
Mgr. - Power Engr. ORIGINAL SIGNED BY W. A. SZELISTOWSKI Date 11/26/71
Nuclear Proj. Mgr. ORIGINAL SIGNED BY J. T. RODGERS Date 11/29/71

REQUIREMENT OUTLINE

PRESTRESSING SYSTEM TENDON CONDUIT

CRYSTAL RIVER - UNIT NO. 3
FLORIDA POWER CORPORATION

RO-3040 JUNE 12, 1970

FPC NO. 321-B4.1B

[signature] 11-17-71
APPROVED - DEPT. PROJECT ENGR. DATE

[signature] 11-17-71
ISSUED FOR CRYSTAL RIVER - UNIT 3 DATE

QUALITY PROGRAM
REVIEW and DOCUMENTATION
REQUIRED

REVISION	REVIEW & DOCUMENTATION REQUIRED		DESIGN ENGINEER
	YES	NO	
A	✓		
B		✓	[signature]

Gilbert Associates, Inc.
525 Lancaster Avenue
Reading, Pennsylvania

S.N.D.-M.L.L.
W.O. 4203-00
ADDENDUM A
May 13, 1971
ADDENDUM B
November 17, 1971

3:05.2 After fabrication has been completed, temporary end caps shall be placed over each end of each section of conduit. These end caps must be securely fixed to the end of the conduit so that normal transportation, handling, etc. will not cause them to be removed or enter the inside of the conduit. The conduit must be clean and dry prior to placing the end caps.

3:06 <u>Rigid Conduit</u>

3:06.1 Rigid conduit shall be round mechanical welded steel tubing 5-1/4 inch O. D. and shall have a minimum wall thickness of 0.065 inches and a minimum I.D. of 5 inches. Conduit shall be manufactured according to ASTM A 513-69, "Standard Specifications for Resistance Welded Steel Tubing." The supplemental requirement of non-destructive Electric Test on the welded seam will be required for all conduit.

3:06.2 Rigid conduit shall be accurately cut and bent to the dimensional requirements as shown on the Florida Power Corporation drawings. Rigid conduit shall have belled ends as detailed and located on the drawings. Quantities of rigid conduit to be supplied under this contract shall be as indicated on the drawings and in this Requirement Outline.

3:06.3 The CONTRACTOR shall provide shop drawings and lists for conduit fabrication and identification, for each length of conduit. Shop drawings shall provide all dimensional information required to fabricate and identify the conduit. Shop drawings shall be submitted to the ENGINEER for approval.

3:06.4 A conduit numbering and identification system will be developed by the OWNER, ENGINEER and CONTRACTOR. Each length of conduit shall be clearly marked with this number for identification on the job site.

3:06.5 In addition to the conduit quantities represented on the drawings, the CONTRACTOR shall supply with the first shipment of Rigid conduit the following stock lengths of conduit, each of which shall have one end belled:

1. Straight conduit
   - 20 lengths @ 20 feet each, total 400 lineal feet.
   - 20 lengths @ 10 feet each, total 200 lineal feet

2. Bent conduit (67' 8-5/8" radius)
   - 20 lengths @ 30 feet each, total 600 lineal feet.
   - 20 lengths @ 20 feet each, total 400 lineal feet.

3:07 Flexible Conduit

3:07.1 Flexible conduit must be capable of being bent by hand to the radii shown on the Florida Power Corporation drawings. Flexible conduit shall be 5 inches I. D. and 5-1/4 inches O.D., minimum 22 gauge (0.028) galvanized steel.

3:07.2 Gasketing materials shall be incorporated in the conduit if necessary to meet the leak-tightness criteria. The gasketing materials shall not decompose when subjected to site weathering and shall be subject to approval by the OWNER and the ENGINEER. The CONTRACTOR shall supply a sample length of the proposed conduit, upon request of the OWNER or ENGINEER, prior to award of contract.

3:07.3 Flexible conduit will be supplied to the job site in 50 foot lengths. The conduit will be cut to length in the field by Others.

3:07.4 The CONTRACTOR shall hydrostatically test the Flexible conduit, to verify conformance with the pressure criterion listed under item 3:04.1. The tests shall be conducted on production samples of conduit, bent to a minimum radius of 20 feet 0 inches. The frequency of conduit testing shall be a minimum of 10% of the total shipment or shop order, randomly distributed over the total footage. The OWNER and ENGINEER shall have access to witness all testing. Test records shall be kept and forwarded to the OWNER and ENGINEER.

3:08 Schedule 40 Conduit

Note: Schedule 40 conduit shall be used in the mat and the dome of the reactor building. The requirements for the Schedule 40 conduit in the mat are noted in items 3:08.1 through 3:08.4 inclusive, and the requirements for the Schedule 40 conduit in the dome are noted in items 3:08.3 through 3:08.7 inclusive. A

3:08.1 The conduit shall be galvanized round steel pipe, 5 inch I. D. Schedule 40, types E or S, grade A, conforming to ASTM A 53-70, "Welded and Seamless Steel Pipe."

3:08.2 The Schedule 40 conduit shall be accurately cut and bent to the dimensional requirements as shown on the Florida Power Corporation drawings. The Schedule 40 conduit shall have sleeve type welded couplings as detailed and located on the drawings. Quantities of Schedule 40 conduit to be supplied under this Contract shall be as indicated on the drawings and in this Requirement Outline.

3:08.3 The CONTRACTOR shall provide shop drawings and lists for conduit fabrication and identification for each length of conduit. Shop drawings shall provide all dimensional information required to fabricate and identify the conduit. Shop drawings shall be submitted to the ENGINEER for approval.

3:08.4 A conduit numbering and identification system will be developed by the OWNER, ENGINEER and CONTRACTOR. Each length of conduit shall be clearly marked with this number for identification at the job site.

3:08.5 The dome conduit shall be galvanized round steel pipe, 5 inch nominal diameter Schedule 40, types E or S, grade B wall thickness 0.258 inches, conforming to ASTM A 53-70, "Welded and Seamless Steel Pipe." B

3:08.6 The dome conduit shall be accurately cut and bent to the required dimensions and as shown on the drawings accompanying this Requirement Outline. The CONTRACTOR shall locate the joints in a dome conduit run (a dome conduit run is from trumpet to trumpet for a particular tendon) to suit his manufacturing and handling requirements, provided he complies with the following:

1. Joints shall not be made at the intersection of conduits.

2. Joint location adjacent to the ring beam shall be as shown on drawing number SC-400-019 "Reactor Building - Dome Conduit Splice Locations Required Adjacent to Ring Beam."

3. The minimum length of a section of dome conduit shall be 20'-0". The dome is defined as that area within a horizontal radius from the centerline of reactor building of 55'-5-1/2". A

Quantities of Schedule 40 conduit to be supplied under this Contract shall be as indicated on the drawings.

3:08.7 Sections of dome conduit shall be joined together at each joint, with a sleeve type coupling. All sleeve couplings shall be made from round steel pipe, 6 inch nominal diameter, types E or S, grade B, wall thickness 0.432 inches, conforming to ASTM A 53-70. B Details of the couplings are shown on drawing SC-400-019. The CONTRACTOR shall weld onto one end of each section of conduit a coupling, except for the section of the conduit which is nearest to the apex of the dome of each conduit run. For this latter case the CONTRACTOR shall forward to the job site sufficient loose couplings to allow installation of the apex section of conduit. The welds shall be fillet type and shall develop the full strength of the conduit. The CONTRACTOR shall submit details of the weld to the OWNER and the ENGINEER for approval. The CONTRACTOR'S welders, who are to perform the shop welding, shall be qualified in accordance with the recommendations of AWS D1.0. The CONTRACTOR shall develop written welding work procedures and submit them to the OWNER and the ENGINEER for approval. The work procedures shall also include:

1. Removal of galvanizing from weld area on outside of the conduit.

2. 10% random liquid penetrant inspection of the shop welds.

ADDENDUM A

Sheet 2 of 3
May 13, 1971

3. The minimum length of a section of dome conduit shall be 20'-0". The dome is defined as that area within a horizontal radius from the centerline of the reactor building of 55'-5-1/2".

Quantities of Schedule 40 conduit to be supplied under this Contract shall be as indicated on the drawings.

"3:08.7 Sections of dome conduit shall be joined together at each joint, with a sleeve type coupling. All sleeve couplings shall be made from round steel pipe, 6 inch nominal diameter, types E or S, grade A, wall thickness 0.432 inches, conforming to ASTM A 53-70. Details of the couplings are shown on drawing SC-400-019. The CONTRACTOR shall weld onto one end of each section of conduit a coupling, except for the section of conduit which is nearest to the apex of the dome of each conduit run. For this latter case the CONTRACTOR shall forward to the job site sufficient loose couplings to allow installation of the apex section of conduit. The welds shall be fillet type and shall develop the full strength of the conduit. The CONTRACTOR shall submit details of the weld to the OWNER and the ENGINEER for approval. The CONTRACTOR'S welders, who are to perform the shop welding, shall be qualified in accordance with the recommendations of AWS D1.0. The CONTRACTOR shall develop written welding work procedures and submit them to the OWNER and the ENGINEER for approval. The work procedures shall also include:

1. Removal of galvanizing from weld area on outside of the conduit.

2. 10% random liquid penetrant inspection of the shop welds.

3. Hydrostatic pressure testing of the weld to ensure leak tightness, to the criteria noted in Item 3:04. The frequency of testing shall be a minimum of 10% of the couplings, selected at random.

4. Painting inside and outside of the coupling and the ungalvanized and heat effected areas of the conduit. The type of paint used shall be capable of preventing corrosion of the conduit for a minimum period of 1-1/2 years, when exposed to the job site environment. The CONTRACTOR shall submit details of the paint to the OWNER for approval."

PRELIMINARY
SPECIFICATION

TENDONS AND ASSOCIATED CONDUIT
REACTOR BUILDING

P-SP-5583 AUGUST 9, 1968

CRYSTAL RIVER - UNIT NO. 3
FLORIDA POWER CORPORATION

FPC-321-B4.3

Gilbert Associates, Inc.
525 Lancaster Avenue
Reading, Pennsylvania

S.N.D.-W.A.D.
W.O. 4203.00

strand in the tendon. The anchor fitting shall be machined and threaded prior to the assembly. After assembly, the axis of the anchor fitting and strand circle shall not be more than 1/4 inch apart nor 1/4 inch from the original axis. Prior to fabrication, procedures shall be developed to ensure that the above tolerances have been met. These procedures shall be submitted to the OWNER for review and approval. Tendons that do not meet the above tolerances shall be rejected. Tendons shall be banded at a spacing of no greater than 10 ft on centers following twisting so as to equalize the strand length across the bundle. The bands shall be approved by the ENGINEER. These bandings shall be removed immediately before the tendon is inserted in the conduit.

4:07 Conduit

4:07.1 General:

The conduit for the tendons shall not be less than 22 gauge steel, not galvanized and shall be so constructed that a hydrostatic pressure of 10 psig can be maintained without leaking water. The conduit shall be sufficiently strong to withstand the weight of a two hundred pound man without a permanent deformation. All conduit that has a permanent deformation shall be replaced prior to placing concrete. Prior to fabrication, procedures to ensure strength and water tightness as specified above shall be developed and submitted to the OWNER and ENGINEER for approval. The vertical conduit through and extending 2'-0" above the foundation shall be Schedule 40 pipe conforming to "Welded and Seamless Steel Pipe, Spec. for," ASTM A 53-67. For each band of dome tendons the conduit, spaced at no greater than 2'-0" center to center, shall be Schedule 40 pipe, conforming to "Welded and Seamless Steel Pipe, Spec. for," ASTM A 53-67. Any additional intermediate conduits required in the dome need only meet the performance criteria specified hereinbefore. The shipping details for all conduit shall be approved by the OWNER and ENGINEER. The CONTRACTOR shall specify but not furnish the frequency and type of supports required for the conduit being furnished.

4:07.2 Corrosion Protection of Conduit:

Both surfaces of the conduit shall be coated with a corrosion inhibitor approved by the ENGINEER immediately after fabrication. The inside surface of the conduit shall be coated with a wax with corrosion inhibitors, as specified hereinafter, in the field. The ends of the conduit shall be capped to prevent the entrance of moisture and shall remain capped during construction. The conduit shall be shipped and stored in a manner to prevent excessive corrosion. A temporary end enclosure shall be installed after the tendons are tensioned. The temporary end enclosure shall be approved by the ENGINEER. Prior to fabrication, procedures for coating, shipping and storing the conduit shall be submitted to the OWNER and ENGINEER for approval.

4:07.3 Conduit Testing:

Ten percent of all flexible conduit shall be tested to verify compliance to item 4:07.1 of this Specification. Records of all tests shall be submitted to the OWNER and ENGINEER prior to shipment of fabricated conduit to the job site.

4:08 Design Bases

4:08.1 The required effective prestress force at any section shall be based upon the following requirements:

1. Vertical force of 457 kips per foot of circumference at a radius of 67'-3".

2. Hoop force of 829 kips per foot of vertical height at a radius of 67'-7", the hoop force for the lower ten feet of wall shall be 415 kips per foot.

3. Dome force of 820 kips per foot of circumference at a radius of 60'-0".

4:08.2 The controlling dimensions for tendon length and curvature shall be as shown on the Drawings. The minimum concrete cover over any tendon conduit shall be 6 inches.

4:08.3 The following minimum coefficients shall be used in the design of the final prestress forces:

1. Straight tendons (vertical tendons without curvation):

   a. $\mu = 0.0$

   b. $K = 0.0$

   c. $\alpha = 0.0$

2. Curved tendons (curved vertical, hoop and dome tendons):

   a. $\mu = 0.16$

   b. $K = 0.0003$

   c. α shall be as shown on the Drawings.

3. Creep and shrinkage strains shall have the following values:

ADDENDUM A

Sheet 1 of 3
June 7, 1972

TITLE PAGE

Delete the existing title and replace with the following title:

"TENDONS - REACTOR BUILDING"

SECTION IV - DETAILED SPECIFICATIONS

4:01 Scope of Work

4:01.1 Delete this item in its entirety.

4:01.2 Alternate Scope of Work:

Lines 2 and 3, after the sixth word "tendons" delete the following words:

"and their associated conduit"

Subitem 1., lines 1 and 2:

After the sixth word "tendons" delete the following words:

"and associated conduit"

4:02 Work Not Included

Subitem 4.:

Delete this subitem in its entirety.

4:05 Materials

4:05.1 Subitem 1.:

Line 1, after the fourth word "be" delete "1/4 in." and replace with the following:

"7mm"

Line 2, after the eighth word "to" add the following words:

"the applicable portion of"

ADDENDUM A

Sheet 2 of 3
June 7, 1972

4:06 Manufacturing Procedures

Subitem 1., Wire System:

Subitem a., lines 1 and 2; after the fifth word "upset" delete the words "to a nominal diameter of 3/8 inch." and replace with the following:

"type."

Subitem b., delete this subitem in its entirety and replace with the following:

"b. The CONTRACTOR shall develop a buttonhead criteria and shall submit it to the OWNER and the ENGINEER for approval. The criteria shall demonstrate that the buttonhead is at least as strong as the wire."

Subitem c., delete this subitem in its entirety.

4:07 Conduit

Delete this Item in its entirety.

4:09 Corrosion Protection

4:09.2 During and After Installation:

Delete this item in its entirety.

4:09.3 Material:

Subitem 1., delete this subitem in its entirety and replace with the following:

"1. The material for permanent corrosion protection of the tendons shall be Visconorust 3001A as manufactured by the Viscosity Oil Company, or EQUAL."

Subitem 2., line 1; after the second word "following" delete the following word:

"additional"

ADDENDUM A

June 7, 1972

4:10 Tensioning

4:10.1 Delete this item in its entirety and replace with the following:

"4:10.1 The CONTRACTOR shall submit to the OWNER predicted elongations for each tendon at each stressed end. The CONTRACTOR shall be available for consultation with the OWNER and the ENGINEER during all phases of installation and stressing."

4:10.2 Delete this item in its entirety and replace with the following:

"4:10.2 The CONTRACTOR shall forward to the OWNER load - strain curves certifying physical properties for each mill heat of steel used for tendons."

4:10.3 Delete this item in its entirety.

4:12 Quality Control Measures

4:12.1 Test Reports:

Subitem 4., lines 2 and 3:

Delete the following sentence:

"The numbering system will be furnished by the ENGINEER."

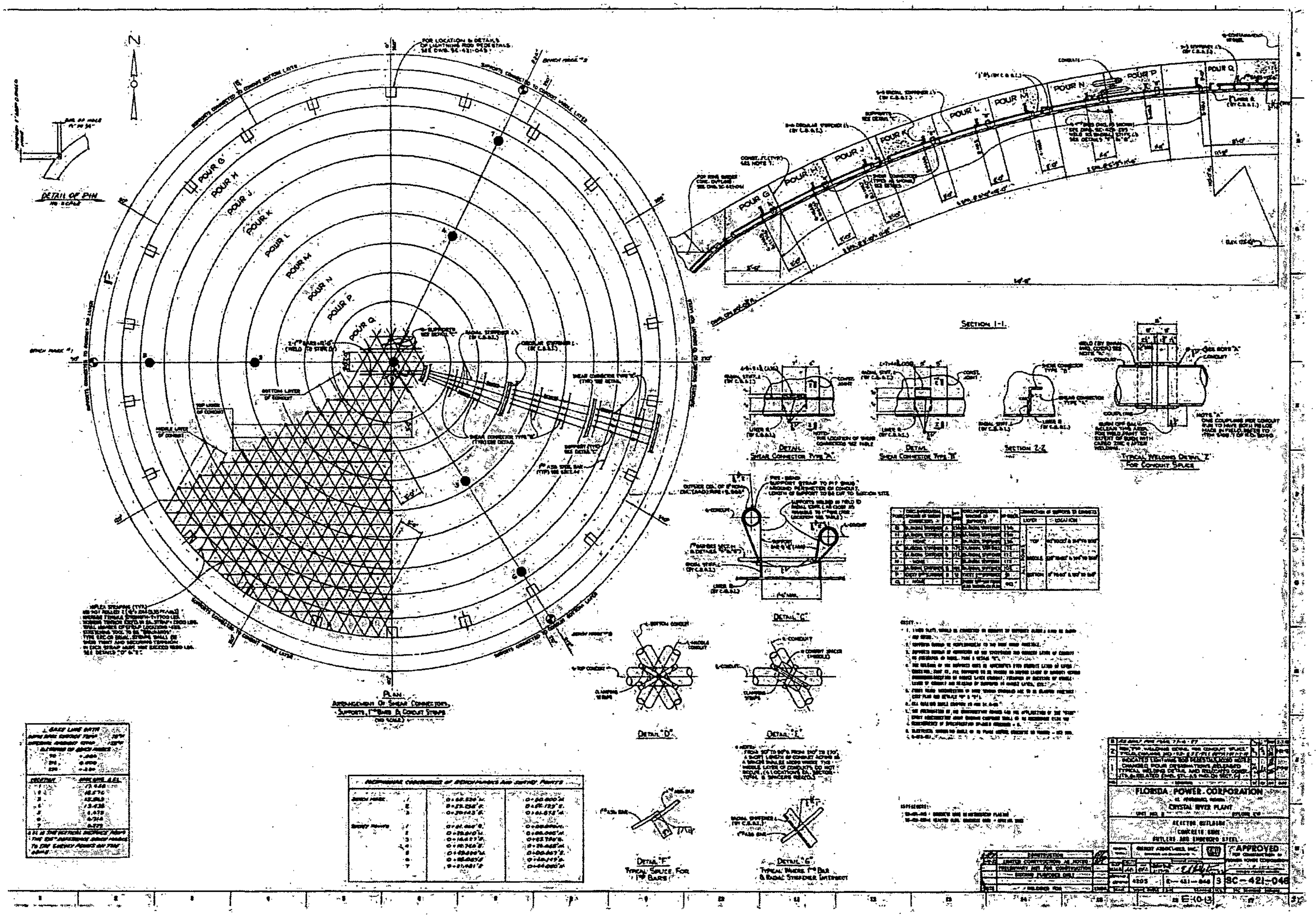
4:12.4 Wax Coverage Test:

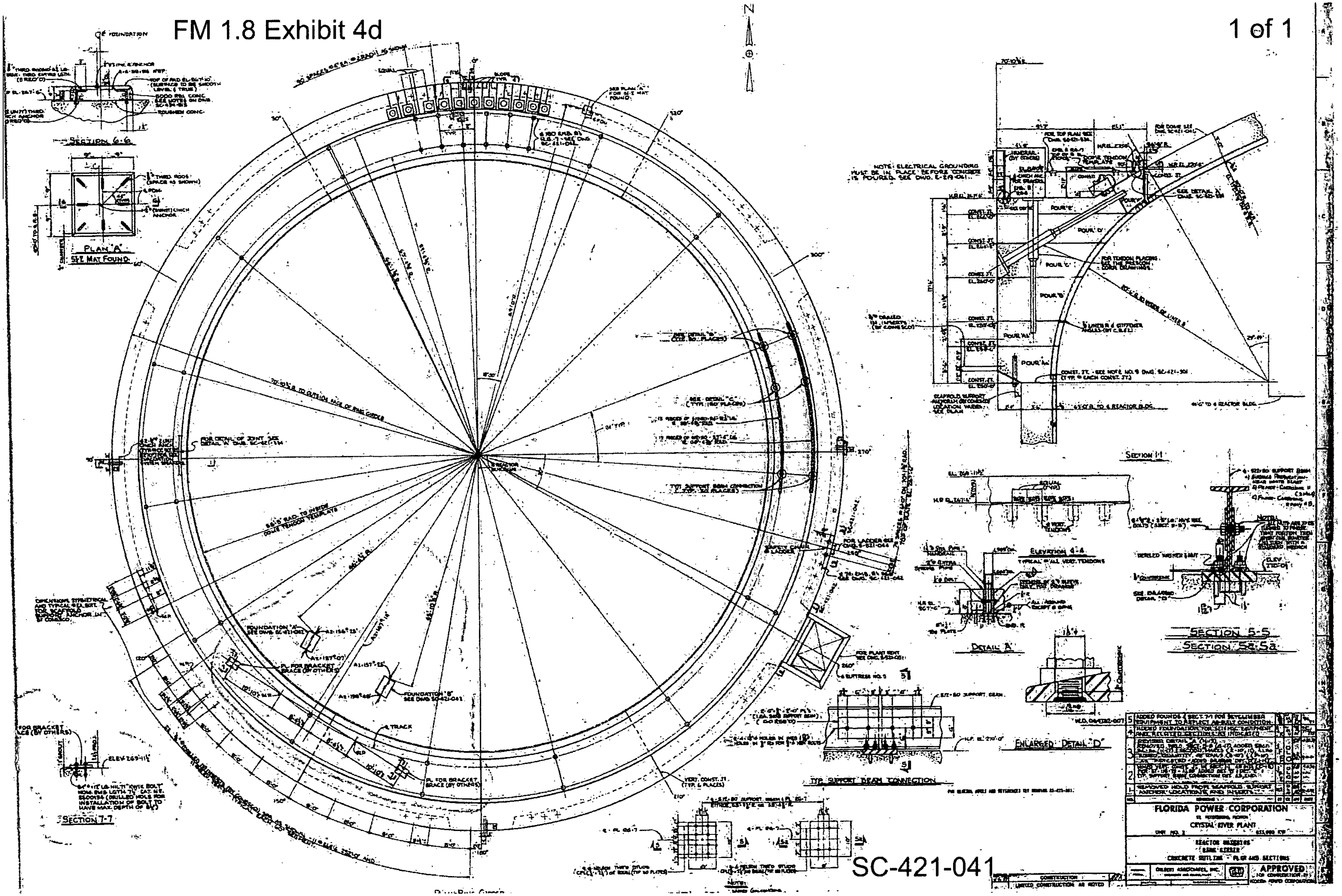
Delete this item in its entirety and replace with the following revised item:

"4:12.4 Wax Coverage Test:

The CONTRACTOR shall perform a test to check the final wax coverage on the tendons. The tendon shall be coated as specified in Item 4:09 of this Specification. The ENGINEER and the OWNER shall witness this test and shall be notified two weeks prior to the test."

NOTE: Enclosed herewith is a revised title page and a completely revised Section IV which reflect the changes set forth by this Addendum. Please replace old title page and Section IV of the Specification with the enclosed revised title page and Section IV.

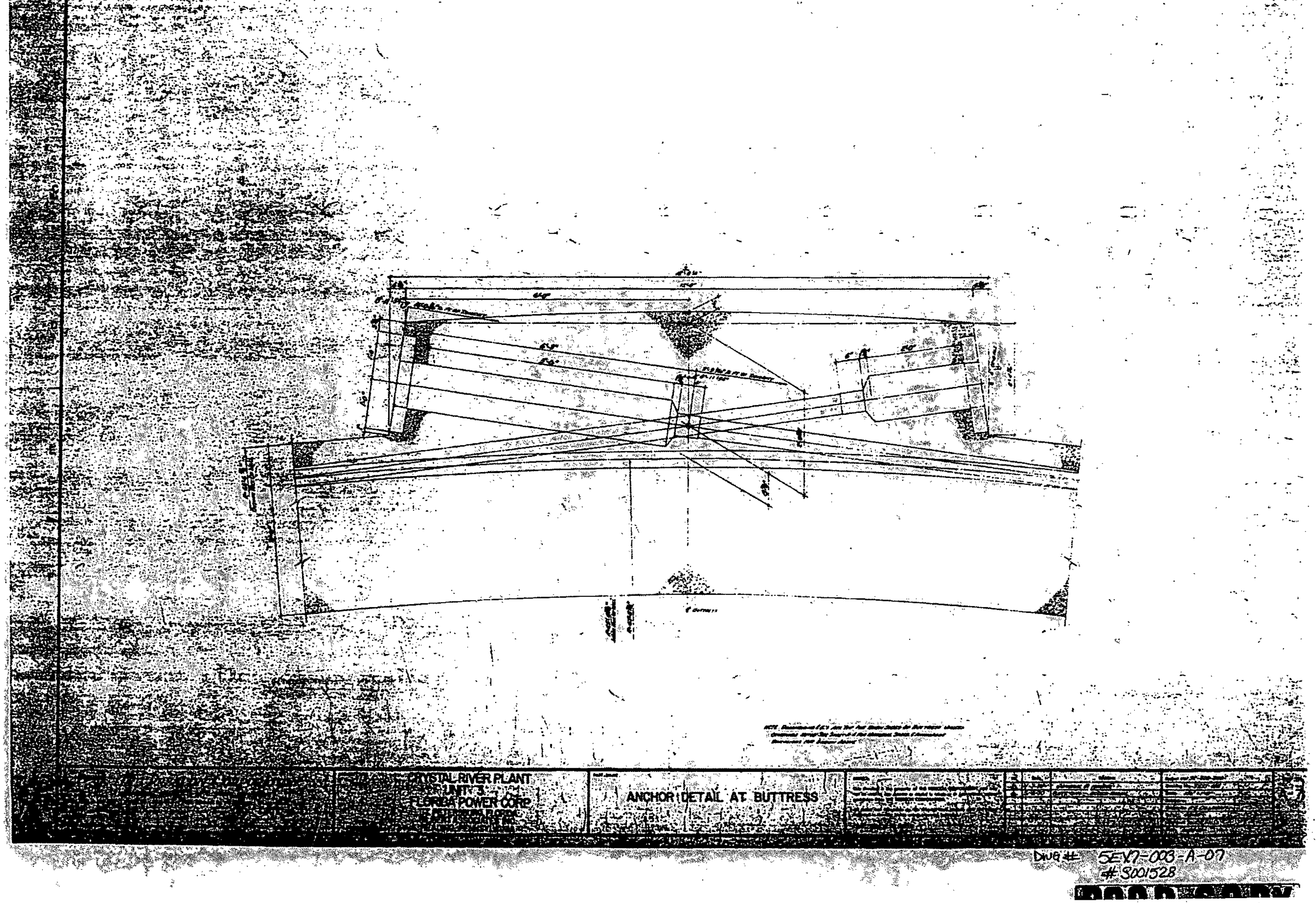

POUR G
POUR H
POUR J
POUR K
POUR L
POUR M
POUR N
POUR P
POUR Q
SECTION 1-1
DETAIL "C"
DETAIL "D"
DETAIL "E"
FLORIDA POWER CORPORATION
CRYSTAL RIVER PLANT
APPROVED

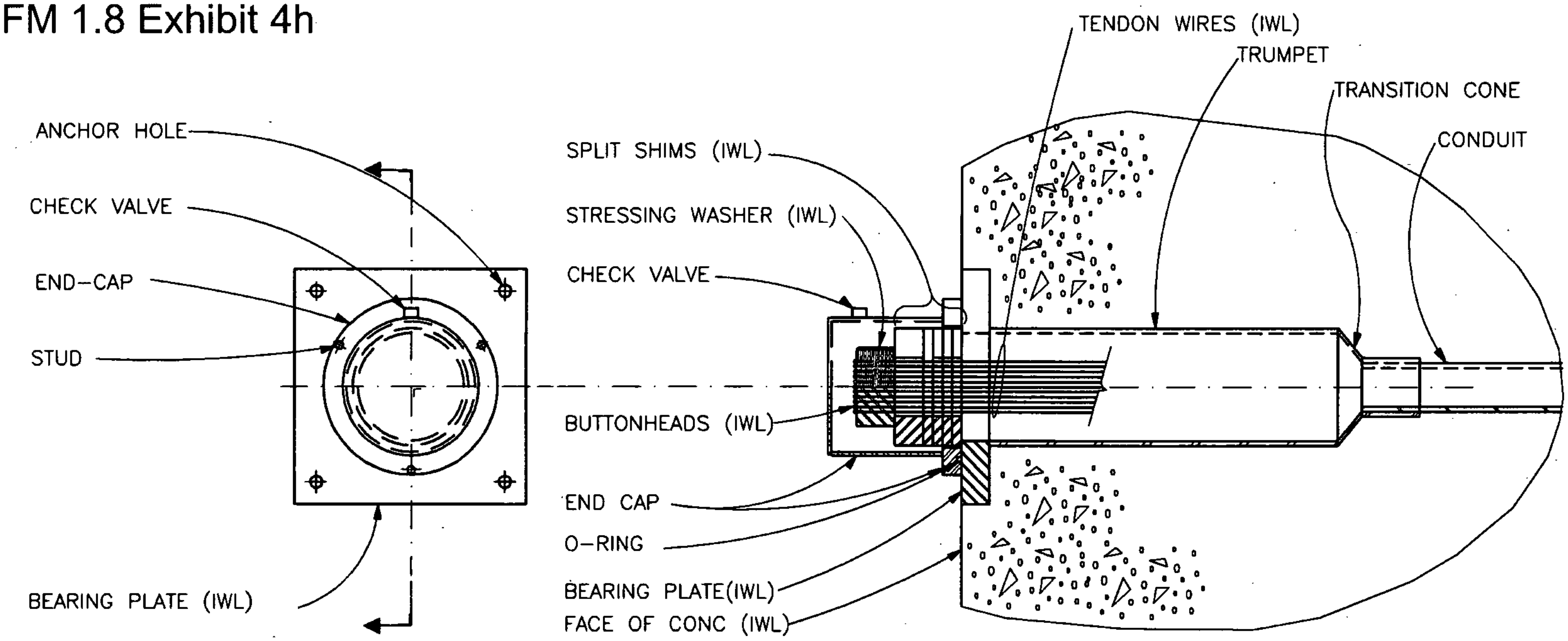

N
SECTION 6-6
PLAN "A"
SECTION I-I
ELEVATION 4-4
DETAIL "A"
SECTION 5-5
SECTION 5a-5a
ENLARGED DETAIL "D"
TYP. SUPPORT BEAM CONNECTION
SECTION 7-7
FLORIDA POWER CORPORATION
CRYSTAL RIVER PLANT
APPROVED

SC-421-041


02/10/2010

FM 1.8 Exhibit 4f


CRYSTAL RIVER PLANT
UNIT 3
FLORIDA POWER CORP.
ANCHOR DETAIL AT BUTTRESS
DWG # 5EX7-003-A-07
#S001528



ELEVATION.

SECTION

NUCLEAR SAFETY RELATED

REFERENCE VENDOR DRAWINGS.(PRESCON CORPORATION)

5EX7-003-A-1	163 WIRE-7MM ANCHORAGE ASSEMBLY DEAD-END BOTTOM VERT.
5EX7-003-A-2	163 WIRE 7MM DEAD END PLATE BOTTOM VERT.
5EX7-003-A-3	163 WIRE-7MM ANCHORAGE ASSEMBLY STRESSING END TOP VERT.
5EX7-003-A-4	163 WIRE 7MM ANCHORAGE ASSEMBLY HOOP & DOME PLATES.
5EX7-003-A-9	PROTECTIVE END CAP STRESSING END.
5EX7-003-A-9A	PROTECTIVE END CAP - BOTTOM VERTICALS.
5EX7-003-A-10	PROTECTIVE END CAP - HOOP, DOME AND UPPER VERTICAL ENDS.
5EX7-003-P-10A	HORIZONTAL TENDON DETAIL - BETWEEN 120°-180°.

NO.	DESCRIPTION	DRAWN	CHKD	APPR.	DATE
1	ISSUED PER DCN 99-016	MAD	LSM	CEE	2/18/99

REVISIONS

FLORIDA POWER CORPORATION

NUCLEAR ENGINEERING

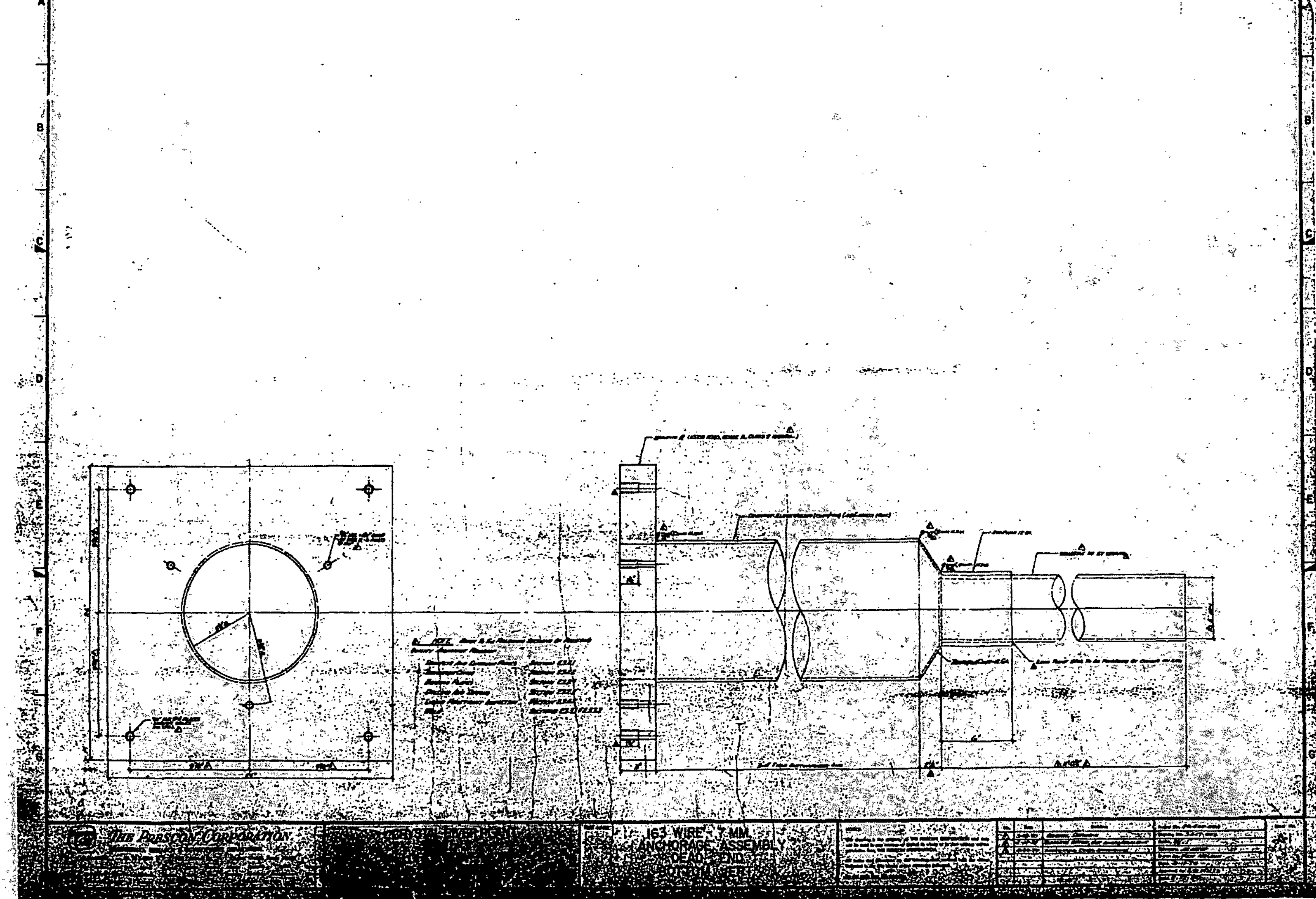
CRYSTAL RIVER UNIT 3

IWE/IWL INSPECTION SHEET TENDON DETAIL

DRAWN	CHKD.	APRVD.	DATE	SCALE
D.C.	CAS	CAS	08/31/98	NONE

DISCP.	SHEET	DWG.	REV.
S	1	S-425-020	1

FILE:S425020.DWG



DWG # SEY7-003-A-01
#S000031

FM 1.8—Increased Stresses Due to Horizontal Tendons Not in the Same Plane

Containment design dictates the center of the hoop tendon sleeves are to be at 812" from the center of containment. This corresponds to 10" in from the outer surface of the concrete wall. Observations have found some of the tendons visibly differing from this expectation (see FM 1.8 Exhibit 1). Failure Mode 1.8 evaluates the significance of that condition. This analysis quantifies the impact on peak tensile stress.

The peak tensile stress in the concrete occurs at the top and bottom of each horizontal tendon conduit hole. This is shown in Figure 1 below (MPR Calculation #0102-0135-05). This is a known stress concentration effect and it is addressed at length in FM 1.2. note that it is primarily a radial tensile stress as both hoop and vertical stresses are highly compressive in all areas.

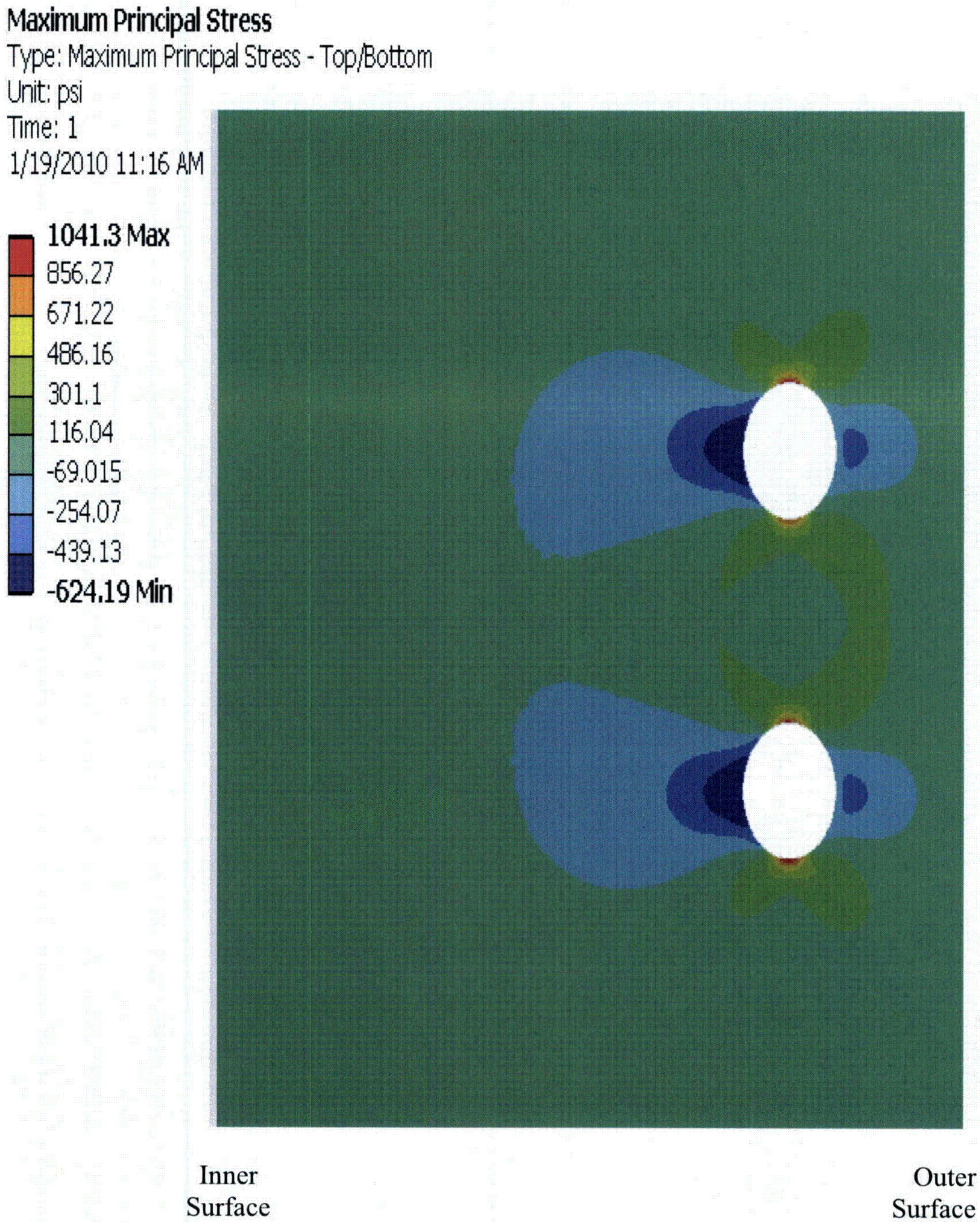


Figure 1: Maximum principal stresses around the hoop tendon sleeves show peak tensile stresses at the top and bottom of the sleeves

The stress shifts from compressive to tensile at the centerline of the horizontal tendon conduit because those tendons provide that compressive stress. The relative peak tensile stress is given by the equation:

Relative Peak Tensile Stress = 100% * d / 42, where d is the distance in inches from the outer surface to the horizontal tendon conduit center (see FM 1.2 for additional details).

For the nominal CR3 case (every tendon aligned), the peak relative tensile stress is 24% (d =10"). If the distance is reduced from the nominal 10" to 9" the peak relative tensile stress drops to 21%. This reduces the peak tensile stresses.

If the distance is increased from the nominal 10" to 11", the peak relative stress increases to 26%. That has a negative effect on minimizing tensile stresses. However, there is a compensating effect. Delamination occurs when cracks propagate from one tendon hole to the next. At the critical radius (10" in from the outer surface) the tendon sleeves take up 28% of the available area (see FM 1.12 for more details). This reduced effective area raises the peak tensile stress to 139% of what they would be with no conduits taking up available space. By moving a conduit out of the radial plane, the available concrete is increased.

Figure 2 shows the out-of-plane effect on the peak stress locations (red) and shows that the peak stress is applied over a greater cross-sectional area. This reduces the effective tensile stress. The effect is calculated to be about 0.5% (Figure 2 exaggerates the displacements of the peak stress locations).

Another benefit is the movement of the peak stress. In a hole in a uniformly stressed material, the peak stress is a factor of 3 located at top and bottom of the hole. If this is shifted around it will drop the peak slightly. Again, the effect will not be large.

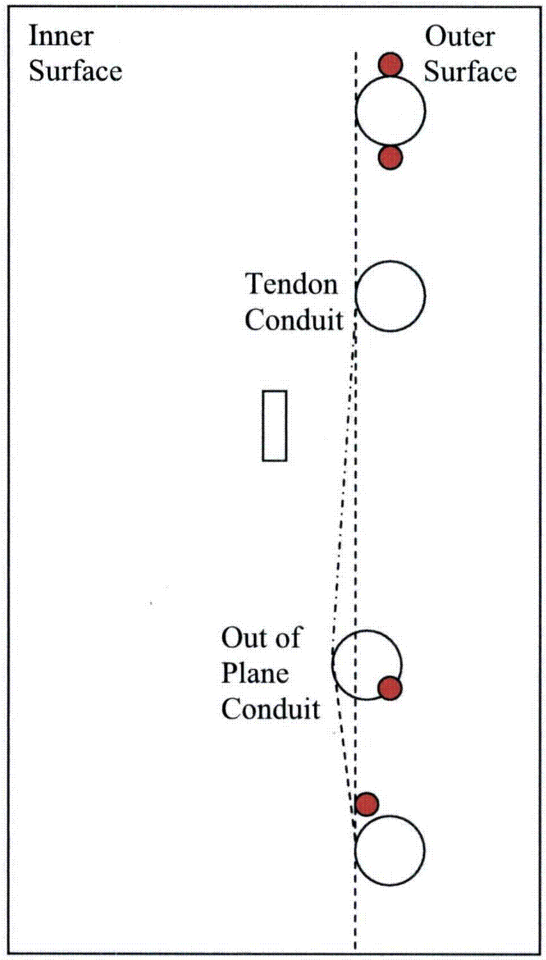


Figure 2: An out-of-plane hoop tendon sleeve leads a larger cross-sectional area and a slight movement of the location of the peak stress. Both effects reduce the effective peak tensile stress.

In conclusion, deviation in planar positioning by one inch to the inside (which is reasonable based upon a review of the photographs of the tendon positions) will increase stresses by a factor of 1.1. This is not a major contributor to the overall failure scenario due to the small magnitude and isolated occurrence. Deviation in planar positioning to the outside and changes in effective areas reduce stresses.

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