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SUBJECT: LTR 1 ENCL 1
RESPONSE TO NRC REQUEST OF 06/09/78... FURNISHING ADDL INFO CONCERNING SUBJECT FACILITY"S CONTAINMENT TENDON SURVEILLANCE PROGRAM... W/ATT DIAGRAMS.

PLANT NAME: H B ROBINSON - UNIT 2 REVIEWER INITIAL: XJM
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August 14, 1978

File: NG-3514 (R) Serial: GD-78-2200

Office of Nuclear Reactor Regulation
Division of Operating Reactors
Attn: Mr. A. Schwencer, Chief
Operating Reactors Branch No. 1
U. S. Nuclear Regulatory Commission
Washington, DC 20555

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261
LICENSE NO. DPR-23
ADDITIONAL INFORMATION - CONTAINMENT TENDON SURVEILLANCE PROGRAM

Dear Mr. Schwencer:

Your letter dated June 9, 1978, requested additional information on the H. B. Robinson Unit 2 Containment Tendon Surveillance Program. The following responses provide the requested information:

Question A.1. Explain why the purchase order for the bars was less comprehensive than the specification in the Robinson FSAR, and why modified specification ASTM A322, grade 5160 was used, especially why the required reduction of area was not specified in the purchase order (see page 1 of the report).

Response: The specification which was sent to bidders included the minimum initial values for those material properties which were essential to meet design requirements. In a prestressed concrete structure, the prestressing elements are designed to induce a compressive stress in the concrete sufficient to maintain the integrity of the structure when service loads are encountered. A specific level of ductility is not critical for this application. It should be noted that the 1977 Edition of ASME Section III, Division 2, for the prestressed concrete containments, does not specify ductility.

The Modified ASTM A322, Grade 5160, is the material proposed and supplied by the chosen vendor, Stressteel Corporation. In their bid documents the 20 percent

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minimum reduction in area was listed, and those documents were the source of the figure given in the H. B. Robinson FSAR. The values stated for minimum properties are for stress-relieved bars. The bars in the surveillance tendon had been stressed between 70 percent and 80 percent of the ultimate strength (160,000 psi) or between 112,000 and 128,000 psi. Since the proportional limit for these bars in the stress-relieved condition varied from 101,000 to 126,000 psi, the bars tested by Battelle had been work hardened to varying degrees.

If a specimen had, for example, been stressed to 125 percent of the proportional limit, the ductility would naturally be reduced. Even though the ductility of some bars was reduced below the values specified for new bars, the ultimate load and the 0.7 percent extension yield load of all specimens exceeded Stressteel's minimum values. Thus, the properties essential to maintaining design preload have remained within the required range.

Question A.2. On page 2, it is stated that the ductility of specimen T6T/T6B was lower by 50% or by 13% than the mean ductility of other specimens, depending on who did the testing. Clarify this difference.

Response: Tests run by Pittsburgh Laboratory for Stressteel Corporation in 1967 on "Telltale" bars sent from the construction site indicated that these bars had a mean reduction in area of 23.6 percent. Bars tested by Battelle, which fractured within the gage length, had a mean reduction in area of 28.8 percent. Bars tested by Battelle were not identified by heat number and no chemical analysis was given so that variation in mechanical properties from one set of tests to the other or within the Battelle tests cannot be correlated with the metallurgy of the specimens.

Question A.3. Considering the past history of some corrosion of the bars in the main tendons, discuss the relevancy of the results of the tests on the special surveillance tendons for a conclusion as to the soundness of the main tendons. Provide a sketch indicating in detail the location of the special surveillance tendons with respect to the containment structure and the main tendons. Indicate their length.

Response: The attached sketches show the relative location of the surveillance tendons to the containment as well as the dimensions of the capsule.

For discussion of the relevancy of the test results, refer to General Responses.

Question A.4. Explain the reliability and provide an estimate for the degree of confidence in your conclusion that the main tendons and therefore the containment are "certainly" safe, considering the small number of tests on special surveillance tendons available.

Response: Refer to General Responses.

Question A.5. Provide additional bases to support your statement that the corrosion in the special surveillance tendons occurred "certainly" before grouting. Voids in grout could generate corrosion. The extrapolation of this statement as to the soundness of main tendons is not acceptable without additional bases since the grouting of main tendons was an operation much more complex than the grouting of relatively short special surveillance tendons.

Response: Voids in the grouting could allow local corrosion if the voids contained a suitable moist corrodent; however, the alkalinity of the grout and the nature of the hydration reaction combine to create a protective environment for carbon steel. The grouting process and the formula for the grout were developed specifically for the tendon application and were engineered to eliminate void forming tendencies and to maximize protection for the tendons. In addition, an alkaline flushing solution was forced through the tendon ducts immediately prior to grouting, to remove any traces of acids, chlorides, or other materials which would attack the bars.

A high level of quality control was exercised during the installation and grouting of the tendon system. The entire process was monitored by the regional AEC inspectors.

Question A.6. Justify your statement on page 3 that multiple failures of bars in a single tendon cannot be "credibly" postulated.

Response: Refer to General Responses.

Question B.1. Figure 1, page 2, of this report shows the orientation of the tendon, but not with respect to the containment structure. Indicate this orientation on the sketch requested in A.3, above.

Response: Refer to attached sketches.

Question B.2. You indicate on page 3 that the surveillance tendon shows some twisting of the rods within the tendon. Discuss the possibility that this twisting causes additional stresses in the bars and in the end connnections. Discuss also the possibility of similar problems existing in the main tendons.

Response: We feel that the twisting as described is unique to the surveillance tendon. Orientation of the bars within the main tendons was monitored and controlled in accordance with Stressteel Corporation's quality control procedures. Jigs were used to maintain alignment of the bars as they were inserted into the duct. Since the surveillance tendons were much shorter than the main tendons, the jig technique was not used in assembling the surveillance tendons. If additional stresses existed in the bars, it was not evident from the testing performed.

Question B.3. It is stated, page 9, (Figure 7) that the welds joining the casing to the bottom and top end plates show some light superficial rusting. Discuss the implications of this observation for the main tendons, especially long range consequences which this may have on the soundness of the containment structure.

Response: Rusting or mechanical damage to the duct or casing has no bearing on the soundness of the containment structure, since the ducts are not structural members. Other mechanical damage was noted on the duct/bar assembly of the surveillance tendon. This entire assembly was encased in reinforced concrete and the damage to the duct probably occurred while the concrete was being removed or during shipment. This type of damage would not be experienced by the containment tendons or ducts.

Question B.4. On page 9 you indicate that some reddish-yellow and light yellow-brown corrosion products were observed on the inside surface of the sleeve and in other locations. Indicate the composition of the corrosion products, the probable cause of the corrosion, and the possible evolution of the corrosion as a function of time and its bearing on the main tendon system.

Describe any pitting present.

Response: The composition of the corrosion cannot be determined at this time. Since the initial inspection was made in 1976, the bars have been stored, but not protected from corrosion; consequently, the bars have developed a good deal of additional corrosion. Analysis of the corrosion at this time would not provide meaningful results.

Battelle has indicated that no deep pitting was observed.

High strength steels in this hardness range, Rockwell C-37, are susceptible to stress-corrosion cracking. Chloride contamination is usually the corrosive agent which promotes cracking in these steels. Since chloride was found in one of the secondary cracks and the SEM fractograph of the flaw was typical of a stress-corrosion crack, the low reduction in area of Rod T6T/T6B most likely was a result of stress-corrosion cracking rather than a metallurgical flaw.

There are two ways the chloride contamination could have occurred. They are: (1) During storage of the rods, chloride contamination on the surface could have caused a breakdown in the protective film in local areas which allowed rust and light pitting of the surface to occur, or (2) possibly during the insertion of the grouting into the tendon, a small amount of chloride contamination was carried into the casing and during hardening of the grouting the rod began to corrode in the moist environment.

Since the chemistry of the grouting itself shows no presence of corrosive ions and since the water leach was highly basic, it probably did not contribute to the corrosion and stress-corrosion cracking. Also it should be noted that only one section out of twelve of the six reinforcing bars was affected.

Thus, the contamination must have come from outside the system before or during the installation of the tendon. If the corrodent had been present when the bars were stressed, it is likely that cracking would have initiated and propogated as long as both stress and corrodent were present. The cracking would contribute to failure of the steel. The specimen in question did not fail the tensile tests, nor is it likely that the corrosion would have ultimately caused

a failure since the bars had been stressed in place for over seven years before removal for testing.

Question B.5. On page 21, you explained the cracking of grout by the snapping back of the rods when cut, and indicate that the snapping was approximately 1/16 inch. Compute, using this information, and the length of the bars, the approximate level of stress/strain maintained in the bars by the grout and justify your assumptions that the cracking of grout was caused by the snapping and not by any other cause.

Response: Assuming that each bar was restrained by the coupling at its center and by the end plate, the stressed length was approximately 8'10". A 1/16" elongation would correspond to a stress of approximately 17,700 psi.

Due to the brittle nature of the grout, any severe external force could have contributed to the cracking. Since no rust or corrosion was found on the inside of the casing or on the bars corresponding to the cracks in the grout, the cracks must have been freshly made. It is possible that bending of the casing during shipment or handling could have caused the cracks, but more likely they resulted from the snapping back of the bars as indicated.

Question B.6. On page 30, in several places you mention corrosion, mill-scale, superficial red rusting and you indicate in the end paragraph that you noted corrosion patches which were significant. You add that corrosion was fairly superficial and that it should not affect the strength of the rod. If corrosion (or hidden pitting) can be disregarded, how do you explain the loss of ductility and reduction of area of the tendons?

Response: The corrosion was not disregarded. It was considered to be the cause of the loss of ductility and reduction of area. The tensile strength of the rod was proven to be acceptable.

Question B.7. In the subsection "Mechanical Properties of Rods" p. 50, end paragraph, you describe the failure of T6T/T6B rod. You recognize the possibility of crack propagation. Provide a complete study of this problem and its possible bearing on the main tendon system. (See also our requests, below on the Battelle report dated March 25, 1977.)

Response: During tensile testing, the slow crack growth referenced in this section occurred at or near the ultimate stress levels in the bar. Although the cracks may have been initiated by the corrosion present in the test rod, their propagation probably would not have occurred at the stress levels existing in the containment tendons (i.e., 70-80% of the ultimate). Therefore, there is no reason to expect that corrosion of this nature would cause failure of the main tendon system.

Question C.1. The investigation was started only after mechanical tests up to failure disclosed the existence of a problem. Provide a discussion of the possibility and consequences of incipient or potential failures at other locations not yet obvious. Especially indicate whether microscopic pitting, which could contribute to rod failure, has been taken into account.

Response: It is indeed a possibility that corrosion of the nature found on the surveillance tendon could exist on the main tendons. The consequences of such corrosion should be no greater than those of the surveillance tendon, i.e., the tensile properties of the steel were not impaired.

Question C.2. Since the primary cause of the failure (generation of initial crack) apparently has not been established, what conclusions can be reached as to the behavior and safety of the main tendon system.

Response: Refer to General Responses.

General Responses

The corrosion referenced by your Question A.3. was documented in a report which was transmitted to the AEC in April, 1968. Briefly stated, the cause of the corrosion was identified and corrective measures were taken to alleviate the problem. Inerting the tendon casing with nitrogen using a back-up system of VPI (Vapor Phase Inhibitor) crystals was concluded to be the best method of preventing and retarding corrosion from manufacture until grouting.

In regard to the mechanical tests performed on the surveillance tendon, we must reiterate our conclusion that the tensile properties of the steel were intact. The surveillance tendon did not fail the tensile test. A lessening of ductility was the only area of concern, and as previously noted, ductility is not a critical factor for prestressed applications of this nature.

In addition to the surveillance tendon program, there are other tests which are performed to verify the integrity of the containment. Specifically they are:

1. Structural Integrity Test performed in 1970 prior to placing the plant in commercial operation.

2. Structural Integrity Retest performed in 1974.

3. Integrated Leak Rate Test performed at three-year intervals since commercial operation.

4. Structural Integrity Retest to be performed after 20 years of operation.

5. Removal and testing of the second surveillance tendon after 25 years of operation.

The analysis and results of the above tests that have been performed to date have been forwarded to your office as required.

We trust that the information provided will be sufficient for you to complete your review.

Yours very truly,

E. E. Utley
Senior Vice President
Power Supply

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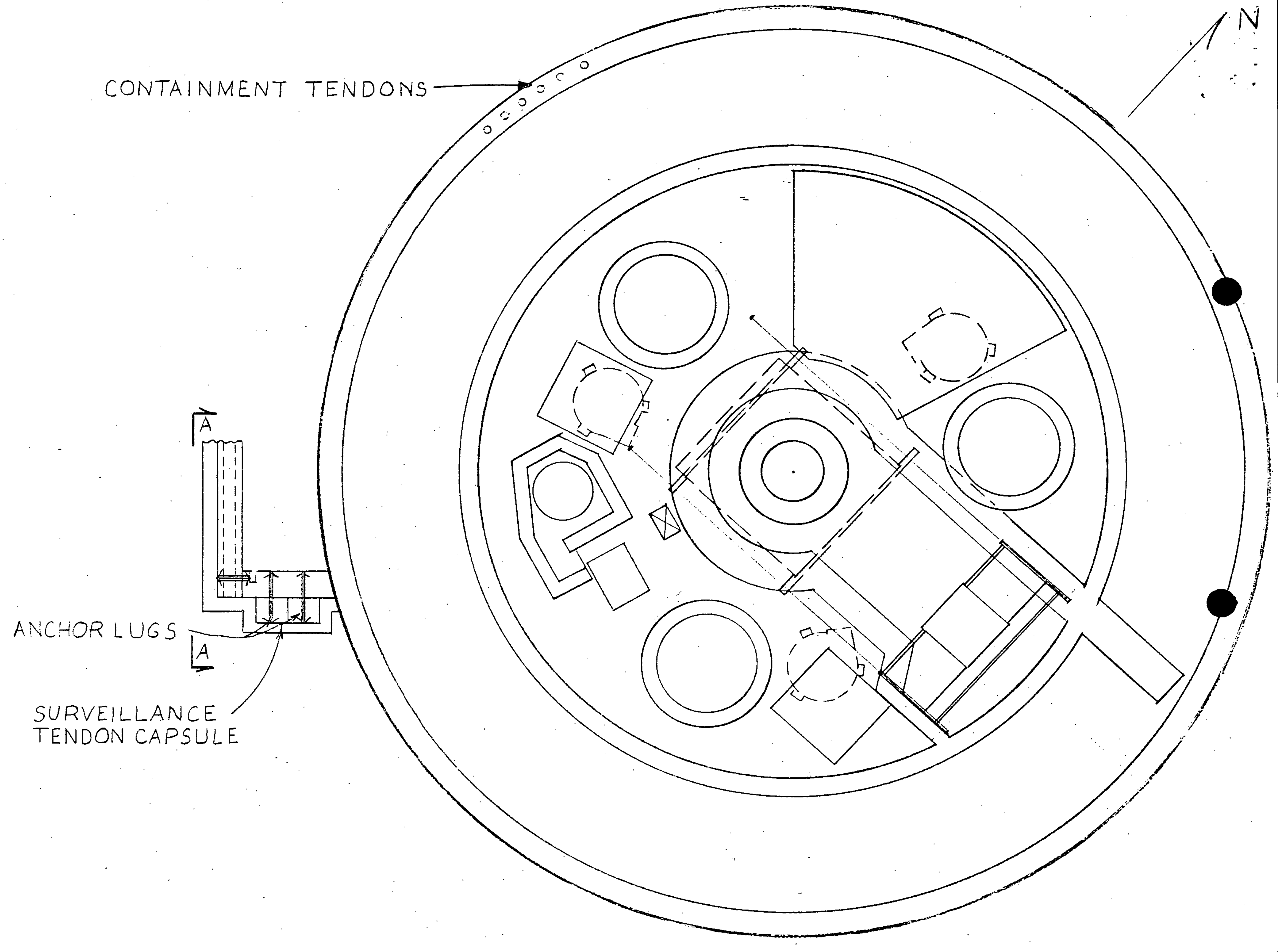
Attachments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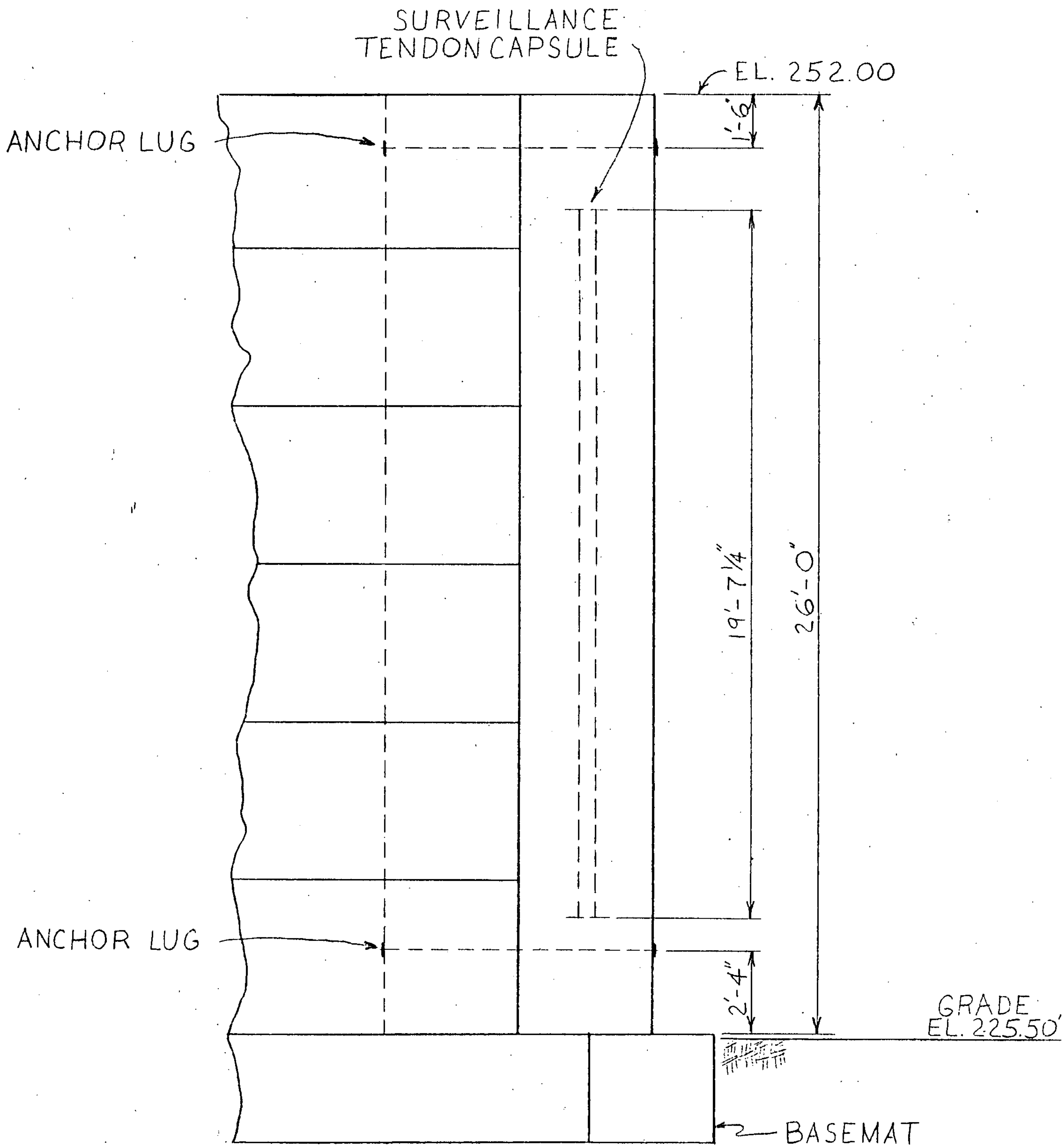
A
ANCHOR LUGS
A
SURVEILLANCE
TENDON CAPSULE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19'-7 1/4"
26'-0"
ANCHOR LUG
2'-4"
GRADE EL. 225.50'
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SECTION A-A