JUN 0 6 1988

Docket No. 50-395

LICENSEE: South Carolina Electric & Gas Company

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FACILITY: V. C. Summer Nuclear Station

SUBJECT: SUMMARY OF MEETING WITH SOUTH CAROLINA ELECTRIC & GAS COMPANY

General

On May 24, 1988, the NRC staff met with the South Carolina Electric & Gas Company (SCE&G) and their consultants to discuss the proposed change to Technical Specification (TS) 3.6.1.6, "Containment Structural Integrity," for the V. C. Summer Station. The meeting was held at Headquarters in Rockville, Maryland. A list of those persons who attended the meeting is included as Enclosure 1.

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The purpose of the meeting was to discuss the SCE&G response of March 17, 1988 to the NRC's request for additional information. The staff provided to SCE&G the information in Enclosure 2 via telecopy for the purpose of focusing the discussion for the meeting. Enclosure 3 was provided by SCE&G for the purpose of demonstrating, based upon the three surveillances of the containment tendons conducted, the projected point in time where the tendon force would be below the present Technical Specification value and the point in time if TS 3.6.1.6 was changed. Enclosure 4 provided a summary of the events involving this proposed Technical Specification change. Enclosure 5 is SCE&G's response to the information presented in Enclosure 2. As a result of this meeting, SCE&G will commit to provide, either in plant procedures or the Technical Specifications, a report on those occasions where the tendon average force data would indicate that the tendon forces would drop below their TS limit prior to the conduct of the next tendon surveillance. The approach to be taken will be discussed with the Project Director for Project Directorate II-1 and the Technical Specification Branch prior to discussing with SCE&G. The lead technical reviewer and his Branch Chief appeared to have all of their technical issues addressed.

151

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Division of Reactor Projects I/II

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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ENCLOSURE 1

ATTENDANCE

MAY 25, 1988 MEETING

SCE&G	NRC	Gilbert/Commonwealth Associates
W. Higgins	J. Hayes, Jr.	D. Krause
J. Todd	C. Tan	J. Herr
	G. Bagchi	C. Chen
		J. Fulton (Private Consultant)

INFORMATION REQUEST ON VIRGIL SUMMER TENDON SURVEILLANCE

5/19/89

1. THE STAFF HAS RESERVATIONS ON THE USE OF TENDON ELONGATION UNDER ACCIDENT PRESSURE AS A MEANS TO REDUCE THE REQUIRED MINIMUM AVERAGE TENDON FORCE FOR THE FOLLOWING REASONS:

   a) ON THE BASIS OF THE ANALYSIS OF THE TENDON INITALLATION & SURVEILLANCE DATA, THE LINEAR RELATIONSHIP BETWEEN TENDON FORCE AND TENDON ELONGATION DOES NOT ALWAYS EXIST, FOR INSTANCE FOR TENDON NO. V68

P. 1 OF 16

$$\begin{array}{r} 1602^{K} \\ -424 \\ \hline 1178^{K} \end{array} \div 10.5'' = 112.2^{K}/IN$$

$$\begin{array}{r} 1461^{K} \\ -424 \\ \hline 1037^{K} \end{array} \div 9.5'' = 109.2^{K}/IN$$

P. 4 OF 16

$$\begin{array}{r} 1583 \\ -424 \\ \hline 1159 \end{array} \div 9.16'' = 126.5^{K}/IN$$

$$\begin{array}{r} 1324 \\ -424 \\ \hline 900 \end{array} \div 8.47 = 106.5^{K}/IN$$

SUCH A CONDITION IS MORE PRONOUNCED IN HOOP AND DOME TENDONS DUE TO THE PRESENCE OF FRICTION.

b) THE COMPUTATION OF ELASTIC SHORTENING, SHRINKAGE, CREEP AND RELAXATION IS AT BEST AN APPROXIMATION. ANY VARIATION MAY CANCEL OUT THE GAIN IN TENDON ELONGATION. ALSO THE INCREASE IN TENDON FORCE MAY RESULT AN INCREASE IN CREEP.

c) FOR HOOP TENDONS, THE BUTTRESSES ARE UNDER COMPRESSION WHICH WILL REDUCE THE TENDON ELONGATION.

d) DEPENDING ON THE AMBIENT TEMPERATURE AT THE TIME OF CONSTRUCTION, THE TENDON FORCE MAY INCREASE OR DECREASE RESULTING IN THE VARIATION OF TENDON FORCES.

ON THE BASIS OF ABOVE CONSIDERATIONS, IT IS FELT THAT THE MARGIN OF SAFETY RESULTING FROM TENDON ELONGATION SHOULD NOT BE USED .. TO REDUCE MINIMUM REQUIRED AVERAGE TENDON FORCE

2. IN YOUR JANUARY 17, 1986 SUBMITTAL IT WAS INDICATED THAT STRESS RELAXATION TESTS WERE UNDERWAY AT FRITZ LABORATORIES. PROVIDE THE DETAILS AND RESULTS OF THE TESTS.

3. PROVIDE ~~AN APPROXIMATE~~ {HAND} CALCULATION WHICH approximates ~~GIVES~~ THE INTERNAL PRESSURE VALUES THAT TOGETHER WITH THE APPLIED PRESTRESSING FORCES WILL RESULT IN ZERO HOOP AND AXIAL MEMBRANE STRESSES.

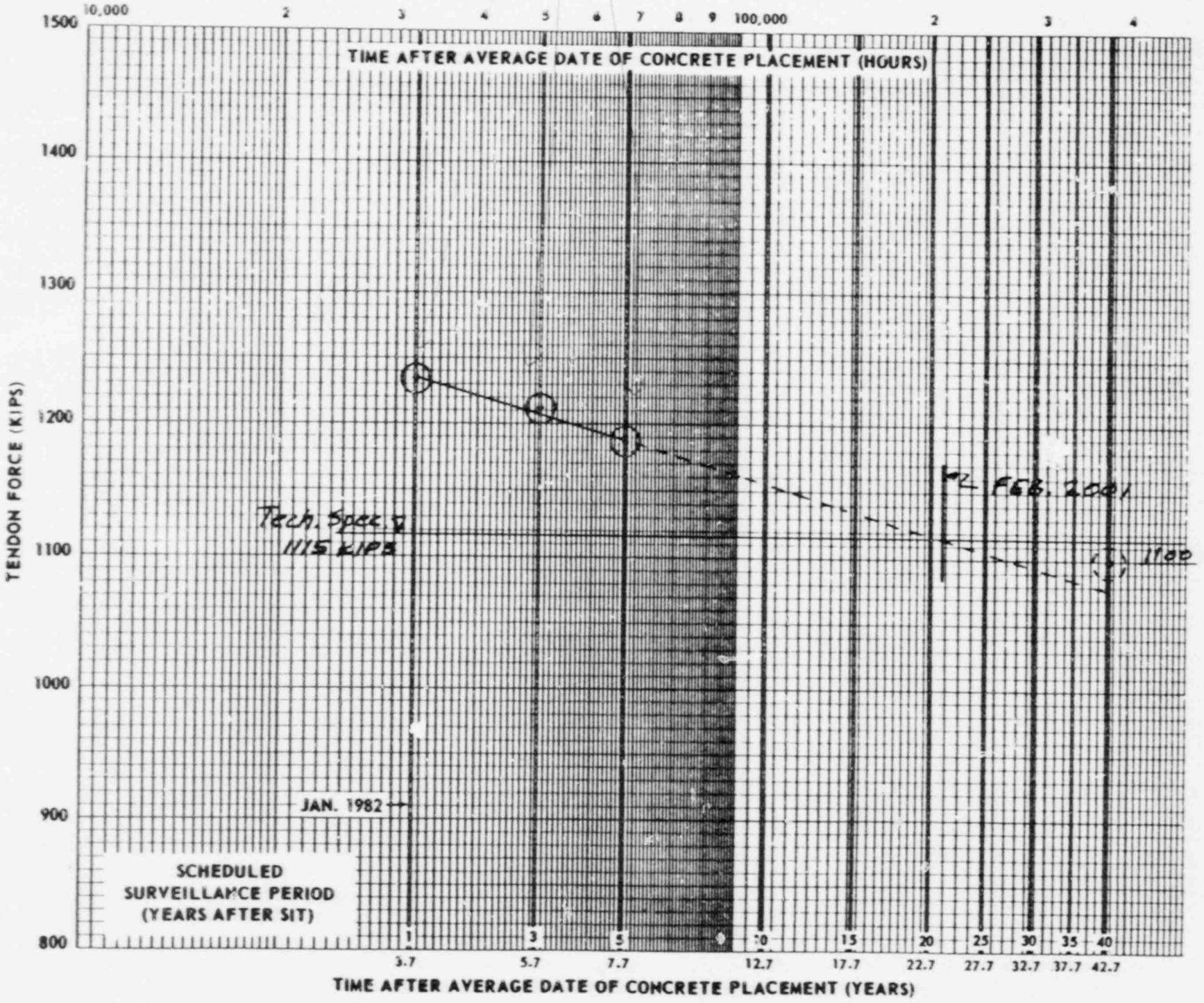

FIGURE 5. FORCE-TIME CURVE FOR AVERAGE DOME TENDON FORCES

ENCLOSURE 3

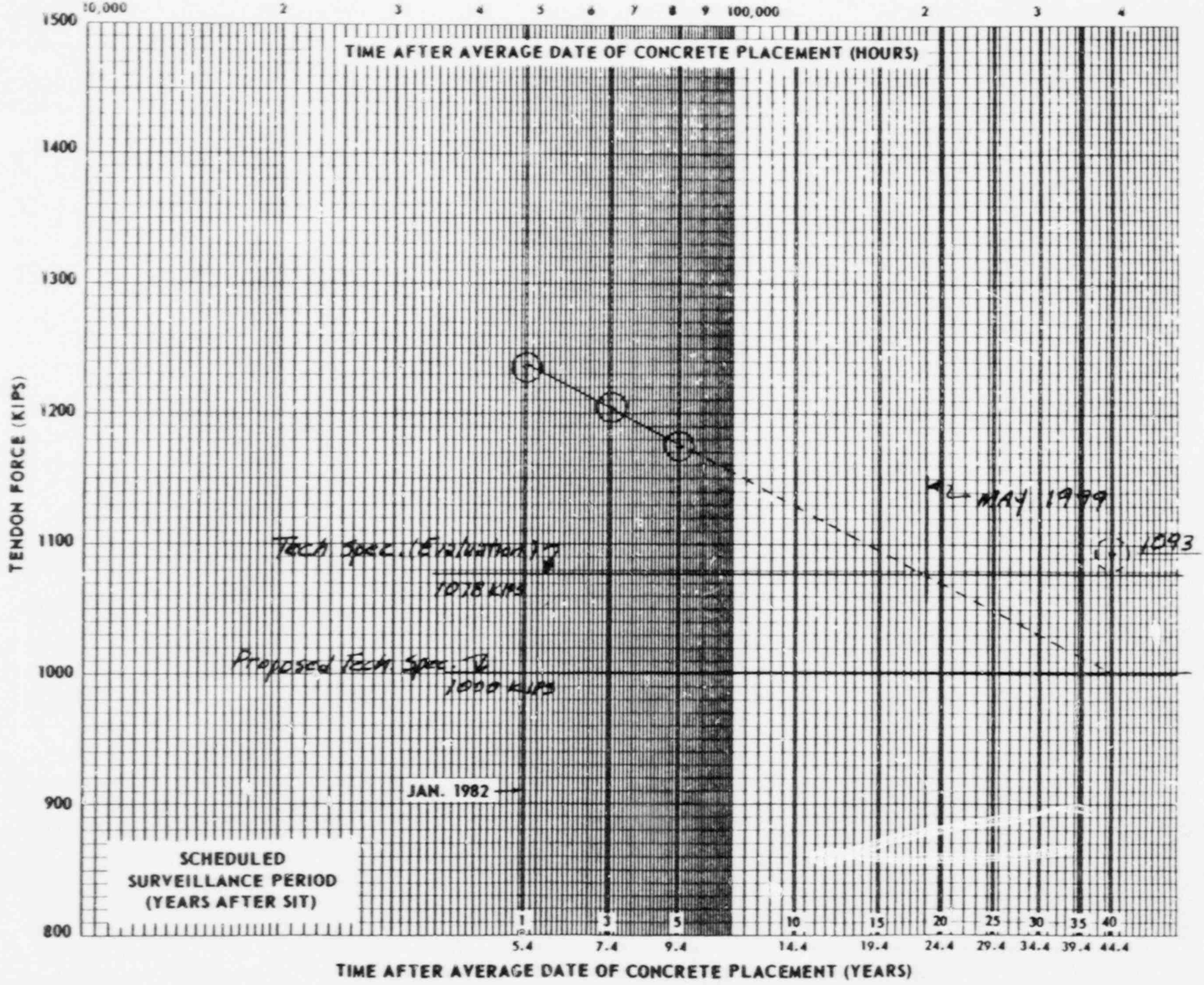

FIGURE 6. FORCE-TIME CURVE FOR AVERAGE HOOP TENDON FORCES

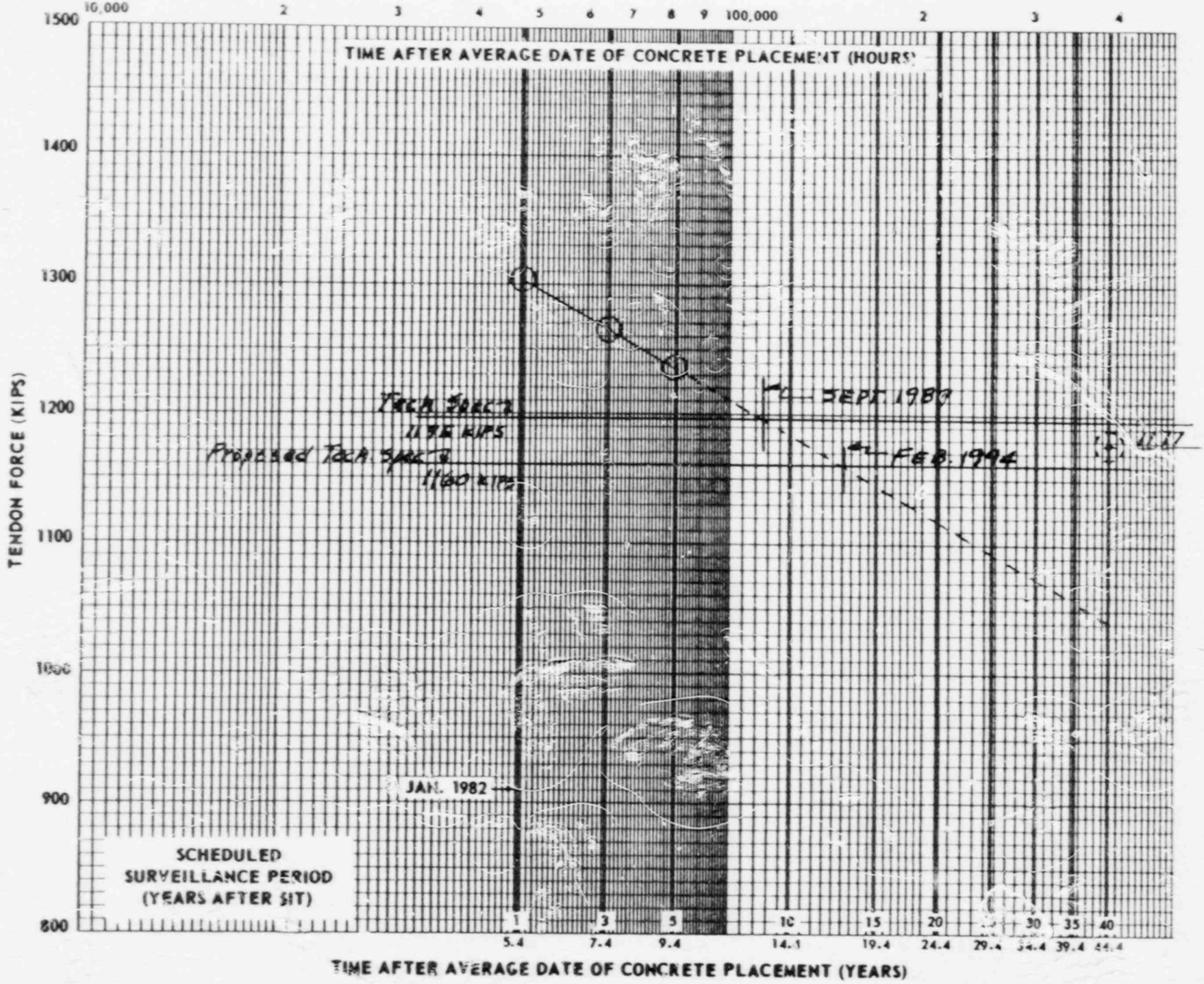

FIGURE 7. FORCE-TIME CURVE FOR AVERAGE VERTICAL TENDON FORCES

SUMMARY OF EVENTS
PROPOSED
TECH SPEC CHANGE

1. Third Tendon Surveillance - November-December 1985

   - Individual tendons below their respective 95% Base predicted values.

   - Average of normalized hoop tendon forces below Tech Spec limit: 1175 kips versus 1181 kips. Vertical and dome tendon group average forces were above their respective Tech Spec limits: Verticals at 1236 kips versus 1195 kips and domes at 1187 kips versus 1115 kips.

   - Vertical tendons projected to go below 1195 kips Tech Spec limit in second half of 1989.

2. Thirty day special report required by Tech Spec filed with NRC (GAI Report No. 2610).

   - Evaluation of individual tendon forces: effects of stress relaxation and effects of prestress loss analysis methodology.

   - Evaluation of analyses previously performed to establish Tech Spec values for minimum required average tendon forces for all three tendon groups.

   - For hoop tendons, a more accurate representation of the hoop tendon forces based on a model of the containment wall indicated that the Tech Spec limit 1181 kips for minimum required average tendon force could be reduced to 1078 kips and provide the 750 kips per ft. minimum required design hoop prestress.

   - Consideration of increase in tendon force due to tendon elongation under containment expansion allowed minimum required average tendon forces to be reduced from current Tech Spec limits: Verticals from 1195 kips to 1160 kips, domes from 1115 kips to 1065 kips, and hoops from 1078 kips to 1000 kips.

   - Recommended: (1) Use final wire stress relaxation test results to determine revised Base values; (2) Use non-interaction prestress loss calculation

method; and (3) Revise Tech Spec limits for minimum required average tendon force.

3. Proposed Tech Spec change to NRC - September 1986

   - Specify Tendon Surveillance Program for remainder of plant operation after Third Surveillance.
   - Reduce required minimum average prestress force levels.
   - Eliminate tables from Tech Spec that related to the first three surveillances.

4. NRC Questions (RFI) First Round - June 1987

5. SCE&G Reply to RFI First Round - August 1987

6. NRC Questions (RFI) Second Round (Informal Transmittal of Questions) - December 1987

7. NRC Questions (RFI) Second Round (Formal Transmittal of Questions) - March 1988

8. SCE&G Reply to RFI Second Round - April 1988

9. NRC Questions Third Round (Informal) - May 1988

RESPONSES TO NRC
INFORMAL INFORMATION REQUEST
DATED MAY 19, 1988

QUESTION 1:

The staff has reservations on the use of tendon elongation under accident pressure as a means to reduce the required minimum average tendon force for the following reasons:

QUESTION 1a:

On the basis of the analysis of the tendon installation and surveillance data, the linear relationship between tendon force and tendon elongation does not always exist, for instance for tendon no. V68:

P3 of 16

1602^k
-424
$1178^k \div 10.5'' = 112.2^k/in$

1461^k
-424
$1037^k \div 9.5'' = 109.2^k/in$

P4 of 16

1562
-424
$1159 \div 9.16'' = 126.5^k/in$

1324
-424
$900 \div 8.47'' = 106.4^k/in$

Such a condition is more pronounced in hoop and dome tendons due to the presence of friction.

RESPONSE TO QUESTION 1a:

The tendon selected as an example, tendon V68, is curved over a portion of its length as it deflects around the personal access opening. The fact that the apparent stiffness of the tendon V68 varies during stressing is due to several

effects. At original stressing of V68, the tendon was initially stressed up to 1602^{k} monotonically. Then the force was reduced, shims installed, and the tendon was seated. As a final operation, the tendon was lifted off and a lock-off force of 1461^{k} was recorded. When the tendon force was reduced from 1602^{k} to 1461^{k}, the friction forces were reversed along the tendon over a certain distance in the curvature region. Because of this effect and possibly measurement inaccuracies, the apparent stiffnes is slightly different (109.2^{k}/in.) from that due to monotonical stressing of the tendon (112.2^{k}/in.).

At the first surveillance, V68 was selected to be detensioned and then retensioned after a test wire was removed. The detensioning of the tendon also caused the friction forces to be redistributed and the apparent stiffness of the tendon increased.

Considering all straight vertical tendons that were involved in the first three surveillances (13 total), and based on the elongations that were measured at original stressing, an average effective Young's modulus, E, of 29.6 x 10^{6} psi was calculated. This value compares with 29.0 x 10^{6} psi used for E in the prestress increase calculations. Consequently, the measured elongations substantiate that the value of E used to determine the increase in prestressing force is conservative.

The above effects which cause differences in the apparent tendon stiffness are associated with end stressing of the tendon. These effects are not nearly as significant in the determination of increase in tendon force due to expansion of the containment for the following reason. Even though tendons are unbonded, there is a high degree of strain compatibility between the tendons and concrete. This condition does not exist when the tendon is stressed by applying a force at each end. For example, the radial expansion of the containment for the accident pressure load case produces essentially a uniform pressure load on the hoop tendons. There is compatibility in the radial displacements of the containment wall and hoop tendons. For all practical purposes, the strains in the tendon are uniform over most of its length and are equal to the hoop strain in the concrete, which is essentially uniform over the containment circumference.

For the dome, the prestress compressive stress levels in the concrete vary depending on the particular tendon. This was taken into account in the determination of the increase in dome prestress (refer to Calculations 1.18.2.3 previously submitted).

QUESTION 1b:

The computation of elastic shortening, shrinkage, creep and relaxation is at best an approximation. Any variation may cancel out the gain in tendon elongation, also the increase in tendon force may result in increase in creep.

RESPONSE TO QUESTION 1b:

Calculations of elastic shortening, shrinkage, creep, and stress relaxation are approximations based on theory and test results. Variation in tendon force losses due to these parameters can result in lower average forces in tendon groups than predicted by calculations. However, to establish the prestress level in the containment, these calculations are not relied upon. Rather tendon surveillances are performed to measure the tendon forces on a sample basis. Lift off measurements of tendon force provide assurance that the required minimum prestress levels are available and also establish whether force losses are occurring in a predictable manner, thus assuring that required minimum prestress levels will be available in the period between surveillances.

The first three surveillances for the V. C. Summer containment indicate that losses greater than predicted have occurred. However, the straight line semi-log paper plot of average measured force for each tendon group versus time for the first three surveillances indicates force losses are occurring in a predictable manner. These measured forces eliminate the approximations in the original calculations to predict losses since actual measured losses from three surveillances are available.

Predicted creep losses will not be influenced by the increased prestress force in the shell which occurs for internal pressure loads. Creep losses occur slowly over time - months and years. The postulated accident pressure loads occur for a period of hours - at most a few days. Any increase in creep will be

insignificantly small during the relatively short duration accident pressure loading.

QUESTION 1c:

For hoop tendons, the buttresses are under compression which will reduce the tendon elongation.

RESPONSE TO QUESTION 1c:

The effect on tendon force of buttress shortening due to compression resulting from hoop tendon prestress force under service conditions is accounted for by taking actual lift-off measurements of tendon force during surveillances. Any elastic shortening loss is reflected in the measured tendon force.

The effect of elastic shortening across the face of the buttress due to the increase in tendon force under accident pressure is negligible. The STRUDL analysis in calculation 1:18.2.1 submitted previously in response to NRC questions indicates a net shortening between the buttress faces of 0.0578 inches for a loading corresponding to 0.7 GUTS force (1402 kips) in the hoop tendons.

The increase in average hoop tendon force occurring under the 1.5 times accident pressure loading is 78 kips. Assuming, conservatively, the full 78 kips increase is reflected at the anchor heads, the elastic shortening of the buttress due to 78 kips can be calculated by direct ratio of the STRUDL analysis results for 1402 kips force.

Elastic Shortening = 78 kips/1402 kips x 0.0578 inches = 0.0032 inches

The tendon force corresonding to the 0.0032 inch shortening is:

Change in tendon force due to elastic shortening across buttress = $\Delta AE/L$ = (0.0032" x 8.345 sq. in. x 29×10^3) ÷ (12"/ft. x 269 ft.) = 0.24 kips or 240 pounds

Therefore, the effect of the elastic shortening across the face of the buttress for the additional 78 kip force per hoop tendon corresponds to less than 1 kip.

QUESTION 1d:

Depending on the ambient temperature at the time of construction, the tendon force may increase or decrease resulting in the variation of tendon forces.

RESPONSE TO QUESTION 1d:

It is agreed that the temperature of the tendon at any point in time can be different from that which occurred at original installation and stressing. This is expected to be the case during normal operating condition with the containment at an elevated steady state operating temperature. In this case, the tendon temperature is higher than that at original stressing. If the containment were not similarly affected by the elevated temperature, the tendon would experience an elastic thermal force decrease. However, it is generally accepted that the average temperature across the containment wall and dome is approximately equal to the tendon temperature. Because of this and due to the fact that the tendons and concrete have similar linear coefficients of thermal expansion (6.5 versus 5.5 micro inches per inch per ° F.), the thermal growth of the containment concrete and the tendon are practically the same, and there is no significant decrease in tendon force due to the elevated steady state operating temperature condition within the containment. For example, based on a 90° F. vertical tendon temperature, a 5 kip decrease in tendon force could result, which represents 0.4% of the minimum required force in the vertical tendons.

QUESTION 1 SUMMARY

On the basis of the above considerations, it is felt that the margin of safety resulting from tendon elongation should not be used to reduce minimum required average tendon force.

RESPONSE TO QUESTION 1 SUMMARY REGARDING MARGIN OF SAFETY

Accounting for increased prestress levels under postulated accident pressure conditions to the extent proposed still provdes significant design margins as indicated in the following discussion.

From one major standpoint, consideration of the tendons in the design of the V. C. Summer containment is conservative by the current standards reflected in the ASME B&PV Concrete Containment Code. In the current Code, under the factored load combinations, tendons are allowed to be considered acting together with the reinforcement for load resisting purposes. This is reflected in Article CC-3423 where the axial tensile capacity of the tendon is limited to 0.90 fpy, in which fpy is the yield strength of the tendon. In effect, the tendons may be considered as non-bonded reinforcement. Consequently, for each factored load combination, after the effective prestress and dead load compression stresses are overcome, the tendons together with the reinforcement are considered to resist the net tensile membrane force and accompanying moment. For V. C. Summer, these code provisions were not used; tendon forces beyond the effective prestress compressive stresses that they produce in the containment are not utilized. Significant reinforcement is provided to resist the net internal forces and moments.

For vertical tendons, for example, under the current Code the tendons at 0.9 fpy have a permissible tensile capacity of 1442^{k} based on the minimum specified yield strength of the tendon wire material. This is significantly greater (by 282^{k}) than the minimum required average tendon force of 1160^{k} that is proposed. The 282^{k} difference is equivalent to over 5 in.^{2} of Grade 60 reinforcement. This advantage was not utilized for the V. C. Summer containment design to determine the required reinforcement. Therefore, again using the vertical tendons as an example, accounting for tendon elongations and the accompanying 35^{k} increase in tendon force beyond its effective prestress level corresponding to 1160^{k} tendon force does not significantly impact the margin provided under the current Code where a 282^{k} increase in tendon force would be allowed.

QUESTION 2:

In your January 17, 1986 submittal, it was indicated that stress relaxtion tests were underway at Fritz Laboratories . Provide the details and results of the tests.

RESPONSE TO QUESTION 2:

Wire stress relaxation is not related to the determination of the minimum required prestress level. Wire stress relaxation is used as part of the input data to determine predicted forces in the individual tendons versus time.

As part of the investigation to determine why greater than anticipated losses were occurring in the tendon, wire stress relaxation tests were performed on tendon wire samples.

The testing is complete. The results indicate that the 8 1/2 percent relaxation used in the original calculations to predict losses is low. Test results indicate between 12 and 13 percent relaxation losses over 40 years.

Testing was performed on wire samples in 68° F., 90° F., and 104° F. environments. The 90° F. tests are representative of the tendon enironment in the containment. Force loss measurements were recorded at various times out to about 10,000 hours. The results were plotted on log-log sheets and projected to the 40 year end of plant life.

Four samples at 68° F. projected to an average relaxation of 9.6% at 40 years.

Three samples at 90° F. projected to an average of 12.8% at 40 years.

Two samples at 104° F. projected to an aerage of 17% at 40 years.

As a check of the 90° F. results, linear interpolation of the 68° F. and 104° F. results to 90° F. indicates 14% relaxation at 90° F. compared to the average of 12.8% for the 90° F. tests.

QUESTION 3:

Provide hand calculations which approximate the internal pressure values that together with the applied prestress in forces will result in zero hoop and axial membrane stresses.

RESPONSE TO QUESTION 3:

The following approximate calculations indicate the value of internal pressure that combined with the effective design prestress will result in zero hoop and axial membrane stresses.

AXIAL

Design Effective Prestress = 335 k/ft.
Internal Pressure: $N_\phi = PR/2 = 335$ k/ft.

$P = 2 \times 335^k/ft./R = 2 \times 335^k/ft./63$ ft. = 10.63 ksf = 73.8 psi
P = 73.8 psi = 1.29 Pa, Pa = 57 psig (DBA)

HOOP

Design Effective Prestress = 750 k/ft.
Internal Pressure: $N_\theta = PR$

$P = 750^k/ft./63$ ft. = 11.90 ksf = 82.6 psi
P = 82.6 psi = 1.45 Pa, Pa = 57 psig (DBA)

The above calculations are approximate in the sense that biaxial effects and dead load compressive stresses are not included.

These calculations demonstrate that the summer containment is designed as a "partially prestressed" structure. That is, the prestress level is not intended to maintain compression at zero membrane stress state under the controlling factored load combinations. For these load combinations, the resulting internal net tensile forces are resisted by significant amounts of reinforcement in the containment. In the hoop direction of the wall, #14 @ 12" spacing (outside face) and #11 @ 12" spacing (inside face) are generally provided. In the vertical direction of the wall, over the lower half, #18 @ 12" spacing (outside face) and #14 @ 12" spacing (inside face) are generally provided. In the upper half of the wall, #14 @ 12" spacing (outside face) and #14 @ 12" spacing (inside face) are generally provided. In the dome, the meridional and hoop reinforcement varies and #11 and #14 bars are provided.

DISTRIBUTION FOR MEETING SUMMARY DATED: JUN 06 1988

Facility: V. C. Summer Nuclear Station

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INFORMATION REQUEST
ON
VIRGIL SUMMER TENDON SURVEILLANCE

5/14/84

1. THE STAFF ~~HAS~~ RESERVATIONS ON THE USE OF TENDON ELONGATION UNDER ACCIDENT PRESSURE ~~AS~~ A MEANS TO REDUCE THE REQUIRED MINIMUM AVERAGE TENDON FORCE FOR THE FOLLOWING REASONS:

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P. 3 OF 16

$$\begin{array}{r} 1602^{K} \\ -424 \\ \hline 1178^{K} \end{array} \div 10.5'' = 112.2^{K}/IN$$

$$\begin{array}{r} 1461^{K} \\ -424 \\ \hline 1037^{K} \end{array} \div 9.5'' = 109.2^{K}/IN$$

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$$\begin{array}{r} 1583 \\ -424 \\ \hline 1159 \end{array} \div 9.16'' = 126.5^{K}/IN$$

$$\begin{array}{r} 1324 \\ -424 \\ \hline 900 \end{array} \div 8.47 = 106.5^{K}/IN$$

SUCH A CONDITION IS MORE PRONOUNCED IN HOOP AND DOME TENDONS DUE TO THE PRESENCE OF ERICTION.

b) THE COMPUTATION OF ELASTIC SHORTENING, SHRINKAGE, CREEP AND RELAXATION IS AT BEST AN APPROXIMATION. ANY VARIATION MAY CANCEL OUT THE GAIN IN TENDON ELONGATION. ALSO THE INCREASE IN TENDON FORCE MAY RESULT AN INCREASE IN CREEP.

c) FOR HOOP TENDONS, THE BUTTRESSES ARE UNDER COMPRESSION WHICH WILL REDUCE THE TENDON ELONGATION.

d) DEPENDING ON THE AMBIENT TEMPERATURE AT THE TIME OF CONSTRUCTION, THE TENDON FORCE MAY INCREASE OR DECREASE RESULTING IN THE VARIATION OF TENDON FORCES.

ON THE BASIS OF ABOVE CONSIDERATIONS, IT IS FELT THAT THE MARGIN OF SAFETY RESULTING FROM TENDON ELONGATION SHOULD NOT BE USED TO REDUCE MINIMUM REQUIRED AVGRAGE TENDON FORCE

2. IN YOUR JANUARY 17, 1986 SUBMITTAL IT WAS INDICATED THAT STRESS RELAXATION TESTS WERE UNDERWAY AT FRITZ LABORATORIES PROVIDE THE DETAILS AND RESULTS OF THE TESTS.

3. PROVIDE AN ~~APPROXIMATE~~ {HAND} CALCULATION WHICH approximates ~~GIVES~~ THE INTERNAL PRESSURE VALUES THAT TOGETHER WITH THE APPLIED PRESTRESSING FORCES WILL RESULT IN ZERO HOOP AND AXIAL MEMBRANE STRESSES.

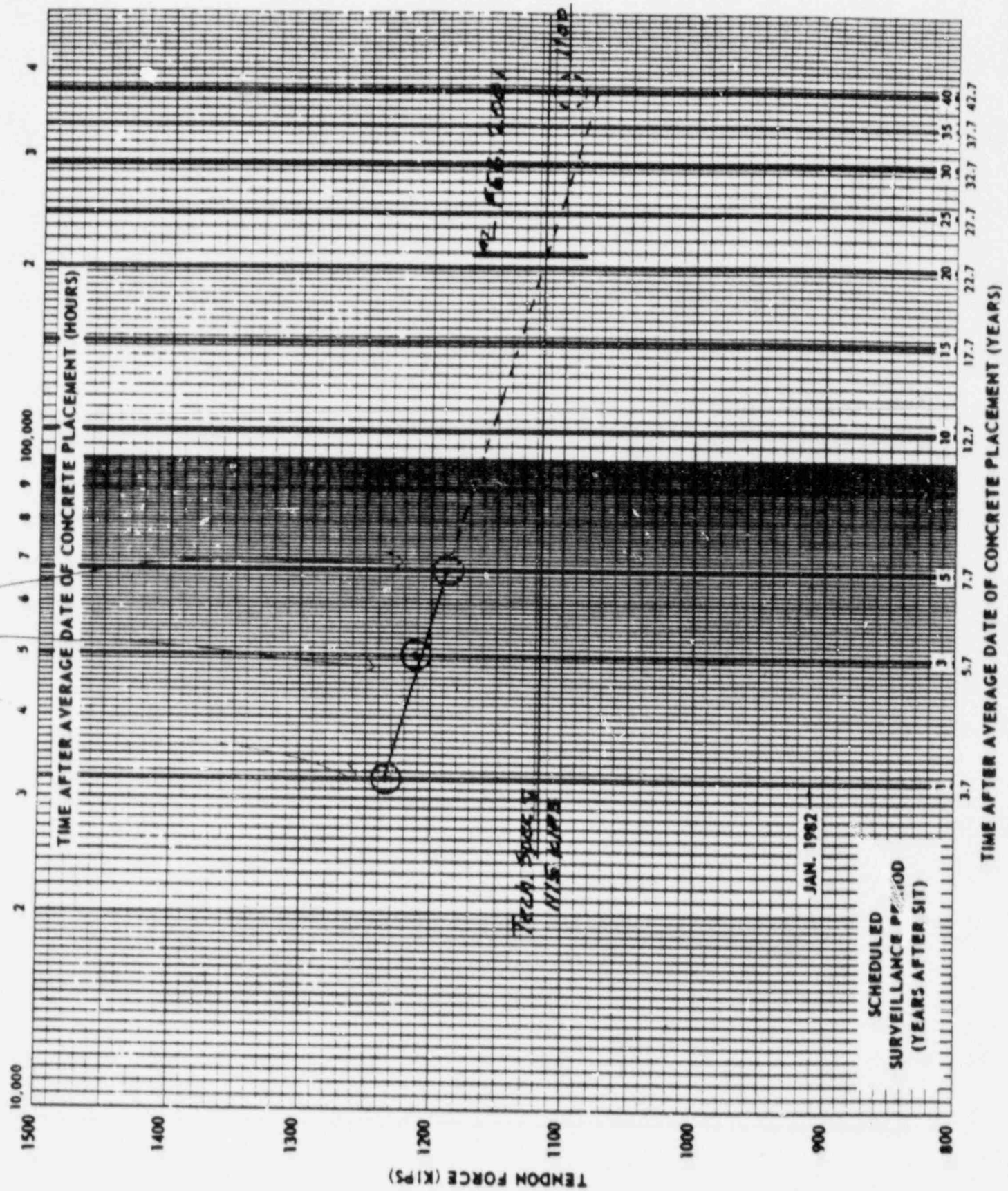

FIGURE 5. FORCE-TIME CURVE FOR AVERAGE DOME TENDON FORCES

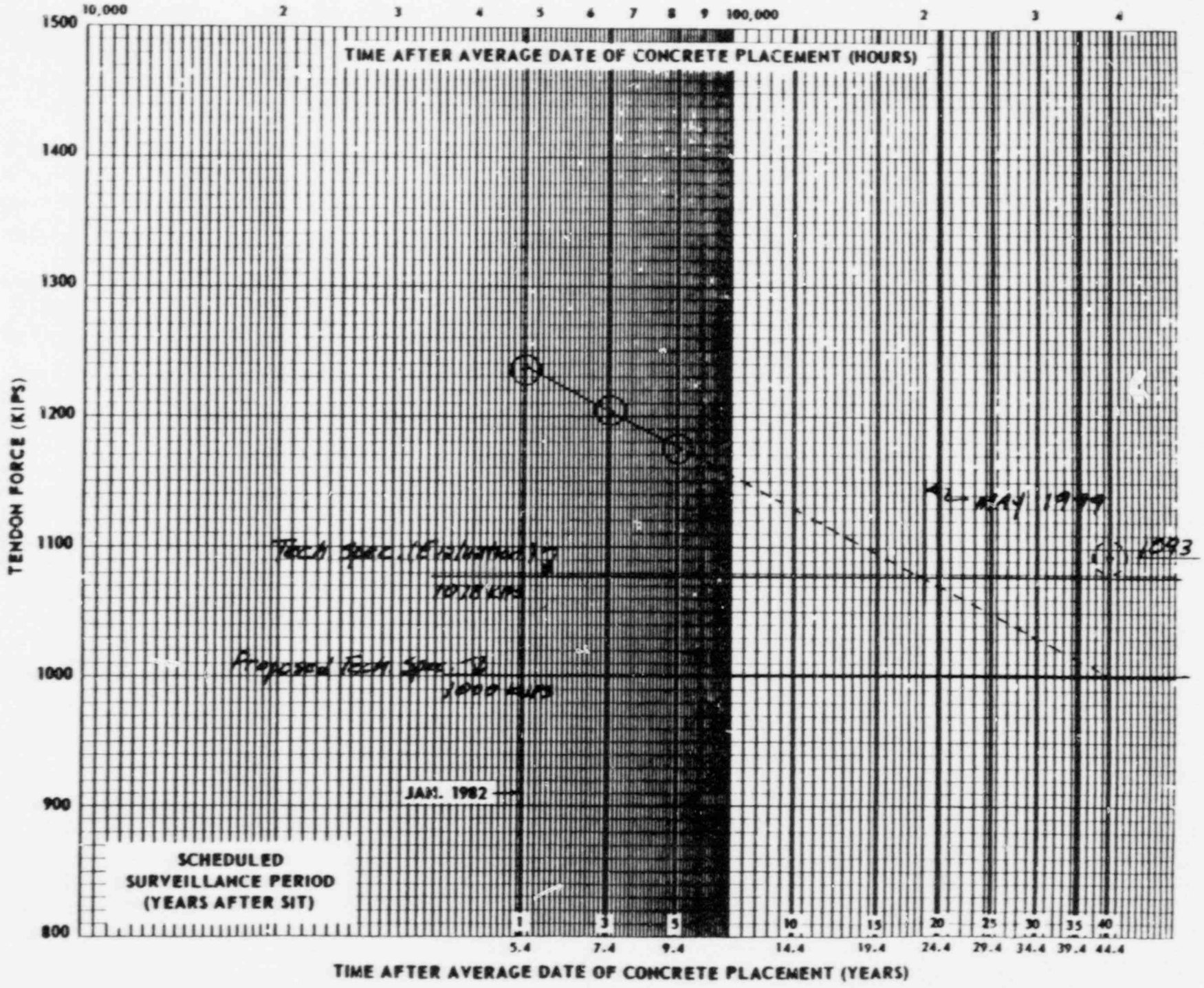

FIGURE 6. FORCE-TIME CURVE FOR AVERAGE HOOP TENDON FORCES

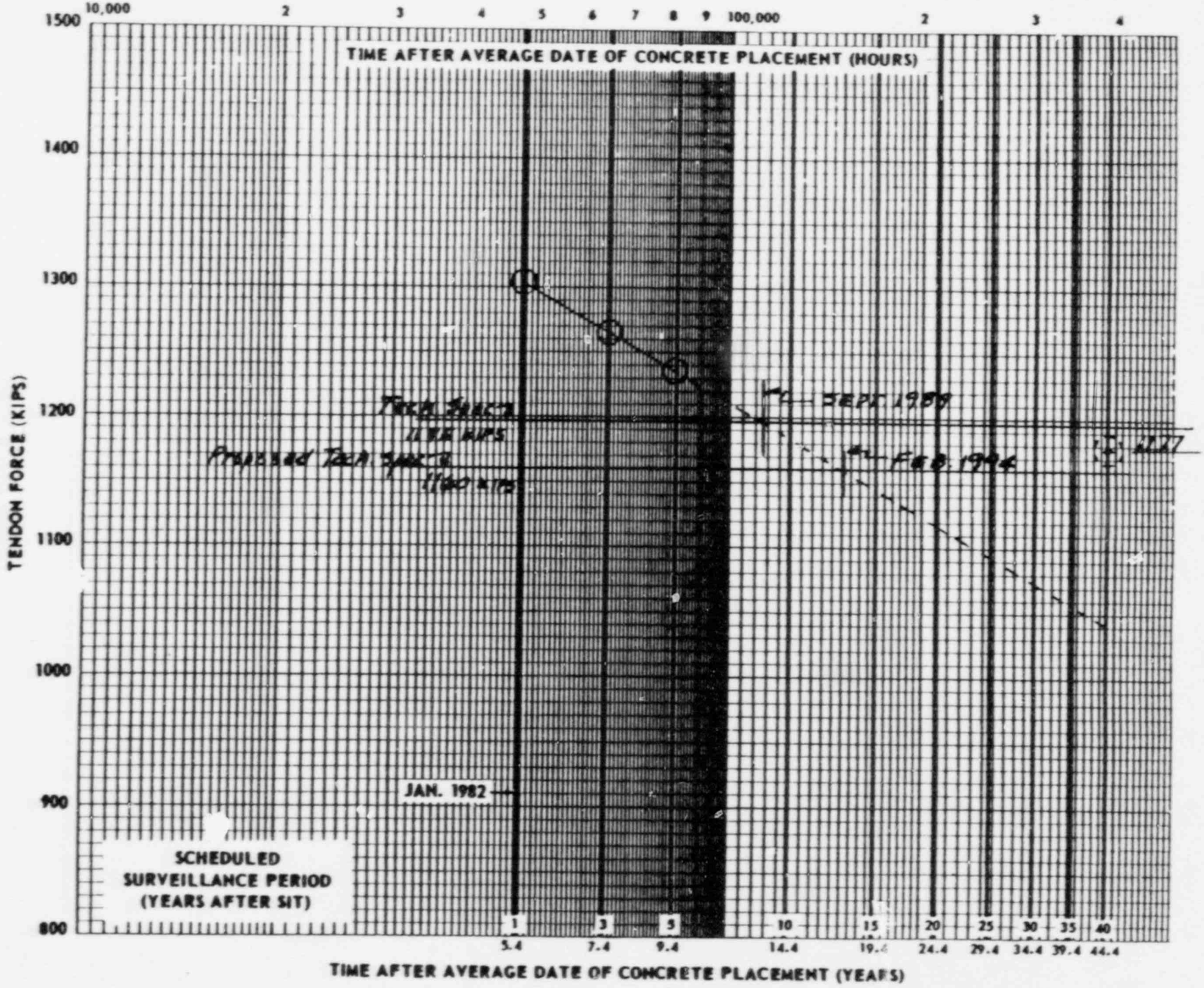

FIGURE 7. FORCE-TIME CURVE FOR AVERAGE VERTICAL TENDON FORCES

SUMMARY OF EVENTS
PROPOSED
TECH SPEC CHANGE

1. Third Tendon Surveillance - November-December 1985

   - Individual tendons below their respective 95% Base predicted values.

   - Average of normalized hoop tendon forces below Tech Spec limit: 1175 kips versus 1181 kips. Vertical and dome tendon group average forces were above their respective Tech Spec limits: Verticals at 1236 kips versus 1195 kips and domes at 1187 kips versus 1115 kips.

   - Vertical tendons projected to go below 1195 kips Tech Spec limit in second half of 1989.

2. Thirty day special report required by Tech Spec filed with NRC (GAI Report No. 2610).

   - Evaluation of individual tendon forces: effects of stress relaxation and effects of prestress loss analysis methodology.

   - Evaluation of analyses previously performed to establish Tech Spec values for minimum required average tendon forces for all three tendon groups.

   - For hoop tendons, a more accurate representation of the hoop tendon forces based on a model of the containment wall indicated that the Tech Spec limit 1181 kips for minimum required average tendon force could be reduced to 1078 kips and provide the 750 kips per ft. minimum required design hoop prestress.

   - Consideration of increase in tendon force due to tendon elongation under containment expansion allowed minimum required average tendon forces to be reduced from current Tech Spec limits: Verticals from 1195 kips to 1160 kips, domes from 1115 kips to 1065 kips, and hoops from 1078 kips to 1000 kips.

   - Recommended: (1) Use final wire stress relaxation test results to determine revised Base values; (2) Use non-interaction prestress loss calculation

method; and (3) Revise Tech Spec limits for minimum required average tendon force.

3. Proposed Tech Spec change to NRC - September 1986

   - Specify Tendon Surveillance Program for remainder of plant operation after Third Surveillance.
   - Reduce required minimum average prestress force levels.
   - Eliminate tables from Tech Spec that related to the first three surveillances.

4. NRC Questions (RFI) First Round - June 1987

5. SCE&G Reply to RFI First Round - August 1987

6. NRC Questions (RFI) Second Round (Informal Transmittal of Questions) - December 1987

7. NRC Questions (RFI) Second Round (Formal Transmittal of Questions) - March 1988

8. SCE&G Reply to RFI Second Round - April 1988

9. NRC Questions Third Round (Informal) - May 1988

RESPONSES TO NRC
INFORMAL INFORMATION REQUEST
DATED MAY 19, 1988

QUESTION 1:

The staff has reservations on the use of tendon elongation under accident pressure as a means to reduce the required minimum average tendon force for the following reasons:

QUESTION 1a:

On the basis of the analysis of the tendon installation and surveillance data, the linear relationship between tendon force and tendon elongation does not always exist, for instance for tendon no. V68:

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1602^k
-424
$1178^k \div 10.5'' = 112.2^k/in$

1461^k
-424
$1037^k \div 9.5'' = 109.2^k/in$

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1562
-424
$1159 \div 9.16'' = 126.5^k/in$

1324
-424
$900 \div 8.47'' = 106.4^k/in$

Such a condition is more pronounced in hoop and dome tendons due to the presence of friction.

RESPONSE TO QUESTION 1a:

The tendon selected as an example, tendon V68, is curved over a portion of its length as it deflects around the personal access opening. The fact that the apparent stiffness of the tendon V68 varies during stressing is due to several

effects. At original stressing of V68, the tendon was initially stressed up to 1602^{k} monotonically. Then the force was reduced, shims installed, and the tendon was seated. As a final operation, the tendon was lifted off and a lock-off force of 1461^{k} was recorded. When the tendon force was reduced from 1602^{k} to 1461^{k}, the friction forces were reversed along the tendon over a certain distance in the curvature region. Because of this effect and possibly measurement inaccuracies, the apparent stiffnes is slightly different (109.2^{k}/in.) from that due to monotonical stressing of the tendon (112.2^{k}/in.).

At the first surveillance, V68 was selected to be detensioned and then retensioned after a test wire was removed. The detensioning of the tendon also caused the friction forces to be redistributed and the apparent stiffness of the tendon increased.

Considering all straight vertical tendons that were involved in the first three surveillances (13 total), and based on the elongations that were measured at original stressing, an average effective Young's modulus, E, of 29.6 x 10^{6} psi was calculated. This value compares with 29.0 x 10^{6} psi used for E in the prestress increase calculations. Consequently, the measured elongations substantiate that the value of E used to determine the increase in prestressing force is conservative.

The above effects which cause differences in the apparent tendon stiffness are associated with end stressing of the tendon. These effects are not nearly as significant in the determination of increase in tendon force due to expansion of the containment for the following reason. Even though tendons are unbonded, there is a high degree of strain compatibility between the tendons and concrete. This condition does not exist when the tendon is stressed by applying a force at each end. For example, the radial expansion of the containment for the accident pressure load case produces essentially a uniform pressure load on the hoop tendons. There is compatibility in the radial displacements of the containment wall and hoop tendons. For all practical purposes, the strains in the tendon are uniform over most of its length and are equal to the hoop strain in the concrete, which is essentially uniform over the containment circumference.

For the dome, the prestress compressive stress levels in the concrete vary depending on the particular tendon. This was taken into account in the determination of the increase in dome prestress (refer to Calculations 1.18.2.3 previously submitted).

QUESTION 1b:

The computation of elastic shortening, shrinkage, creep and relaxation is at best an approximation. Any variation may cancel out the gain in tendon elongation, also the increase in tendon force may result in increase in creep.

RESPONSE TO QUESTION 1b:

Calculations of elastic shortening, shrinkage, creep, and stress relaxation are approximations based on theory and test results. Variation in tendon force losses due to these parameters can result in lower average forces in tendon groups than predicted by calculations. However, to establish the prestress level in the containment, these calculations are not relied upon. Rather tendon surveillances are performed to measure the tendon forces on a sample basis. Lift off measurements of tendon force provide assurance that the required minimum prestress levels are available and also establish whether force losses are occurring in a predictable manner, thus assuring that required minimum prestress levels will be available in the period between surveillances.

The first three surveillances for the V. C. Summer containment indicate that losses greater than predicted have occurred. However, the straight line semi-log paper plot of average measured force for each tendon group versus time for the first three surveillances indicates force losses are occurring in a predictable manner. These measured forces eliminate the approximations in the original calculations to predict losses since actual measured losses from three surveillances are available.

Predicted creep losses will not be influenced by the increased prestress force in the shell which occurs for internal presure loads. Creep losses occur slowly over time - months and years. The postulated accident pressure loads occur for a period of hours - at most a few days. Any increase in creep will be

insignificantly small during the relatively short duration accident pressure loading.

QUESTION 1c:

For hoop tendons, the buttresses are under compression which will reduce the tendon elongation.

RESPONSE TO QUESTION 1c:

The effect on tendon force of buttress shortening due to compression resulting from hoop tendon prestress force under service conditions is accounted for by taking actual lift-off measurements of tendon force during surveillances. Any elastic shortening loss is reflected in the measured tendon force.

The effect of elastic shortening across the face of the buttress due to the increase in tendon force under accident pressure is negligible. The STRUDL analysis in calculation 1:18.2.1 submitted previously in response to NRC questions indicates a net shortening between the buttress faces of 0.0578 inches for a loading corresponding to 0.7 GUTS force (1402 kips) in the hoop tendons.

The increase in average hoop tendon force occurring under the 1.5 times accident pressure loading is 78 kips. Assuming, conservatively, the full 78 kips increase is reflected at the anchor heads, the elastic shortening of the buttress due to 78 kips can be calculated by direct ratio of the STRUDL analysis results for 1402 kips force.

Elastic Shortening = 78 kips/1402 kips x 0.0578 inches = 0.0032 inches

The tendon force corresonding to the 0.0032 inch shortening is:

Change in tendon force due to elastic shortening across buttress = $\Delta AE/L$ = (0.0032" x 8.345 sq. in. x 29 x 10^3) ÷ (12"/ft. x 269 ft.) = 0.24 kips or 240 pounds

Therefore, the effect of the elastic shortening across the face of the buttress for the additional 78 kip force per hoop tendon corresponds to less than 1 kip.

QUESTION 1d:

Depending on the ambient temperature at the time of construction, the tendon force may increase or decrease resulting in the variation of tendon forces.

RESPONSE TO QUESTION 1d:

It is agreed that the temperature of the tendon at any point in time can be different from that which occurred at original installation and stressing. This is expected to be the case during normal operating condition with the containment at an elevated steady state operating temperature. In this case, the tendon temperature is higher than that at original stressing. If the containment were not similarly affected by the elevated temperature, the tendon would experience an elastic thermal force decrease. However, it is generally accepted that the average temperature across the containment wall and dome is approximately equal to the tendon temperature. Because of this and due to the fact that the tendons and concrete have similar linear coefficients of thermal expansion (6.5 versus 5.5 micro inches per inch per ° F.), the thermal growth of the containment concrete and the tendon are practically the same, and there is no significant decrease in tendon force due to the elevated steady state operating temperature condition within the containment. For example, based on a 90° F. vertical tendon temperature, a 5 kip decrease in tendon force could result, which represents 0.4% of the minimum required force in the vertical tendons.

QUESTION 1 SUMMARY

On the basis of the above considerations, it is felt that the margin of safety resulting from tendon elongation should not be used to reduce minimum required average tendon force.

RESPONSE TO QUESTION 1 SUMMARY REGARDING MARGIN OF SAFETY

Accounting for increased prestress levels under postulated accident pressure conditions to the extent proposed still provdes significant design margins as indicated in the following discussion.

From one major standpoint, consideration of the tendons in the design of the V. C. Summer containment is conservative by the current standards reflected in the ASME B&PV Concrete Containment Code. In the current Code, under the factored load combinations, tendons are allowed to be considered acting together with the reinforcement for load resisting purposes. This is reflected in Article CC-3423 where the axial tensile capacity of the tendon is limited to 0.90 fpy, in which fpy is the yield strength of the tendon. In effect, the tendons may be considered as non-bonded reinforcement. Consequently, for each factored load combination, after the effective prestress and dead load compression stresses are overcome, the tendons together with the reinforcement are considered to resist the net tensile membrane force and accompanying moment. For V. C. Summer, these code provisions were not used; tendon forces beyond the effective prestress compressive stresses that they produce in the containment are not utilized. Significant reinforcement is provided to resist the net internal forces and moments.

For vertical tendons, for example, under the current Code the tendons at 0.9 fpy have a permissible tensile capacity of 1442^{k} based on the minimum specified yield strength of the tendon wire material. This is significantly greater (by 282^{k}) than the minimum required average tendon force of 1160^{k} that is proposed. The 282^{k} difference is equivalent to over 5 in.^{2} of Grade 60 reinforcement. This advantage was not utilized for the V. C. Summer containment design to determine the required reinforcement. Therefore, again using the vertical tendons as an example, accounting for tendon elongations and the accompanying 35^{k} increase in tendon force beyond its effective prestress level corresponding to 1160^{k} tendon force does not significantly impact the margin provided under the current Code where a 282^{k} increase in tendon force would be allowed.

QUESTION 2:

In your January 17, 1986 submittal, it was indicated that stress relaxtion tests were underway at Fritz Laboratories . Provide the details and results of the tests.

RESPONSE TO QUESTION 2:

Wire stress relaxation is not related to the determination of the minimum required prestress level. Wire stress relaxation is used as part of the input data to determine predicted forces in the individual tendons versus time.

As part of the investigation to determine why greater than anticipated losses were occurring in the tendon, wire stress relaxation tests were performed on tendon wire samples.

The testing is complete. The results indicate that the 8 1/2 percent relaxation used in the original calculations to predict losses is low. Test results indicate between 12 and 13 percent relaxation losses over 40 years.

Testing was performed on wire samples in 68° F., 90° F., and 104° F. environments. The 90° F. tests are representative of the tendon enironment in the containment. Force loss measurements were recorded at various times out to about 10,000 hours. The results were plotted on log-log sheets and projected to the 40 year end of plant life.

Four samples at 68° F. projected to an average relaxation of 9.6% at 40 years.

Three samples at 90° F. projected to an average of 12.8% at 40 years.

Two samples at 104° F. projected to an aerage of 17% at 40 years.

As a check of the 90° F. results, linear interpolation of the 68° F. and 104° F. results to 90° F. indicates 14% relaxation at 90° F. compared to the average of 12.8% for the 90° F. tests.

QUESTION 3:

Provide hand calculations which approximate the internal pressure values that together with the applied prestress in forces will result in zero hoop and axial membrane stresses.

RESPONSE TO QUESTION 3:

The following approximate calculations indicate the value of internal pressure that combined with the effective design prestress will result in zero hoop and axial membrane stresses.

AXIAL

Design Effective Prestress = 335 k/ft.
Internal Pressure: $N_\phi = PR/2 = 335$ k/ft.

$P = 2 \times 335^{k}/ft./R = 2 \times 335^{k}/ft./63$ ft. = 10.63 ksf = 73.8 psi
P = 73.8 psi × 1.29 Pa, Pa = 57 psig (DBA)

HOOP

Design Effective Prestress = 750 k/ft.
Internal Pressure: $N_\theta = PR$

$P = 750^{k}/ft./63$ ft. = 11.90 ksf = 82.6 psi
P = 82.6 psi × 1.45 Pa, Pa = 57 psig (DBA)

The above calculations are approximate in the sense that biaxial effects and dead load compressive stresses are not included.

These calculations demonstrate that the summer containment is designed as a "partially prestressed" structure. That is, the prestress level is not intended to maintain compression at zero membrane stress state under the controlling factored load combinations. For these load combinations, the resulting internal net tensile forces are resisted by significant amounts of reinforcement in the containment. In the hoop direction of the wall, #14 @ 12" spacing (outside face) and #11 @ 12" spacing (inside face) are generally provided. In the vertical direction of the wall, over the lower half, #18 @ 12" spacing (outside face) and #14 @ 12" spacing (inside face) are generally provided. In the upper half of the wall, #14 @ 12" spacing (outside face) and #14 @ 12" spacing (inside face) are generally provided. In the dome, the meridional and hoop reinforcement varies and #11 and #14 bars are provided.