ATTACHMENT NO. 3

MILL TEST REPORT FOR

TENDON 32H14

P.O. 344C

Ark Doc 7

Inspection Certificate

Uncoated Stress Relieved Wire For Prestressed Concrete

Messrs Mitsubishi Corporation

Order No. [illegible]37-197B

Quantity 313 coils 299,693 lbs.

Destination Charleston

Inspection Date April 6, 1972

Shipping Mark

SUZUKI METAL INDUSTRY CO., LTD.

HEAD OFFICE & AKABANE WORKS NO. 1-18 AKABANE-KITA KITA-KU, TOKYO, JAPAN

NARASHINO WORKS NO. 2-7-0 HIGASHINARASHINO NARASHINO, CHIBA, JAPAN

ST

ST
HYTA-3767-B
ST
CHARLESTON
SIZE 1/4 INCH
MADE IN JAPAN
HEAT NO. H-21921 G-22072
NO. 695-1001 1002-1007

P. P. Manager, Inspection Dept.

68E-0021-04

1 Specification : A.S.T.M A421-65 BA and Prescon's Spec. (Arkansas Job)

(1) Chemical Composition

Carbon	:	0.72~0.93%
Manganese	:	0.40~1.10%
Phosphorus max.	:	0.040%
Sulfur max.	:	0.050%
Silicon	:	0.10~0.35%

(2) Wire

Nominal Diameter	:	1/4	inch
Tolerance of Diameter	:	+0.002, -0.001	inch
Application	:	Type BA	
Tensile Strength	:	min. 240,000	psi
Yield Strength	:	min. 210,000	psi
Elongation in 10"	:	min. 4.0	%
Cast		Laid free on a substantially flat surface, shall form an arc of a circle not less than 12 feet in diameter.	

2 Test Results

(1) Chemical Composition %

Composition / Charge No.	C.	Si.	Mn.	P.	S.	Cu.	Inspection No.
H-21921	0.75	0.25	0.82	0.019	0.014	0.02	695-1001
G-22072	0.74	0.24	0.78	0.019	0.007	0.02	1002-1007

RESPONSES TO NRC QUESTIONS ON ARKANSAS NUCLEAR ONE - UNIT 1 CONTAINMENT BUILDING THIRD YEAR TENDON SURVEILLANCE

QUESTION I:

The information provided to-date indicates the following variations in strength may cause concern (see pages 2-1, 2-3, and 4-1 of November 4, 1977 report):

tendon 31H40)
tendon 31H39) liftoff forces lower than required
tendon 31H50)
tendon 32H14 - Some wire samples failed at less than guarantee minimum ultimate strength. This information involves only hoop tendons.

The information given on page 4-2, however, is different. It indicates that the average lift-off force (per wire) for all vertical tendons is approximately +0.41% higher than expected, but that the average value of lift-off forces for both hoop and dome tendons is lower than expected for dome tendons -0.68% (approximately); for hoop tendons - 1.1% (approximately)1. Another contradiction can be found in information provided in Figures 4.1, 4.2, and 4.3. It can be seen that, per wire, the lift-off force was lower than expected for:

V95 (Vertical)
1D20; 3D21; 2D08 (Dome)
32H24; 32H40; 32H32; 31H39; 31H41; 31H50; 31H40 (Hoops)

I-1. Explain these contradictions and correct them.

RESPONSE:

The expected average prestress force per wire is a prediction of the force per wire averaged over all tendons. The average minimum design prestress force per wire is the minimum force per wire, averaged over all tendons, at which the containment is expected to have adequate prestress to withstand the design loadings. The expected average prestress force per wire must be equal to or greater than the average minimum design prestress force per wire during the design life for the plant. For purposes of the tendon surveillance test, the average minimum design prestress was taken as the minimum acceptance criterion for tendon lift-off force. The concern expressed about the lift-off forces for tendons 31D40, 31H39, and 31H50 was brought about because the lift-off forces were too low to meet the acceptance criterion used during the first year tendon surveillance in 1975. During investigation of that potentially reportable condition, the lift-off force acceptance criterion was found to be more conservative than necessary. A more up-to-date method for calculating normalizing factors also came to light during this investigation. Once the acceptance criterion and normalizing factor calculations were revised (see response to Question III-6), the criterion of the operating procedure was met. Thus, all tendon lift-off forces were found to be acceptable.

The average value of lift-off force for each tendon group was found to agree with the expected force per wire to within ±1.1% That is excellent agreement of measured forces with predictions. Since the expected average prestress force per wire is based on an average over all tendons, having a number of tendons with somewhat lower force than the expected average prestress force is anticipated and is not a contradiction. (See Attachment No. 1 for discussion of expected average prestress force.)

I-2. Explain the significance of lower lift-off forces for the stability of the structure.

RESPONSE:

The lift-off forces measured during the surveillance test had a satisfactory average value for each tendon group, and all individual tendon lift-off forces were greater than the recalculated minimum acceptance value (average minimum design prestress). See response to Question III-6. Therefore, the tendon lift-off forces are satisfactory, and no adverse structural effect is indicated.

I-3. Explain the significance of ultimate strength of wire samples lower than the guaranteed minimum strength for the stability of the structure.

RESPONSE:

At the end of 40 years all anticipated losses will have occured and the average stress in the tendon will be 55% of its ultimate strength. The containment is designed for a pressure of 1.5 P. Therefore the containment has an ultimate capacity to resist the accident condition, excluding the effect of the liner plate and reinforcing steel, of $1.5 \times \frac{1.00}{0.55} = 2.73$ times the design pressure given in the FSAR. If the capacity of the liner plate and the reinforcing steel be included the factor would be in excess of 3.0.

Twenty wires have been tested during the first two surveillances for tensile strength. Only one wire broke below the minimum guaranteed strength. As discussed in the response to question II this is attributed to the method of wire removal.

For the purpose of demonstrating the effect of a reduction in wire ultimate strength on the safety of the containment the above sample will be used.

The reduction of ultimate wire strength for the single wire is 14%. When added to the total wires tested the average ultimate strength, using the guaranteed minimum strength for the other 19 wires, the reduction becomes less than 1%. As can be seen this has virtually no effect on the ultimate capacity of the containment.

QUESTION II:

In your letter dated August 24, 1977, you stated that 46 tendons have the same heat of material as tendon 32H14. In the November 4, 1977 report, the problem of the heat is not mentioned. Explain this contradiction and possible omission of the heat problem.

RESPONSE:

Based on additional tests, both physical and chemical, and the results from physical tests done on the same heat of material from another tendon during the first year surveillance, it was determined that the low breaks were a result of deforming the wire during wire removal. The Bauschinger effect discusses the problem with erratic results where the wire has been stressed beyond yield in one direction and then tested to failure in the opposite direction. (See Appendix I of the Report.) ASTM 421 states that samples used in tensile test having a permanent radius of curvature less than 12 feet shall not be used for tensile tests.

Since it was not established that this heat of material is below the minimum guaranteed ultimate strength and previous tests conducted on another tendon of the same heat during the first year surveillance were acceptable, it was not considered a reportable item and therefore not included in the third year tendon surveillance report.

For the purpose of verification a wire from tendon 32H14 will be removed during the fifth year surveillance for test purposes.

QUESTION III:

The documents furnished suggest that the acceptance values and the normalizing factors used in the one-year surveillance in 1975 be modified and that after such a revision the normalized tendon lift-off forces will exceed the required minimum values. This approach is questionable, since one of the goals of successive surveillance operations is to establish historic continuity in the evaluation of the safety of the structure. A modification of the basic criteria will destroy this continuity. It is imperative first to establish the significance of not satisfying the original criteria and normalizing procedures. To clarify this problem, answer the following questions:

III-1. It is indicated in your letter of August 24, 1977 that the lowest value recorded and accepted as valid for the ultimate strength of the wire samples was 229 ksi; the highest was 246 ksi. The required ultimate strength of the wires required in ASTM A-421-74 is 240 ksi. The maximum deviation was, therefore, approximately -4.6%. It is also indicated that the stress at elongation of 1% was less than the required 192 ksi. In addition, some samples with ultimate strength lower than 240 ksi had an elongation smaller than that required by the specification of 4.0%. The wire manufacturers have a great amount of statistical information available. Therefore, present a study of the significance of these deviations. (See pages 5-2 and 5-3, Tables 5.1, 5.2, 5.3, and Appendix G.)

RESPONSE:

The following firms were contacted for information on wire.

1. Prescon - San Antonio, Texas
2. INRYCO - Melrose Park, Illinois

Prescon, in addition to their Japanese source, uses Armco wire on occasion. INRYCO uses both Armco and Florida Wire and Cable as their domestic wire sources, in addition to occasionally using a foreign source. INRYCO indicated that they prefer to use domestic material suppliers.

This was discussed with Armco and Florida Wire and Cable. Both companies indicated that they use their own company specifications to buy rod stock from other producers. When they commence wire drawing operations, tensile specimens are taken from the beginning and end of each wire spool.

Both companies claim to have very low rejection rates. As a consequence, they only keep raw test results on file, and have not performed any statistical analyses. Furthermore, both companies have other product lines so that when any tendon wire is rejected, it is downgraded and diverted to another product because it is too expensive to attempt any reprocessing of the tendon wire back through their system.

In view of the lack of statistical data from these sources we cannot do a study on the significance of the deviations from ASTM A421 of the tendon wire samples tested during the last surveillance inspection.

However some statistical data furnished by the vendor when he submitted his original bids is available. In their proposal under a section giving engineering data they discussed a series of tests covering 330 to 340 coils of wire representing 25 heats of material. They found from the results of tensile test that the standard deviation was approximately 1% to 2%.

III-2. There is a confusion between "sample" length and "gage" length. For example in the letter dated August 24, 1977, the expression "100 inch sample" is used; also on page 2-3 of the report the expression "10 inch samples" and "100 inch samples" are used. In Tables 5.1, 5.2, and 5.3 in Appendix H the expression "measure gage length" is used throughout. Clarify these contradictions.

RESPONSE:

The terms "sample length" and "gage length" are used interchangeably. In either case, the distance between the gripping mechanisms on each end of a tensile specimen is designated.

III-3. Explain the meaning of the expression "guaranteed minimum ultimate strength" (pages 5-3 and 5-4). What are the tolerances and permitted deviations on the "guaranteed" values?

RESPONSE:

"Guaranteed minimum ultimate strength" means that a coil of wire is not acceptable for tendon fabrication if a tensile test indicates ultimate strength of less than 240 ksi for any test sample from the coil.

As discussed in the response to Question III-1, statistical data on rejection rates has not been maintained by the manufacturers contacted. However, data are available for the heat of material used in fabricating tendon 32H14. Tensile tests were made on 31 samples with a low break of 245.0 ksi and a high break of 258.0 ksi.

III-4. Clarify the meaning of "improper" wire removal procedures. If the reason for the difficulties is in the use of a sheave approximately 12 inches in diameter, explain why this procedure did not damage the wires in vertical and dome tendons. See page 3 in Appendix I. The mention of "Bauschinger Effect" may be inappropriate since this effect has been mostly investigated for uni-axial tensile tests or torsion, and the problems presented in this documentation are much more complex (see page 5-4 of the report and page 3 of Appendix I.) Describe the future wire removal procedure as planned at this time.

RESPONSE:

In this case the "improper" wire removal procedure caused permanent bending of the tendon wire from the hoop and dome tendons. The wire from the vertical tendon was removed without permanent deformation. The tensile tests for samples from the dome tendon indicate ultimate strength of at least 240 ksi. That proves nothing one way or the other concerning the Bauschinger effect explanation for low tensile test results. Qualitatively, a reduction of ultimate tensile strength would be expected as a result of permanent bending. Quantitatively, the reduction may or may not be great enough to cause low ultimate strength test results.

For future tests, wire removal procedures will be specified on a per case basis and any wire removal procedure causing permanent wire deformation will be considered as unacceptable.

III-5. In several locations in the report, it is indicated that some buttonheads are "offsize." The original design of buttonheads by the manufacturers is very sophisticated. Therefore, explain what is meant by "offsize" and justify the statement that this did not influence the strength of the tendons. (See page 2-1 and Appendix D.) Discuss other imperfections of the buttonheads, such as cracking, offset, etc.

RESPONSE:

"Offsize" buttonhead refers to a buttonhead which is either larger or smaller than that shown for the GO-NO GO GAGE. This inspection is not intended to be a basis for acceptance or rejection of the tendon but rather a recording of the as-built condition.

After a tendon is detensioned and inspected it is retensioned to 80% of the minimum guaranteed ultimate strength based on the total number of effective wires in the tendon. This is in accordance with Section 8.1.5 of the Operating Procedure 1304.91, Appendix A of the report. The tendon is then shimmed to a force equal to/or larger than the lift-off force determined at the time of detensioning the tendon in accordance with Section 8. .6 of the above procedure.

By subjecting the tendon to a stress in excess of the required lift-off force without a buttonhead failure, the adequacy of the wire anchorage has been established.

In Section 3.2 anchorage components of the Three Year Surveillance Report, it is noted (page 3-2) that no split buttonheads were found.

"Offset" buttonheads refers to buttonheads which are not concentric with the wire.

III-6. On page 2-2, it is stated that with two revisions of the basic criteria, all the tendons are considered acceptable. This statement seems to be inappropriate since, as indicated above, the use of new criteria may be objectionable in itself. Therefore, qualify this statement.

RESPONSE:

Containments are designed based on the average tendon which is subjected to an average elastic loss. Losses due to friction, elastic concrete creep and shrinkage and steel relaxation are considered when originally determining the number of tendons required.

The amount of existing prestress is determined by obtaining lift-off measurements at the tendon end anchor. The end anchor force is subjected to all losses except friction. Based on past field experience and tests performed on concrete for creep and shrinkage and on steel wire for relaxation, it has been determined that approximately 70% of the losses occur during the first year and the following expressions can be used to determine the average wire force which should exist after one year and at the end of life. If exactly the required amount of prestress has been supplied, then the end of life value and the minimum required value will be the same if the surveillance acceptance criteria is the same as the original design criteria.

Wire force 1 year after post-tensioning:

$$\begin{matrix}\text{Wire}\\\text{force}\end{matrix} = \begin{bmatrix}\text{Wire}\\\text{area}\end{bmatrix}\left[\begin{pmatrix}\text{Initial}\\\text{stress}\end{pmatrix} - \begin{pmatrix}\text{Average}\\\text{elastic}\\\text{loss}\end{pmatrix} - \left(.70\right)\begin{pmatrix}\text{Creep,}\\\text{shrinkage \&}\\\text{relaxation loss}\end{pmatrix}\right] \tag{1}$$

Wire force end of life:

$$\begin{matrix}\text{Wire}\\\text{force}\end{matrix} = \begin{bmatrix}\text{Wire}\\\text{area}\end{bmatrix}\left[\begin{pmatrix}\text{Initial}\\\text{stress}\end{pmatrix} - \begin{pmatrix}\text{Average}\\\text{elastic}\\\text{loss}\end{pmatrix} - \begin{pmatrix}\text{Creep,}\\\text{shrinkage \&}\\\text{relaxation loss}\end{pmatrix}\right] \tag{2}$$

Since all tendons cannot be anchored at exactly the same value and at the same time, then a correction for the initial anchorage value and the elastic loss must be made so that the value will be typical of the entire average tendon population. This is done by determining a normalizing factor by which the lift-off value is multiplied when making corrections:

$$\begin{matrix}\text{Normalizing}\\\text{factor}\end{matrix} = \frac{\begin{bmatrix}\text{Average initial}\\\text{anchor force}\\\text{all tendons}\end{bmatrix} - \begin{bmatrix}\text{Average}\\\text{elastic}\\\text{loss}\end{bmatrix}}{\begin{bmatrix}\text{Actual}\\\text{tendon}\\\text{lift-off}\end{bmatrix} - \begin{bmatrix}\text{Actual}\\\text{elastic}\\\text{loss}\end{bmatrix}} \tag{3}$$

When reducing the data from the first surveillance for presentation, a technique similar to Eqs. (1) through (3) was used. However, when applying Eqs. (1) and (2), the average elastic loss was not subtracted and the required values were too high. When using Eq. (3), again, the average elastic loss was not subtracted in the numerator and the normalizing factors were too high.

When reducing the data from the second surveillance, the elastic loss was considered. In addition, the method of determining friction which used the tendon end values was compared with presently used methods which use a weighted-average value and it was determined that the friction forces were slightly overestimated, and therefore less tendons than were put in, would actually satisfy the design criteria. Since these tendons were put in, then it is acceptable to have a lower minimum required wire force level. All these changes were incorporated and included in the second surveillance report.

For additional information, see Attachment 1.

Since the lower limit is an average value for all tendons surveyed it follows that some tendons may fall below the average minimum design prestress at some point in time. Therefore it is important that this value be set to allow for individual tendons to fall below the average minimium design prestress by an acceptable margin.

Operating Procedure 1304.91 does not specify a margin therefore when the low lift-off values for the tendons discussed in Section 2.1 of the report were discovered, an engineering evaluation was made. The evaluation showed that when using the current method for calculating friction, as mentioned above, the average minimum prestress per wire could be lowered and still satisfy the design criteria. The method for calculating friction is similar to that given in BC-TOP 5. (Example for Hoop Tendons.)

With the two changes discussed above the acceptance criteria given in the Operating Procedure was met.

III-7. On page 2-2 of the Report, it is indicated that the "available" equipment could not perform adequately the wire continuity test. Explain why the needed equipment was not available for this important test.

RESPONSE:

The wire continuity test could not be performed adequately because the stressing washer could not be pushed along the tendon the 2 to 4 inches necessary to allow grasping each wire with a special tool for pulling on each wire. A number of different ways were tried to push on the stressing washer; none of them worked. All the equipment considered standard in the tendon surveillance business was on hand, but it simply wasn't adequate. In addition, a hydraulic vibrator was used, but it was unsuccessful also.

In all cases where the stressing washer could not be pushed far enough to allow the test to be run, the wires were checked by one of the two methods listed on page 2-2 so that the continuity of all wires was verified.

III-8. "No corrosion" is indicated on page 2-2. Explain the procedure establishing this negative condition, especially whether the procedure used permitted the discovery of any small pitting. See also Appendix G.

RESPONSE:

The anchorage hardware was cleaned with solvent, brushes, and rags, then it was visually inspected for corrosion. Corroded areas with diameter or width greater than about 1/50 inches would have been detected.

III-9. Discuss in detail the testing of wires. You should cover all important facets of the testing procedure including, but not limited to:

a. failing inside of gripping jaws. Influence of the shape of the jaws.

b. the influence of curvature and twisting of tendons as installed on the resistance of wire to removing, which may have predeformed the wires in a complex way.

c. rate of speed of the testing machines.

d. ambient temperature during testing.

e. possible eccentric loading by the machines, bending or twisting of the wire samples.

f. influence of the type of machine.

g. comparison of testing methods used by the manufacturers, by Pittsburgh Testing Laboratory, by Hales Testing Laboratory and by any other organization participating in testing of wire samples. Conformance with ASTM specifications.

h. influence of the temperature of filler and its pressure.

i. influence of the average temperature of tendons in place.

j. machine calibration.

RESPONSE:

III-9a The procedure used for field testing of wires is given in the Attachment No. 2, "Procedure for Testing of 100-Inch Gage Length Wire Specimens."

The wires tested by Pittsburgh Testing Laboratory were gripped in serrated jaws. Wire failure inside the gripping jaws indicates that the jaws caused stress concentration and the shape of the jaws affects any stress concentration. Therefore, the break strength in these tests is, possibly lower than the actual ultimate strength of the wire material.

The tests by Hales Testing Laboratory were conducted on buttonheaded wire samples following a procedure in accordance with ASTM A-421.

III-9b. The force needed to remove the wires is less than 3000 lbs. (25% of ultimate). Therefore, deformation because of curvature and twisting of the tendon is not likely.

III-9c. In all cases, the testing machine speed was in the range which is normal for steel tensile tests as specified in ASTM E8. Therefore, rate of loading had no influence on test results.

III-9d. Although ambient temperature was not recorded, all wire tests were done with ambient temperature between 50°F and 85°F. Therefore, ambient temperature had no influence on test results.

III-9e. Since a buttonheaded wire is self-centering loading from bending and twisting did not bring about premature wire failure. Bending or twisting for the tests by Pittsburgh Testing Laboratory would not be applicable for the reasons discussed in the response to III-9a.

III-9f. The only influence which the type of testing machine could have is in the calibration. The hydraulic cylinder used for the field tests was calibrated before and after the wire tests, and the testing machines used by Hales and by Pittsburgh were certified as having been calibrated according to good materials testing laboratory practice as specified in ASTM E4.

III-9g. All tensile tests were done in accordance with ASTM A-421 with two exceptions for the field tests:
(1) Sample length of 100 inches was used instead of 10 inch length. The longer sample length was used to comply with the requirement for the longest practical sample as stated in Regulatory Guide 1.35.

(2) The extension under load was measured with a device having the smallest division equal to 0.0003 in/in of gage length instead of 0.0001 in/in specified in ASTM A-421 for reasons of practical field application.

Tests performed by Pittsburgh Testing Laboratory used jaws to grasp the wires while Hales Testing Laboratory installed buttonheads on the wires and the tests were performed with much better results.

III-9h. The filler temperature during installation is high enough to make the filler quite fluid (115°F to 200°F) but not hot enough to affect the steel heat treatment. After installation, the filler temperature is in the range 30°F to 100°F; that would have no affect on the steel heat treatment either. The filler pressure has no effect on the mechanical properties of the tendon wire.

III-9i. The average temperature of tendons in place was within the range 30°F to 100°F at all times. Therefore, the in-place temperature had no influence on wire strength.

III-9j. Wire test machine calibration was addressed in response to Question III-9f.

III-10. Add to information provided regarding filler (page 3-1 and Appendix C) a discussion clarifying the problem of shrinkage of the filler when cooling (outside of trumpets). What procedures have been used to check on possible voids at intermediate points in tendons due to the cooling shrinkage?

RESPONSE:

The filler material is installed under a pressure of about 100 psi and at a temperature of around 115°F. The sheathing is vented at the high points and drained at the low points thus ensuring that the sheathing is filled and the wires fully coated. As the filler cools it will shrink about 5% by volume and voids may occur. However the wires will remain coated. There are no provisions for physically determining the presence of a void within the sheathing. However, during the surveillance, wires are removed from each family of tendons and inspected for corrosion as well as the tensile and elongation tests. See Section 7.2 of the Operating Procedure 1304.91, Rev. 2. All of the inspection wires in the third year surveillance were classified as #1 corrosion level bright metal, see Appendix G, Wire Inspection Data Sheets. From this it is concluded that the filler material is performing its intended purpose, that of inhibiting corrosion of the tendon wires.

III-11. Indicate whether local bending of bearing plates has been checked.

RESPONSE:

The bearing plates have been visually inspected, and no deformation has been observed.

III-12. Indicate how accurately the absence of pitting in anchor hardware has been observed, and the minimum size observable.

RESPONSE:

See response to Question III-8.

III-13. In Appendix B the normalizing formulae are presented. Discuss the possibility that factors neglected in these formulae may be more important than factors which have been included. (See Appendix B and page 4-1.) Some of the neglected factors are:

- First surveillance formula does not include concrete creep and concrete shrinkage or thermal effects and concrete placing variation.
- Integration along the tendon may introduce questionable properties of materials.
- Subsequent surveillance formula do not appear to include the following: thermal effects, shrinkage, detailed effects on creep, bearing plate displacements, changes in concrete, Young's elasticity modulus and Poisson's ratio, jack orientation, cracking of concrete.
- Indicate the tolerances in normalizing factors.

RESPONSE:

Attachment 1 gives extensive information on how the containment posttensioning requirements are originally determined. Also discussed is the method of determining predicted values, normalizing factors and a rational acceptance criteria.

III-14. Tables 4-1 and 4-2, pages 6-1 and 6-2 and Appendix B indicate that the elongations have been measured between the outside face of the bearing plate and the inside face of the anchor head. Discuss whether the precision of these measurements is sufficient to establish the adequacy and the correctness of lift-off forces.

RESPONSE:

Since the lift-off force is measured independently using a calibrated hydraulic ram, the precision of elongation measurement has no effect on "adequacy and correctness" of lift-off forces and used as an order of magnitude verification.

III-15. Discuss ram calibration. In page 4-3 of the report it is indicated that load cell calibration is "traceable" to the National Bureau of Standards. This expression is too vague. Indicate whether the NBS did in effect calibrate the load cells and if not, what is the significance of this procedure for the reliability of the calibration. It is also indicated in the same page that the uncertainty of the measurements is O.K. (two times standard deviation). Define the standard deviation for such a small number of measurements and discuss the basis for accepting an uncertainty of twice the standard deviation in this case. Discuss also whether the participation of NBS, University of California, University of Arkansas, Wiss, Janney, Elstner and Assoc., Inc., and Zabel Calibration Service in different phases of the calibration operations leads to compatible results. (See Appendix F.)

RESPONSE:

Tendon Stressing Rams

The rams used for measuring lift-off force and restressing the tendons were calibrated using a load cell belonging to AP&L. In January 1977, the load cell was calibrated by University of California using a testing machine which was certified as having calibration last done in November 1976 using load cells and a dynamometer ring calibrated by NBS in November 1969, April 1971, and April 1975. Calibration of the rams allows determination of the multiplying factor for converting hydraulic pressure measurement to ram force. To accomplish a ram calibration, nine sets of pressure vs. force readings were taken for each of nine pressures. The scatter of those data is the measurement uncertainty. The standard deviation is one possible measure of that uncertainty. To calculate standard deviation, the usual algorithm was used:

$$S = \sqrt{\frac{\Sigma X^2 - \frac{1}{n}(\Sigma X)^2}{n-1}}$$

where S is the standard deviation, X is a data point value, and n is the number of samples.

By stating the uncertainty as two standard deviations, the implication is made that any single measurement made with that ram has a 95% chance of being within a band of ±2S about the indicated force.

Wire Test Ram

The wire test ram used in the field was calibrated before the test by University of Arkansas and after the test by Wiss, Janey, Elstner and Assoc., Inc. The two calibrations agreed within 1.3%. That agreement by two independent calibrations should be taken as verification of the accuracy of ram calibration. Zabel Calibration Service calibrated the load machine used by Wiss, Janey, Elstner and Assoc., Inc. to calibrate the wire test ram.

III-16. On page 5-1 of the report it is stated that 13 wires from 23 surveillance tendons showed anomalies which were judged to be inconsequential. This is presented in some detail in 8 paragraphs on the same page. However, this information appears to indicate lax quality control during erection and not sufficient attention provided during previous surveillance operations. Discuss this problem.

RESPONSE:

The two wires identified as missing from tendon 31H40 were reported discontinuous and removed during the one year surveillance. The construction records of tendons 21H45, 32H40 and 32H48 showed that a wire was removed for inspection during the installation process. During initial installation the stressing operation was suspended for an extended period due to a failure of the stressing ram. Upon resumption of the stressing operation a wire was removed from some tendons for corrosion inspection. Of the remaining seven discontinuous wires, three failures were directly related to construction or initial posttensioning. The remaining four wires failed either during the three year time interval following initial posttensioning or during surveillance retensioning. This represents a failure rate of 4/4255 or 0.09% of the population inspected. The observed failures are therefore judged inconsequential to the overall tendon system. (See response tc Question I-3)

III-17. On page 5-4 of the report a brief discussion is given of the metallurgical investigation, presented in a more detailed way in Appendix I. The appropriateness of including the use of 12 inch sheave and the "Bauschinger" effect as explanations of the weakness of some wire samples has been questioned above.

a. Discuss the manufacturing, testing, and quality controls of Suzuki, Limited, also the possible effect of transporting the wires through long distance shipping.

b. Explain whether the fact presented in page 2 (Appendix I) that one wire showed evidence of rust on the failed end, whereas the other failed wire did not, corresponds to a normal condition, to be expected, or may indicate some special circumstance causing different behavior of the two wires.

RESPONSE:

III-17a Suzuki has been asked to furnish information on their manufacturing processes, testing procedures, standards of acceptability and quality control practices. This information has not been received as of this submittal. While the method of transporting the wire may have some effect on the wire, quality control procedures upon receipt and prior to fabrication would have disclosed coils of wire which did not meet the specification requirements. A sample was taken from each end of each coil of wire and tested prior to releasing the coil for fabrication. Therefore the effects of improper shipping methods would have been revealed and the wire rejected prior to fabrication.

III-17b The evidence of rust on the one wire fragment was a result of handling and storage after the wire test. It had no significance with respect to the wire test results.

III-18. Appendix A describes the Surveillance Procedure. State whether this procedure is in accordance with Regulatory Guide 1.35, with the ASME/ACI Pressure Vessel Code, Section III, Division 2, with the Technical Specifications and with Bechtel's Topical Report BC-TOP 5.

RESPONSE:

The Surveillance Procedure described in Appendix A was checked for compliance with the Technical Specifications and submitted to the Plant Safety Committee during the preparations for the surveillance. The procedures are in accordance with Regulatory Guide 1.35 and Bechtel's Topical Report BC-TOP 5.

III-19. Appendix E presents data sheets on retensioning, retensioning force and elongations. Discuss the possible errors in this operation and the tolerances which should be used to evaluate the results. On page 4-3, it is stated that Ram #1 failed, was repaired and recalibrated. Discuss the consistency of results obtained by using a recalibrated Ram. Evaluate the possible errors. See Question . 15 above on calibration. (See also Appendix F.)

RESPONSE:

Retensioning forces are subject to the following errors:

Nominal force	Systematic Error (%)	Uncertainty (%)
1000 lb/wire	-6.6 or less	0.5
80% of Ultimate	0.6 or less	0.5
Lift-off force	-0.4 or less	0.5

The systematic errors are taken from the calibration curves shown in Figure F.1 of the Surveillance Report. The uncertainty is two times the standard deviation of the calibration data as discussed in the response to Question III-15.

Elongations were resolved to .020 inch least count and are considered accurate to within ± the least count (i.e., ±.020 inch). Ram #1 was repaired and recalibrated, but was not used for tendon work after that. As a point of information however, it could have been used if needed with accuracy equivalent to its performance before the failure and repair.

III-20. Appendix H presents data sheets on tendon wire tests. Discuss the possible errors and tolerances to be applied to results. See also Question 9 above on wire testing.

RESPONSE:

The forces for the wire tests are subject to random errors in using the hydraulic cylinder and to any errors in reading the pressure gage. Random errors (uncertainty) are of no consequence since the calibration data as given by the University of Arkansas contain no deviation and no scatter was encountered. Pressure gage reading errors are judged to be within ±20 psi which is equivalent to 36 lb. force. The error from that source is then equal to or less than ±36 lb. or +0.3% of the guaranteed ultimate strength.

The displacement measurement for determining the elastic limit is accurate within ±.001 inch. Since the maximum length measured with this device was 1 inch, the accuracy for that measurement was ±0.1%. The displacement measurement for ultimate elongation was accurate within ±1/32 inch which is ±0.03% of the gage length.

III-21. The list of references presented in the report (Appendix I, page 4a) includes only references which date from 1958, 1963, and 1971. Present some references which are more up to date, especially on "Bauschinger Effect."

RESPONSE:

A computer search was conducted using the following files:

a) NTIS (National Technical Information Service)
b) Metadex (ASM Metal Abstracts)
c) Engineering Index

No additional published data were found regarding the Bauschinger Effect and its influence on the mechanical properties of wire. Several references were found where the Bauschinger Effect had been investigated with regard to its influence on the mechanical properties of various steel alloys and non-ferrous alloys. Abstracts, when available, were reviewed and papers selected which contain useful information.

References on Bauschinger Effect

1. Nakajima, K., et al, Bauschinger Effect in Pipe Forming, Transactions of the Japanese Iron and Steel Institute, Vol. 15, 1975, pp 1-10.

2. Wilson, E. G., Stress Varied Creep of 20% Cr-25% Ni-Nb Stabilized Austenitic Stainless Steel, Proceedings of Meeting at the University of Sheffield, England, September 20-22, 1972, pp 111-121.

3. Dietrich, Hermann and Schmidt, Werner, Effect of Minor Permanent Deformations on the Mechanical Properties of Steels, TEW Technical Bulletin, Vol. 1, June 1975, Krefeld, German, pp 85-93.

4. Gupta, S. P., Kodali, Surya, P., Effect of Pre-Strain on the Bauschinger Effect, Scr. Metall., Vol. 10, February 1976, pp 111-114.

5. Pepe, J. J., The Compression and Tensile Behavior of a Cold-Worked High Strength Steel, Report No. WVT-TR-74004, February 1975, Watervliet Arsenal, New York.

III-22. Indicate (Appendix I) whether the chemical analysis agrees with Suzuki results.

RESPONSE:

The chemical analysis done by Anamet Laboratories agrees very closely with the chemical analysis contained in the Inspection Certificate furnished by Suzuki Metal Industry Co., Ltd. as a part of the documentation package. A copy of this documentation is enclosed as Attachment 3.

III-23. Conclusions are presented on page 2-4 of the November 4, 1977 report. Modify these conclusions in accordance with the answers to these questions.

RESPONSE:

During the process of answering these questions, no information came to light to cause a change of the fundamental test conclusion. No abnormal degradation of the containment structure is indicated for Arkansas Nuclear One - Unit No. 1.