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SACRAMENTO MUNICIPAL UTILITY DISTRICT

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RANCHO SECO NUCLEAR GENERATING STATION
UNIT NO. 1

ATTACHMENT A

ANSWERS TO DRL QUESTIONS ON VSL TENDON SYSTEM
DOCKET 50-312

SEPTEMBER 1969

QUESTION 1. Provide a detailed review of the extent to which the proposed VSL anchorage system meets ACI-ASCE Committee 423 (tentative recommendations for concrete members prestressed with unbonded tendons). Where tests supporting the suitability of the system are described, provide the detailed test data as attachments to the review.

ANSWER The tendon supply specification, which is included in Supplement 2 to the PSAR, includes all the pertinent requirements for the anchorage system recommended by the ACI-ASCE Committee 423; a possible exception is the percent of ultimate strength used during cyclic tests. VSL has subsequently conducted cyclic tests over a wider range of loadings than that required by either the tendon supply specification or the ACI-ASCE 423 recommendation. The results are provided in Section IV of Attachment B. As previously stated in Supplement 2, we believe the VSL anchorage system meets the requirements of our specification.

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QUESTION 2. We understand that the Swiss Government has developed a set of requirements for tendon systems and that the VSL design has been evaluated with respect to these requirements. Please provide a detailed review of the extent to which the proposed VSL System meets the Swiss requirements.

ANSWER

The VSL Corporation Strand System meets the requirements of any existing building code in Switzerland, and the system is approved by all major agencies including the SIA (Society of Swiss Civil Engineers and Architects) and the Swiss Federal Railways, the latter being renowned for its rigorous requirements with respect to the performance of a tendon under dynamic loading. Excerpts of the SIA and Swiss Federal Railways Specifications are included in Attachment B, Section XI C. These specifications are not considered to be part of our design criteria and therefore, we have not conducted a detailed review.

QUESTION 3. Provide a detailed description of the VSL System to include material composition, manufacturing process, heat treatment and dimensions (including tolerances) for bearing plate, anchor head, wedge grips, trumpet and tendon.

ANSWER In addition to the information provided in Supplement 2 to the PSAR, a detailed description of the VSL Strand System stating materials, compositions, manufacturing process, heat treatment and dimensions including tolerances is included in Attachment B, Sections VII, Manufacturing Quality Assurance Program for Rancho Seco; Section IX, Drawings for Rancho Seco; and Section X, Materials for Rancho Seco. It should be noted that the anchor head material has been changed from AISI 10L50, as stated in Supplement 2, to AISI 1026 to obtain improved impact characteristics and to take advantage of the more extensive history of prior use with respect to impact properties.

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QUESTION 4. Indicate the NDTT requirements that will be imposed, the basis for these requirements, and the techniques, sampling procedures, and standards that will be used to qualify the material to these requirements. Indicate also the attention that will be given to avoidance of stress concentrations and notch effects such as may be due to flame cutting and welding.

ANSWER As previously stated in the PSAR, we do not consider brittle fracture to be a serious problem, but we have requested low temperature testing from VSL as stated in Supplement 2.

Although it is felt unnecessary to do so, the center holes of bearing plates are being machined after flame cutting. The ASTM A537 steel used for bearing plates has a maximum carbon content of .24 and is therefore not as susceptible to flame cutting induced stress risers. In spite of the fact that this is a pressure vessel steel, designed for weldability, the welding on the VSL E5-55 Strand Bearing Plate has been minimized. The trumpets are welded to the edge of the center hole with a 1/8 in. weld to minimize heat transfer into the steel. The only other weld on the bearing plate is a tack weld to fasten the grease vent to the edge of the plate.

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QUESTION 5. Provide additional discussion on the performance capability of the VSL System with regard to ductility, ultimate strength, seismic loading and the capability of the system to maintain long term loading without delayed failure or excessive relaxation. Describe all applicable test data supporting the planned system's performance capability including sufficient information on materials and geometry of the test assembly to verify that the materials used, and the features of the assembly, are closely related to the specifications for the proposed system to permit an acceptance as valid supporting test data.

ANSWER The ductility, ultimate strength, and cyclic load capacity are presented in Sections I through VI of Attachment B. The ability of the VSL anchorage to provide long-term load retention without delayed failure is borne out by a history of successful application. VSL Corporation has never experienced a delayed failure. A survey of more than twenty VSL Licensees indicated no occurrences of a delayed failure with the VSL System. For a list of unbonded wedge tendon installations, see Sections XI, A and B of Attachment B. The relaxation of a tendon is independent of the anchorage and entirely dependent on the strand test data provided by the strand manufacturer which is included in Section X of Attachment B.

Basically, the materials used in VSL anchorage components in the U.S. are the same as those used in Switzerland. When identical steel is unavailable in the U.S., a superior steel is used. In tests on anchorage components conducted in Switzerland, it should be noted that the Ck 45 steel used in Swiss anchor heads is inferior in both yield strength and impact characteristics to the steel proposed for anchor heads for Rancho Seco. Ck 45 normalized gives 48,500 psi for a 1.58 in. round, and 37,800 psi at the half radius of a 12.5 in. round; this as opposed to the 50,000 psi mid-radius yield strength required for VSL E5-55 Anchor Heads for Rancho Seco.

The prime consideration in the selection of wedge steel is the hardenability characteristic. Tensile strength and elongation characteristics prior to heat treating, are not indicative of the final product and therefore, are not specified upon purchase. The FAG 180 steel, used in Switzerland because of its availability, contains slightly higher quantities of alloying elements. However, since the performance of the wedge is only a function of the geometry and the hardness of the core and case, this is of no significance.

Samples of wedges which have been subjected to static and dynamic loading are shown in Section V of Attachment B.

QUESTION 6. Evaluate the potential deleterous effects that manufacturing and field induced variables may have on the performance of this system as determined by laboratory testing. Consider such variables as:

a. Service condition of wedges and bearing block (dry, lubricated, dusty, gritty).

b. Corrosion at wedge-strand and wedge-bearing block interface.

c. Hydrogen embrittlement.

d. Out of tolerance or at tolerance dimensions of wedge grip and bearing block parts.

e. Out of tolerance, or at tolerance hardness properties of wedges.

ANSWER Although the effects of variation in surface finish is not a determining factor in performance, it is closely controlled to prevent laxity in manufacture and field application. It is true that excessive dirt or lubrication is detrimental to the functioning of the VSL System. For this reason, the wedges will be shop-installed in the anchor head and kept in place with a retainer plate. Provisions for insuring proper interface surface conditions for wedge and anchor head are contained in Section VII of Attachment B, Manufacturing Quality Assurance Program. See the investigation reported in Part 2 of Section V for the effects of lubricants and rust on the anchorage performance.

To the best of our knowledge, hydrogen embrittlement has never occurred in a properly encased and protected tendon.

We would like to refer to a paper presented by Professor A. Rauen and Professor O. Russwurm of the Laboratory for Testing and Material of the Munich University during the F.I.P. Symposium of June 3-7, 1968 in Madrid. The authors state that hydrogen embrittlement has most frequently been observed on prestressing steel in pretensioning beds, where the steel was surrounded by concrete using cement containing excessive sulfate. In the presence of the latter, sufficient hydrogen is formed that may enter into the prestressing steel. Other cases of hydrogen embrittlement occurred where aluminum forms were used.

ANSWER TO QUESTION 6 (CONTINUED)

The author further states that only tempered prestressing steel, as it is commonly used in Germany, is susceptible to hydrogen embrittlement. Cold drawn steel, because of the cold forming process which it has undergone, has greatly reduced susceptibility to absorb hydrogen.

The wedge angle, surface finish, depth of case and tolerances have been optimized by experimentation to produce the lowest clamping force compatible with the development of the maximum strength of the strand.

Tolerances on the VSL anchorage components may be exceeded by 100% without downgrading or affecting the performance of the system. These limits were determined by tests during development. Nevertheless, no components are accepted which exceed tolerances.

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QUESTION 7. Discuss the attention that will be given to strand arrangement and twist in curved tendons. Evaluate the potential deleterous effects that the selected arrangement (twists and curvature) may have on the performance of the system.

ANSWER Curved tendons were discussed in Section 4.4 of PSAR Supplement 2. No predetermined twisting of any tendons is required or considered desirable.

With dome and vertical tendons, it is also felt that combing of strands is not necessary. These tendons, as they are pulled into the sheathing, assume the relative positions within the sheathing that they will hold after stressing. With horizontal tendons, there will likely be some shifting of strand from the bottom of the sheathing as the tendon is stressed. This situation will be minimized by a factor inherent to the sheathing configuration; namely, the extreme length of these tendons which minimizes the effect of disparities in the lockoff length of individual strands over and above what would be expected. This is due to the unequal length paths the strand may have within the sheathing. Tendons will be wound for shipment to jobsite with the 55 strands wound side by side, and bundled only at the Kellums Grip. A retainer plate (see Section IX, Attachment B, Drawing 1) will be shop-installed behind the Kellums Grip on the horizontal tendon, to comb out the strands and maintain their relative position as they are drawn into the sheathing. Biaxial stresses along the length of the tendon due to its curvature are very difficult to analyze, but experience gained from installed tendons indicate the design capacity need not be reduced to account for these stresses.

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QUESTION 8. With regard to the proposed corrosion protection system document:

a. The experience available for the corrosion inhibitor proposed.

b. The capability of the corrosion inhibitor to penetrate between and provide protection for the wedge grip-strand interface.

c. The provisions that will be made to accommodate corrosion inhibitor thermal expansion.

ANSWER The materials used for corrosion inhibitors are the same as stated in previous submittals of the PSAR, specifically, paragraph 5.1.3.3 of Section 5 and related portions of Appendix 5J. There have been no modifications to the requirements set forth in the applicable sections of the PSAR.

VSL will conduct tests in the future to determine the techniques required to penetrate an anchor assembly completely. They have shown, by past tests on grouted systems, that full penetration can be obtained and it is felt that the same results can be obtained with grease.

The final detailed provisions for the specific material which will be incorporated into the design, including the allowance for thermal expansion of the grease, will be determined later using all available experience gained from other plants.

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QUESTION 9. Clarify the reported "percent of guaranteed ultimate strength". Also tabulate anchorage efficiency performance data on the basis of actual ultimate strength of strand for any data reported.

ANSWER The terms "guaranteed ultimate strength" and "actual ultimate strength" must be defined before any comparison can be made. The "guaranteed ultimate strength" is a finite number determined by the strand supplier and is the value used in design. As stated in Supplement 2, the "actual ultimate strength" is dependent upon the method of testing and is a variable number because different methods of testing are used. Wedges similar to the VSL wedge can be and are used by this strand manufacturer to determine the "actual ultimate strength". When testing a single strand using VSL wedges, this value can be obtained as stated in Supplement 2. The "actual ultimate strength", as specified by ASTM 416, does not require a tensile break in the "clear span". Therefore, considering these factors, the "guaranteed ultimate strength" is only used in design. The reduction in "actual ultimate strength" when multi-strand tendons are tested, is primarily due to differential strand length. The "actual ultimate strength" of the tendons to be used in the containment will approach the "actual ultimate strength" of a single strand tendon because the effect of differential strands length diminishes with increased tendon length.

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QUESTION 10. Provide a detailed description of the Quality Assurance Program for the VSL System. Include a description of the Quality Assurance Organization and the measures to be taken to assure an independent design evaluation. Describe the Quality Control measures to be followed to include specifically the measures to be applied to Quality Control of wedge threads, taper angle, anchor head, tendon casing placement, tendon tensioning and wedge to anchor head interface service condition.

ANSWER The Quality Assurance and Quality Control procedures for the fabrication of anchorage components are as outlined in Section VII of Attachment B. The proper wedge/anchor head interface conditions are as shown in Section VII.

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QUESTION 11. Indicate the provisions to be taken to ensure proper centering of the stress head on the bearing plate to avoid high local stresses.

ANSWER The anchor head is centered automatically by the jack chair which is centered by pinning directly to the bearing plate.

QUESTION 12. Provide evidence to show that wedge anchors (with maximum wedge offset) remains stable and no strand slippage occurs with sudden reduction of tendon load or as the result of tendon vibration.

ANSWER The three dynamic tests, Section IV of Attachment B, provide evidence showing the stability of a VSL Wedge Gripper. The VSL System has been approved by the California Division of Highways, which requires tests with wedge halves being offset 1/4 in. without significant reduction in tendon efficiency.

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