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SUPPLEMENTAL INFORMATION ON REACTOR BUILDING DESIGN AND CONSTRUCTION

THREE MILE ISLAND NUCLEAR STATION

METROPOLITAN EDISON COMPANY

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Supplemental Information on

Reactor Building Design and Construction

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1. GENERAL CRITERIA

The tendons, including anchorage components, and the anchorage zone will be designed generally in accordance with the criteria for the Reactor Building as defined in Appendix 5B Three Mile Island Nuclear Station Preliminary Safety Analysis Report (PSAR) and are classified as Class I elements per the definition contained in Appendix 5A of the PSAR.

The strength of the Reactor Building is not dependent upon developing the ultimate strength of the tendons and anchorage components, but is controlled by stresses and strains in the concrete and liner. However, the tendons and hardware are designed and tested to a severe criteria to ensure development of the ultimate capacity of the tendons. As an example the anchor nuts are proof tested for the ultimate load of the tendons as an acceptance criteria. In addition, performed tests indicate that the nut has an ultimate capacity of approximately 50 percent greater than the minimum specified ultimate strength of the tendon as reported in Amendment 11 of the PSAR.

The anchorage zone will be designed in accordance with the ACI codes and the PCI recommendations. The reinforcement in the anchorage zone will be designed to the provisions of the ACI 318-63, "Working Stress Design" and "Prestressed Concrete." For example the reinforcement in the anchorage zone will be designed for 70 percent of the ultimate capacity of the tendon with an allowable stress of 20 ksi (for 40 ksi yield material).

When the reinforcement required for "Working Stress Design" under construction and operating conditions is greater at a section than that required for "Ultimate Strength Design" under factored loads, the reinforcement required for "Working Stress Design" will govern.

In addition to the load combination described in Appendix 5B of the PSAR where design is based upon an "Ultimate Strength Design" approach, the Reactor Building will also be designed to accommodate construction and the controlling operating load combinations and will be in accordance with ACI 318-63 "Working Strength Design" and "Prestressed Concrete." The analysis of the Reactor Building for operating condition will include an evaluation of thermal transients for initial start-up, start-up during cold weather, protracted shutdown, and seasonal variations during operating condition.

The finite element solution will be used to evaluate the effect of thermal gradients in thickened portions of the Reactor Building such as the buttresses and ring girder.

2. ANCHORAGE ZONE ANALYSIS

The design of the anchorage zone will be as described in Supplement 1 the Answer to Questions 7.9 and 7.11 (Amendment 11) of the PSAR (Methods by Guyon and Leonhart) except that this method will be modified to conservatively over estimate the three dimensional effect of stress distribution.

In addition to the above, the anchorage zones in the buttresses, ring girder, and haunch at the base of the wall will be checked using a plane stress or axisymmetric finite element solution depending upon location. Controlling loading combinations and thermal transients will be considered. The analysis will include an evaluation of the effects of creep and shrinkage and cracks if such effects are found to significantly cause a stress redistribution.

The reinforcement in the anchorage zone will be designed for the most unfavorable load combination. When reinforcement is exposed to shear by crossing predicted cracks in the concrete, the reinforcement will be conservatively designed to account for shear as well as tension.

3. PRESTRESSING TENDONS

3.1 Friction and Efficiency Tests

A series of tests have been conducted on curved tendons using the BBRV wire system to evaluate the efficiency of the tendon and the friction factors. These tests are as follows:

Location	
Frick, Switzerland	121 - 7mm wires, 180° horizontal curvature
South Haven, Michigan	90-1/4 in. wires - approx. 107° horizontal curvature
Middletown, Pennsylvania	90-1/4 in. wires - approx. 30° horizontal and 50° vertical curvature

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The combined results of the above gives a coefficient of friction of 0.1217 and a wobble coefficient of 0.000343. The details of these tests were reported in "Friction Testing on Large Multi-Wire Post-Tensioning Tendons" by H. Wahl and T. Brown presented at the 1968 ASCE National Meeting on Transportation Engineering in San Diego. The coefficients used for design are 0.16 and 0.0003 respectfully.

Three tests from the Frick series were also used to determine the ultimate strength efficiency of the curved tendon. These tests indicate that the tendons had not less than 95 percent efficiency. This efficiency is based upon 180° curvature and stressing from one end of the tendon. However the design of the Reactor Building does not require that the ultimate strength of the tendon be reached. The load in the tendon will not be greater than 70 percent of the minimum guaranteed ultimate strength under any combination of loadings.

3.2 Tendon Redundancy

Section 2 "Prestressed Concrete" of Appendix 5B of the PSAR states,"The load capacity determined for tensile membrane stresses will be reduced by a capacity reduction factor "ϕ" of 0.95 which will provide for the possibility that small variations in material strengths, workmanship, dimensions, and control may combine to result in under capacity." Considering the above "ϕ" factor, it is possible to have a symmetrical failure of up to 5 percent of the tendons and meet the design criteria for the factored loads.

A study was performed to determine the effect of the total loss of three adjacent 169 wire tendons either vertically or circumferentially in the cylinder or in the dome. This study indicates that the loss of three adjacent tendons will not jeopardize the capability of the Reactor Building to withstand the design accident loading condition.

3.3 Anchorage Component Performance

A stress analysis will be performed on anchorage hardware components to determine approximate stresses/strains (order of magnitude) at critical sections as further substantiation of the performance demonstrated by the tests reported in Amendment 11 to the PSAR. In addition, existing or additional test data will be evaluated to ensure it substantiates performance of anchorage components based on maximum eccentricities of assembly items.

3.4 Material Properties

The steels tabulated in Table 1 are used in the manufacture of the component parts of the tendon anchorage system:

TABLE 1

ITEM	DESCRIPTION	ASTM	AISI	SAE	CARBON	Mn	P MAX.	S MAX.	Cr	Mo	Si
Wire	Uncoated stress relieved	A-421			.72/.93	.40/.11	.04	.05			.10/.35
Tubing (Sheathing)	Tubing D.O.M.		1018	1018	.15/.20	.60/.90	.04	.05			
			1020	1020	.18/.23	.30/.60	.04	.05			
Bearing Plate	Plate HR (as rolled)	A-36			.31 max.	.85/1.25	.05	.063			.13/.33
Transition Funnel	Sheet HR or CR		1008		.10 max.	.30/.50	.04	.05			
Split Shims	Plate HR (as rolled)	A-36			*.30	*.75/1.25	*.05	*.063			*.13/.33
Composite Washer	Bar HR annealed		4140	4140	.38/.43	.75/1.00	.035	.04	.80/1.1	.15/.25	
			4142	4142	.40/.45	.75/1.00	.035	.04	.80/1.1	.15/.25	
Washer Nut	Bar HR annealed		4140	4140	.38/.43	.75/1.00	.035	.04	.80/1.1	.15/.25	
			4142	4142	.40/.45	.75/1.00	.035	.04	.80/1.1	.15/.25	
Washer	Bar HR annealed		4140	4140	.38/.43	.75/1.00	.035	.04	.80/1.1	.15/.25	
			4142	4142	.40/.45	.75/1.00	.035	.04	.80/1.1	.15/.25	

*These quantities may vary with the thickness as required by the ASTM-A36-67, Specifications.

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Typical mechanical properties for the steels listed in the Table 1 are as follows:

Designation	f'_s ksi	f_{sy} ksi	%Elong. 2 in.	% Red. A
ASTM A 36 *+	58	36	23	NR
ASTM A 421 *	240	80% f'_s	4% in 10"	NR
AISI 1018	69	48	38	62
AISI 1020	65	43	36	59
AISI 1008	NA	NA	NA	NA
AISI 4140 HR	89	62	26	58
AISI 4142 HR	Similar to AISI 4140 - Above.			
AISI 4140 & 4142 Heat Treated	180	160	12	40

*Guaranteed minimum properties.

+Silicon killed fine grain practice.

NA - Not applicable - This part is spun, which changes its properties, and these properties have not been investigated because this part does not contribute to the structural integrity of the system.

While each component part of the anchorage system will experience a variety of stresses in three dimensions, those which are of primary concern and principal in magnitude are:

Bearing Plate - Bending (tension and compression), bearing (compression) and shear.

Split Shims - Bearing and shear.

Anchor Head - (Washer or composite washer) - bearing and shear.

Bushing - (Shim nut or washer nut) - shear and bearing.

3.5 Low Temperature Characteristics

The performance of the tendon wire as evidenced by tests on mechanical properties at temperatures substantially lower than the lowest service temperature has been established for cryogenic LNG storage tanks. Further testing of one or more full size prototype, stressed tendon anchorage systems will be performed by increasing tendon stress at a temperature at least 30° F lower than the lowest service metal temperature.

3.6 Fabrication Procedures

3.6.1 Tubing (Sheathing): Material purchased in multiples of required length.

3.6.1.1 Operations:

a. Tubing is saw-cut to length.

b. Tubing is inserted in central hole of bearing plate and secured using a seal weld utilizing E-7018 low hydrogen electrode.

3.6.1.2 Effects:

"Carbon steel material in carbon range less than .30 and wall thickness less than 3/4 in. generally do not crack during or after welding nor do any significant changes take place in their physical properties or metallurgical structure." (Welding Handbook - Applications of Welding - 5th Ed. - Sect. 5 - page 85.7)

3.6.2 Bearing Plate: Material purchased as hot-rolled plate.

3.6.2.1 Operations:

a. Plate is flame-cut to size.

b. Central hole is flame-cut.

c. Four mounting holes are jig-drilled and tapped.

d. Tubing is mounted as in 3.6.1.1 b

3.6.2.2 Effects:

a. "There is no detrimental effect when low and mild carbon non alloy steels containing less than 0.35 carbon are flame cut." (Procedure Handbook of Arc Welding - 6th Ed.)

The steel surface after flame cutting has reached a temperature of approximately 1600° F and the removed metal oxidized to form Fe_3O_4. Residual quantities of this oxide will remain on this surface. The effect of heating and subsequent air cooling is similar to normalizing.

b. In machining the drilled and tapped holes, small residual stresses will be produced on the machined surface. Also, this operation may produce stress risers. The location of these holes (outside the stressing chair area) make this of little concern.

c. Refer to Item 3.6.1.1 b.

3.6.3 Transition Funnel: Material purchased as hot-rolled or cold-rolled sheet.

3.6.3.1 Operations:

Funnel is spun-formed to shape.

3.6.3.2 Effects:

Spinning is a cold working operation. This part, however, is not part of the structural system.

3.6.4 Split Shims: Material purchased as hot-rolled plate.

3.6.4.1 Operations:

Plate is flame-cut to size and shape.

3.6.4.2 Effects:

Refer to Item 3.6.2.2 a.

3.6.5 Anchor Head (Washer or Composite Washer): Material purchased as bar, saw-cut to length sufficient for facing both faces.

3.6.5.1 Operations:

a. Piece is machined to finished size.

b. Wire holes are drilled.

c. Wire holes are removed and deburred and checked for tolerances.

d. Part is heat-treated per specification MIL-H 6875 b to a hardness of 40 to 44 measured on the Rockwell C scale.

e. Threads are then machine cut and checked for tolerances.

f. Part is cleaned, corrosion protection applied, and part is stored for use or shipment.

3.6.5.2 Effects:

a. Any residual stresses resulting from machining prior to heat treating are essentially cancelled during heat treating.

b. During heat treating, parts are placed in a controlled atmosphere oven and brought up to approximately 1550° F, which is above the upper critical range (austenitic range) then quenched in oil to approximately 800° F and air cooled to ambient. This will produce the mechanical properties described previously.

c. Cutting the threads will leave small residual stresses of little significance. The metal surface exposed after machining is more subject to corrosion and will be protected as described below in Section 3.7 "Corrosion Protection."

3.6.6 Washer-Nut: Material purchased as bar with center hole trepanned to approximate (smaller) inside diameter, saw-cut to length sufficient for facing both faces.

3.6.6.1 Operations:

a. Piece is finished to size.

b. Part is heat-treated per specification MIL-H 6875 b to a hardness of 40 to 44 measured on the Rockwell C scale.

c. Threads are then machine cut and checked for tolerances.

3.6.6.2 Effects:

Same as 3.6.5.2.

3.7 Corrosion Protection

The corrosion protection system for the complete tendon will be applied during various stages of tendon fabrication. The surface of all wires will be coated with a heavy wax base

corrosion inhibitor in the tendon fabricating shop. This material contains a blend of high melting point waxes, low melting point petrolatums, some viscous oils, water displacing agents, corrosion inhibiting compounds, as well as polar additives which function as corrosion inhibitors and wetting agents insuring a tightly adherent protective coating which is chemi-absorbed on the surface of the wire and will not be removed by any mechanical means which does not also remove the surface of the steel wire.

The anchor head will be coated with a thin film corrosion inhibitor in the machine shop. This material will contain corrosion inhibitors, a water displacing agent, and a fairly small percentage of wax which is compatible with the final coating system. After the application of this material, a hard rigid plastic shield will be installed over the external threads to protect them from damage during handling and shipping. The bushings or shim nuts will have the same thin film corrosion inhibitor applied to the internal threads, that is, the threads which will transmit the load of the tendon to the shims. The external threads of the bushing will be protected with a soft thermal plastic. After the field formed buttonhead operation is complete, a coating of the same corrosion inhibitor, which was used in the shop, will be applied to this end of the tendon.

After the tendon is stressed, buttonheads will be bearing against the anchor head at a stress level exceeding the yield strength of the anchor head material and the threads that transmit the load from the tendon to the shims will have a contact stress of approximately 2,000 pounds per square inch. Under these contact loads no corrosion is anticipated. An additional coating of wax material will be applied to the external surfaces of the anchorage system prior to installing the protective cap.

4. QUALITY CONTROL

The detailed procedure for quality control during fabrication, shipping, and erection will be submitted by the tendon supplier (Ryerson) to the Construction Manager (UE&C) and Engineer (GAI) for approval in sufficient time to meet the general requirements of the construction schedule.

The procedures shall include a detailed outline of the following, all of which are to be in conformance with the technical specifications:

a. Purchase of materials and mill test including chemical and physical properties and records.

b. Handling, storage, and fabrication.

c. Acceptance and rejection criteria and the fabrication tolerances.

d. Corrosion protection during storage, fabrication, shipping, and erection.

e. Shipping and erection.

f. Installation sequences and stressing operations.

g. Field tolerances.

The approved quality control procedures will detail provisions to assure that each manufactured tendon to be shipped to the construction site, will be assigned an individual number and identified in such a manner that each such tendon can be identified at the construction site.

The Construction Manager (UE&C) shall audit the manufacturer's shop quality control program to assure compliance with the quality control plan and receiving and material control, testing, dimensional checks, documentation, corrosion protection, coiling, and packaging for shipment, as described in the detailed procedures.

The coiled tendons will be shipped in a handling frame. Each coiled tendon will be banded in the shop during coiling and will be enclosed in an approved protective cover. The handling frame will be securely attached to the frame of the carrier.

Before unloading, each tendon carrier assembly shall be visually inspected. On evidence of damage to the assembly, the protective cover will be removed and the tendon visually examined by the UE&C Field Quality Control Receiving Inspector (QCRI). Disposition of damaged tendons shall be documented.

During handling and erection, particular attention shall be given to protection from mechanical damage and corrosive elements.

The identification of tendons, anchor heads, and shims with mill test certificates and test reports shall be documented and forwarded to the UE&C Field Supervisor - Quality Control.

Fabrication and erection tolerances shall comply with the detailed procedures for fabrication, erection, and quality control as submitted by Ryerson. The allowable tolerance between the actual elongation and that indicated by the Jack-Dynamometer shall not exceed ± 5.0 percent of that predicted by calculations which use average load elongation curves. Discrepancies shall be corrected and, if caused by differences in load elongation from averages, shall be so documented.

In addition to the foregoing, MPR Associates, Inc. has been retained by the Metropolitan Edison Company for Quality Control and will include in their quality control engineering effort the reviewing of all procedures developed for tendon fabrication and erection, monitoring of fabrication and erection activities, and auditing of quality control records.