ATTACHMENT NO. 1

CONTAINMENT TENDON SURVEILLANCE

LIFT-OF ACCEPTANCE CRITERIA

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LIFT-OFF ACCEPTANCE CRITERIA

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LIFT-OFF ACCEPTANCE CRITERIA

1.0 INTRODUCTION

The following information has been assembled to aid in the understanding of the purpose and requirements of tendon surveillance in prestressed post-tensioned concrete nuclear containments with unbonded tendons. The major emphasis is on the determination and acceptability of tendon lift-off measurements.

It is essential when determining acceptance based on surveillance results that the reviewer consider and have knowledge of basic containment design.

Tendon surveillance has been performed by Bechtel Power Corporation on many containments and was first done on the Palisades Containment in 1972 based on procedures developed by Bechtel. Since that time, Regulatory Guide 1.35 has been issued and a working group under ASME Section XI has been attempting to develop standards. Present containment design and construction is covered by the ASME Section III, Division 2 Code.

Bechtel has sent comments to the NRC on Regulatory Guide 1.35. The comments and suggestions were based on extensive experience in containment tendon surveillance. The main objective was to try and get standardization of data reduction for the industry, using what was considered as the most meaningful technique. In addition it was pointed out that problems were coming in the future with the present Regulatory Guide 1.35 acceptance criteria. The Bechtel letter to the NRC and the response are in Appendix A. The NRC response was extremely disappointing. Therefore the material contained herein is provided as further back-up for previous comments.

2.0 CONTAINMENT TYPES AND DESCRIPTIONS

The first generation of prestressed containment structures (Type I) used about 500 ton capacity tendons, with six buttresses in the cylinder and ellipsoidal domes. These containments had about 500 hoop, 180 vertical and 165 dome tendons.

By the next generation of containments (Type II), it was found feasible to use larger and longer tendons. The tendon capacity was about 1,000 tons and three buttresses were used. With the larger tendons and three buttresses, the tendons were reduced to about 160 hoop, 90 vertical and 85 dome tendons. A comparison of the hoop tendon configuration is shown in Figure 2-1 for the three and six buttress containments.

In addition to the changes listed above, the minimum prestress level was reduced from 1.5P (design pressure) to 1.2P for some containments. An approximate estimate of the amount of prestress in a containment can be obtained by using the following expression:

$$X = \frac{F+D}{P}$$

where:

X = level of prestress

F = effective prestress force at end of design life

D = dead load

P = force resulting from internal pressure

For the Type I and Type II containments, $X \geq 1.5$, and in the later Types II and III containments, $X \geq 1.2$. The 1.5 criteria essentially requires the containment to resist the factored loads by the effective prestress which is the initial force in the tendon at installation minus the losses from friction, concrete creep and shrinkage, and prestressing steel relaxation. The very conservative 1.5 criteria was used for the first containments since they were new in the U.S. As further experience and knowledge of containments developed, it was determined that the 1.2P could replace the 1.5P criteria and still maintain the required degree of safety.

The 1.2 criteria allows membrane concrete cracking when the containment is designed for combined factored loads. This cracking allows the tendon to be retensioned from the effective value until force equilibrium is satisfied. Under these combined factored loads, which include the effects of the design accident combined with the Safe Shutdown Earthquake, the tendon is allowed to reach a stress level of 90% of the yield.

Both criteria require that the containment remain in membrane compression during the initial structural integrity test (SIT) since the test pressurization is equal to 1.15P. With the test pressurization of 1.15P, both the 1.2 and 1.5 containments would respond about the same due to the test pressurization.

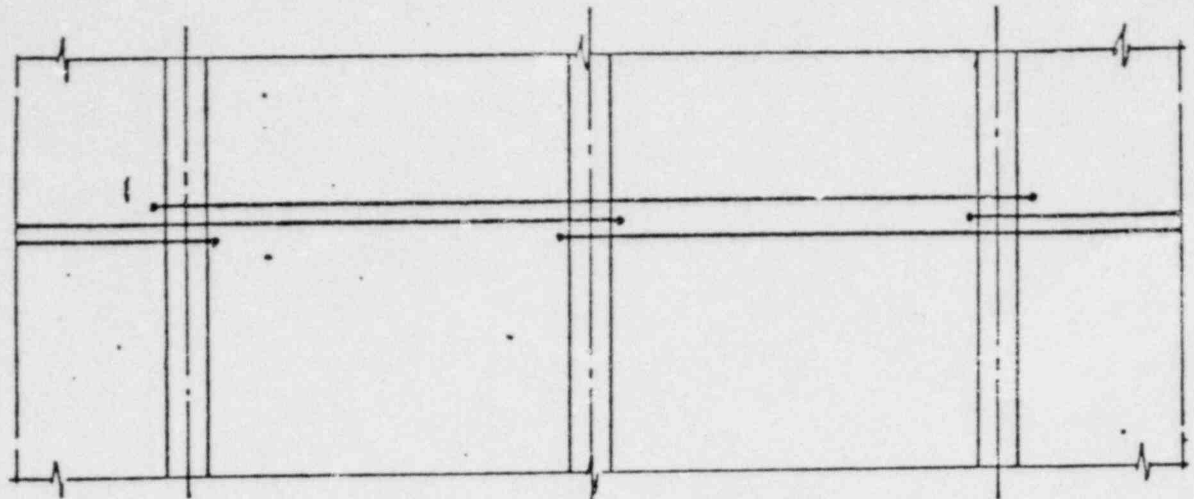
The latest generation of containments (Type III) has simplified the configuration from ellipsoidal to hemispherical domes, which eliminated the ring girder and enabled the dome and vertical tendons to be combined in a single tendon which anchors in the tendon gallery. For containments with hemispherical domes and 1.2P minimum prestress level, there are about 150 hoop and 70 combined dome-vertical tendons which anchor in the tendon gallery. A comparison of containment tendon layout is shown in Figure 2-2.

The number of tendons stated previously for containments can vary due to size, magnitude of design pressure and earthquake, and the amount of prestress loss due to concrete creep and shrinkage and prestressing wire or strand relaxation.

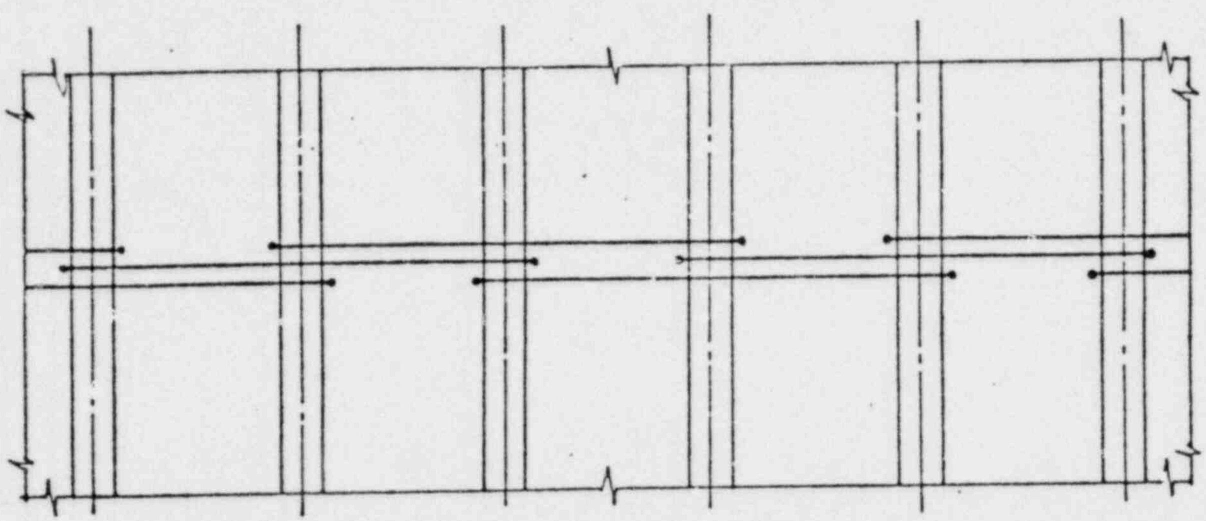
Figure 2-3 shows a comparison of the three types of containments that have been designed by Bechtel Power Corporation in the past and are presently under design.

FIGURE 2-1

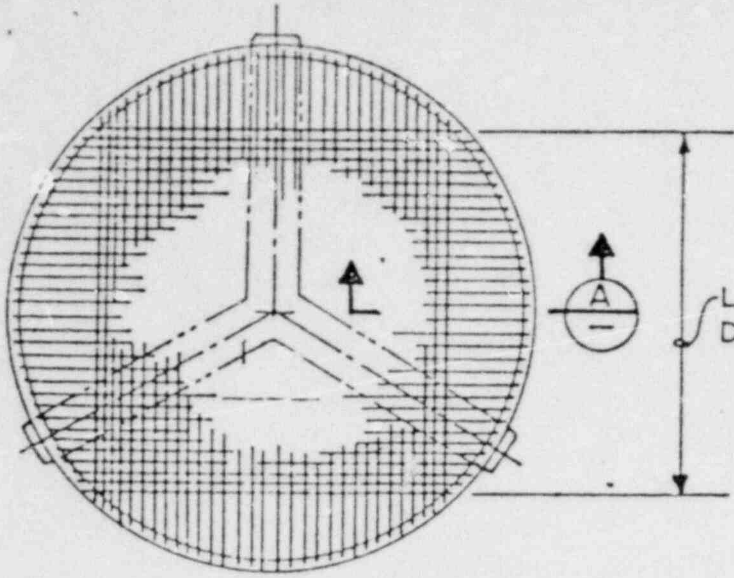
CONTAINMENT HOOP TENDON CONFIGURATION



DEVELOPED ELEVATION
HORIZONTAL WALL TENDONS
(3 BUTTRESSES)

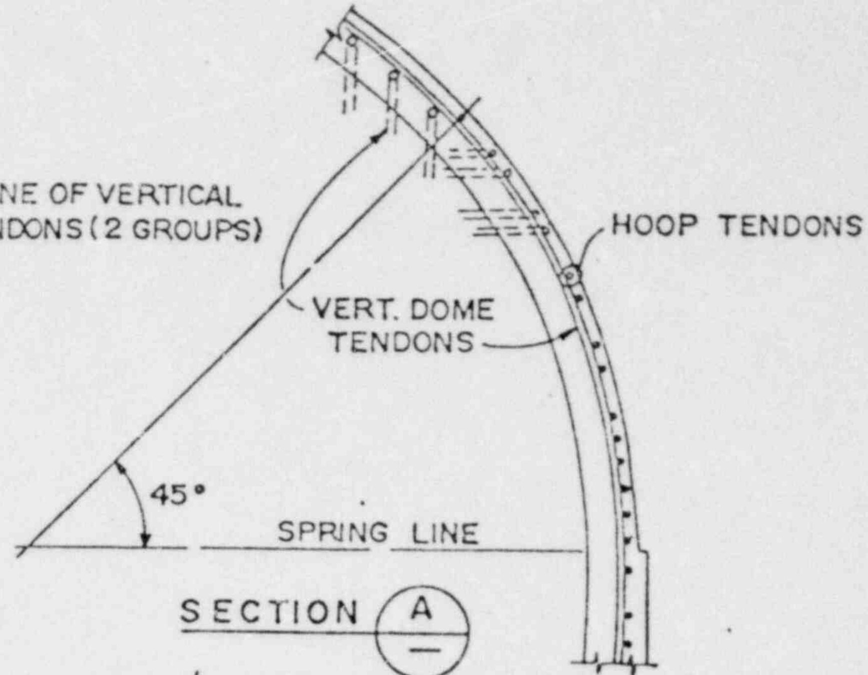


DEVELOPED ELEVATION
HORIZONTAL WALL TENDONS
(6 BUTTRESSES)

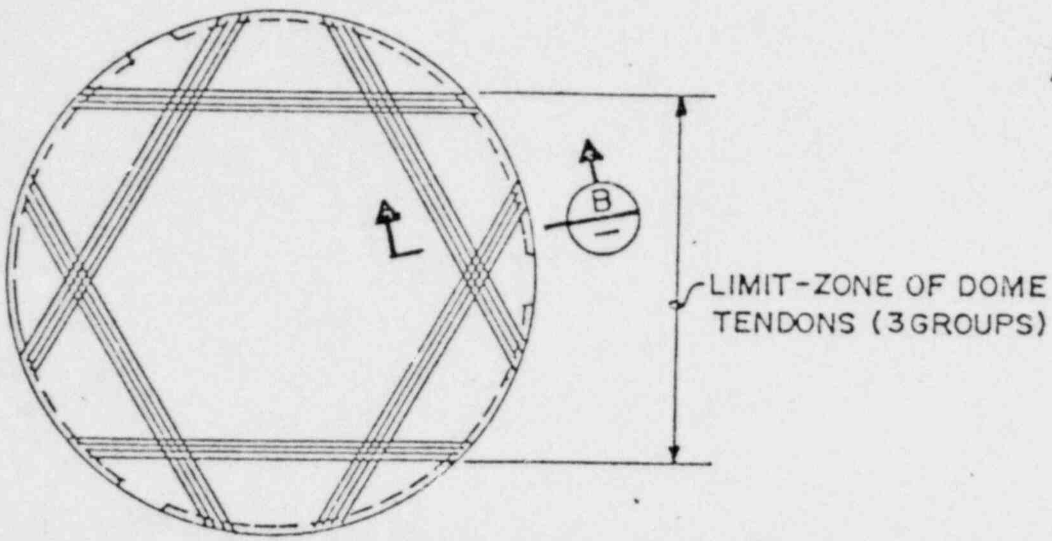


PLAN - HEMISPHERICAL DOME

TYPE III

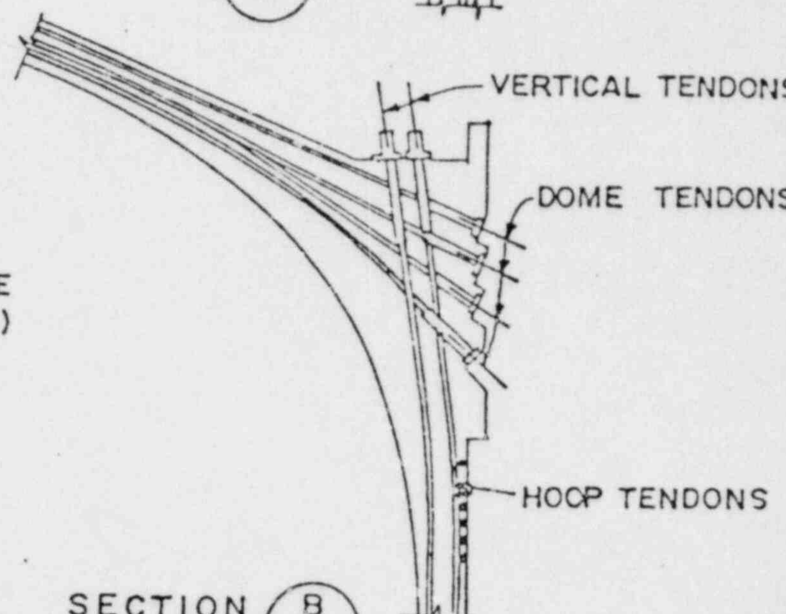


SECTION A



PLAN - SPHERE TORUS DOME

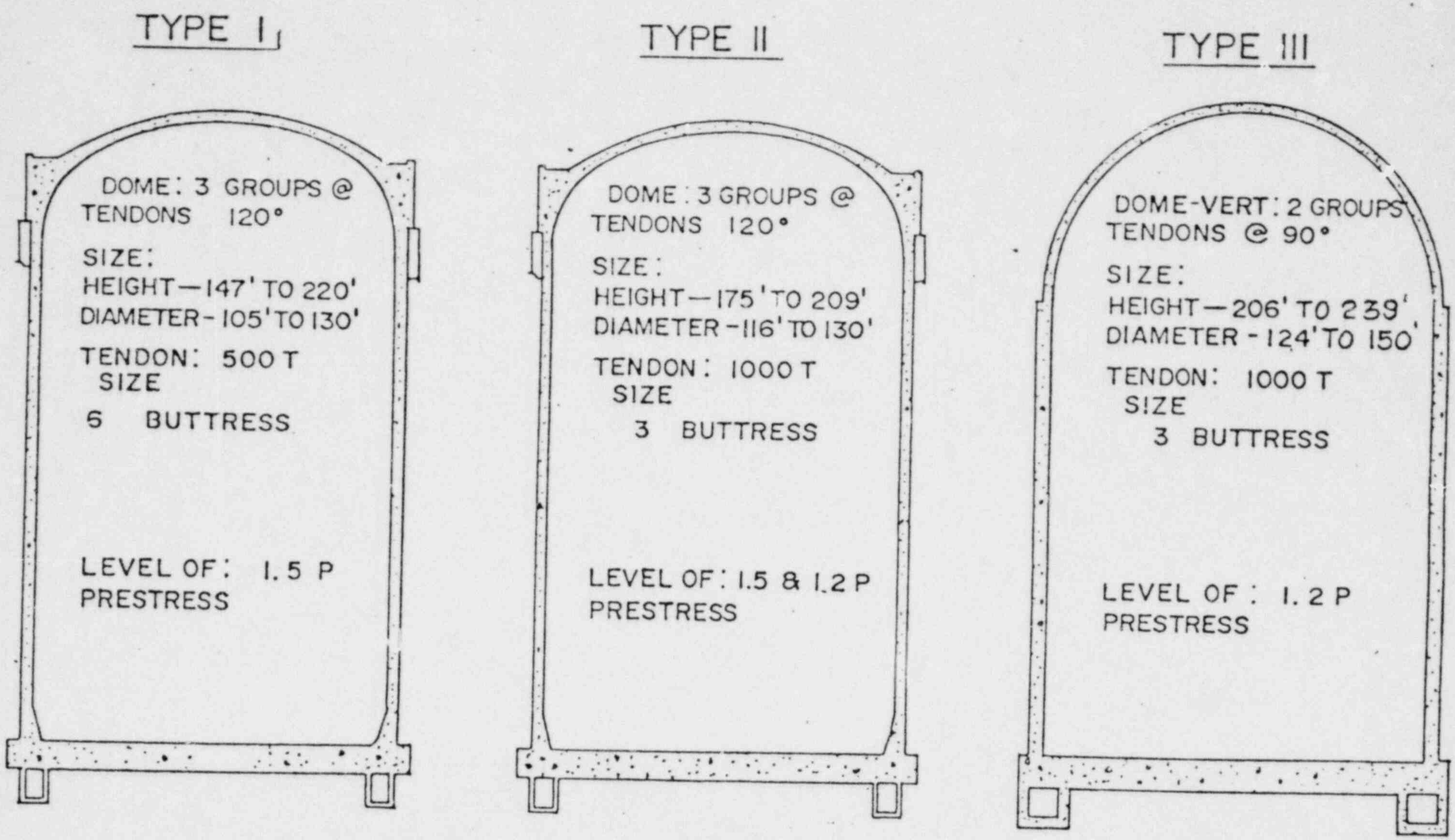
TYPE II



SECTION B

FIGURE 2-3

BECHTEL CONTAINMENTS



3.0 CONTAINMENT DESIGN

In order to set tendon surveillance acceptance criteria, the basic assumptions used in the containment design must be considered. Present containments are designed in accordance with Article CC-3000 of the ASME Section III, Division 2 Code. Prior to issuance of this code, the design was done using similar criteria based on ACI-318.

For illustration the post-tensioning system in the hoop direction of a containment will be designed; however, any interaction between the hoop and vertical directions will be neglected for simplicity. The code and past criteria have required that the containment resist the operating loads and the structural integrity test pressurization utilizing only the effective prestress and dead load. The effective prestress is usually defined as the amount of prestress left after all losses are deducted considering a 40 year plant life. The structural integrity test is performed at a pressure equal to 1.15 times the calculated accident pressure.

Another condition requires that the post-tensioning system resist factored load combinations such as accident condition of $1.5P_a$ without exceeding the ultimate strength. For ASTM A-421 wire, the allowable for this case is $.72f_{pu}$ where f_{pu} is the wire ultimate strength. For this design case the concrete is allowed to have membrane concrete cracking and the tendons are allowed to increase in stress until equilibrium is reached.

The following containment will be used to show the design process and, since it will be desirable for illustration to cover the entire tendon population, only ten tendons will be used.

Basic Design Information

a) Design accident pressure = 60 psi

b) Inside radius = 65 ft

c) ASTM A-421 prestressing wire:

Ultimate strength f_{pu} = 240 ksi

Yield strength $f_{py} = .8f_{pu}$ = 192 ksi

Modulus of elasticity E_s = 29×10^3 ksi

d) Concrete:

Ultimate strength f'_c = 5000 psi

Modulus of elasticity E_c = 5×10^3 ksi

e) Losses: in determining the effective prestress, it is necessary to evaluate the prestressing losses.

° Elastic: these losses occur since it is not possible to tension all the tendons at once. For a very large number of tendons, the stress loss in the first tendon tensioned will approach the following value assuming a stress in the concrete of $.3f'_c$:

$$L_{max} = (.3f'_c)\frac{E_s}{E_c} = (1.5)\frac{(29\times10^3)}{5\times10^3} = 8.7 \text{ ksi}$$

For a small sample of only ten tendons, then the average loss of all tendons will be:

$$L_{ave} = \left(\frac{N-1}{N}\right)\frac{L_{max}}{2} = \left(\frac{10-1}{10}\right)\frac{8.7}{2} = 3.9 \text{ ksi}$$

- Friction: using a curvature and wobble coefficient of friction of $\mu = .14$ and $k = .0003$ for a 240° tendon results in a friction loss of about 10 ksi.
- Wire Relaxation: for normal relaxation wire, the loss is considered as 8% of the value at tendon seating and is therefore: $(.08)(.7)(240) = 13.4$ ksi
- Concrete Creep And Shrinkage: these values are determined from tests on concrete cylinders made from the design mix and are based on uniaxial compression. 500μ in/in of loss at 40 years will be assumed here and the resulting loss is: $(29\times10^3)(.0005) = 14.5$ ksi

All losses are based on testing and the interaction of losses is not considered since this is conservative. A summary of losses after 40 years is:

Average elastic	3.9 ksi	31.8 ksi
Relaxation	13.4 ksi	
Creep and Shrinkage	14.5 ksi	
Friction	10.0 ksi	
Total:	41.8 ksi	

Assuming that the tendon is anchored at $.70f_{pu}$ (168 ksi), then the effective stress in the wire at 40 years is $168 - 41.8 = 126.2$ ksi. It is permissible to anchor at a higher value than $.70f_{pu}$ to compensate for elastic losses; however, this will not be used in this example.

Since the containment must resist the test pressure of $1.15P_a$ with effective prestress, then to be conservative a value of $1.20P_a$ will be used. Therefore, the effective membrane prestress force should be:

$$F_{eff} = 1.2PR = (1.2)\,\frac{(144)}{1000}\,(60)(65) = 674 \text{ k/ft}$$

A 182-$\frac{1}{4}$" diameter wire tendon will be used here and the tendon capacity at a stress of 126.2 ksi is:

$$\text{Tendon capacity} = (182)(.0491)(126.2) = 1127.7 \text{ kips}$$

Therefore, the average tendon spacing must be:

$$\text{Tendon spacing} = \frac{1127.7}{674} = 1.67 \text{ ft} = 20 \text{ in}$$

Based on this spacing, the $1.5P_a$ condition will be checked:

$$1.5P_a = (1.5)\,\frac{(144)}{1000}\,(60)(65) = 842 \text{ k/ft}$$

The tendon capacity at an allowable stress of $(.9)(.8)f_{pu} = (.72)(240) = 173$ ksi is:

$$\text{Tendon capacity/ft} = (182)(.0491)(173)/1.67 = 926 \text{ kips/ft}$$

Since 926 > 842, then the $1.5P_a$ load combination is satisfied.

4.0 GENERAL ACCEPTANCE CRITERIA

As was previously illustrated in Section 3.0, the designer wanted to make sure the containment would not have membrane cracking during the structural integrity test at a pressure of $1.15P_a$. Therefore the effective prestress level was set at $1.20P_a$ and all losses were conservatively considered. The design was also based on the average or typical tendon. It has been conservatively assumed in the past that it was necessary to have a minimum average effective stress in the wire of 126.2 ksi or 1128 kips/tendon or (126.2)(.0491) = 6.2 kips/wire. It has also been shown that, by using this amount of effective prestress, the factored load condition of $1.5P_a$ is well under the tendon ultimate strength. If the minimum wire force is 6.2 kips, then the force at the end anchor must be:

(136.2)(.0491) = 6.69 kips/wire due to the absence of friction loss.

The amount of prestress loss is somewhat arbitrary since it does not really affect the ultimate strength of the containment. It was important to supply a sufficient prestress level so that the containment would not have membrane cracking during the structural integrity test. However, when surveillance is being performed, the SIT has been completed and this requirement is no longer necessary assuming that future tests will only be made up to a pressure level of about P_a for leak rate determination.

The effective required prestress in the actual structure determined by surveillance measurements should be based on the conditions that the containment will really experience during its lifetime. These will be test conditions, operating conditions, and possibly the occurrence of the Operating Basis Earthquake (OBE).

Therefore it is not necessary to have the same acceptance criteria for effective prestress when performing surveillance as it was when sizing the system initially. A good criteria would be to require an average level of about 10% higher than the expected future test pressurization, provided this is higher than the OBE. For the previous example, the required force per wire would be:

$$\frac{1.10}{1.20}(6.69) = 6.13 \text{ kips/wire}$$

Past experience has shown that about two-thirds of the losses occur in the first year after post-tensioning. Therefore the average force per wire will be:

$$\left[168 - .667(31.8)\right](.0491) = 7.21 \text{ kips}$$

Figure 4-1 illustrates the average tendon wire force versus time. The expected loss curve is shown together with some minimum values. The shape of the expected loss curve is approximate and only time will tell a more exact shape based on actual measurements.

The minimum value line of either 6.69 or 6.13 kips/wire is the most important value on the curve since the average prestress for a group of tendons must be above or equal to this value. If a spacing of 18" were used instead of 20" for the same design conditions, then the containment would be slightly over-designed and the following minimum value could be used:

$$\frac{18}{20}(6.13) = 5.52 \text{ kips/wire}$$

The only purpose of the expected loss curve is to predict the general trend in losses to predict future conditions. This curve should not be used in the acceptance criteria.

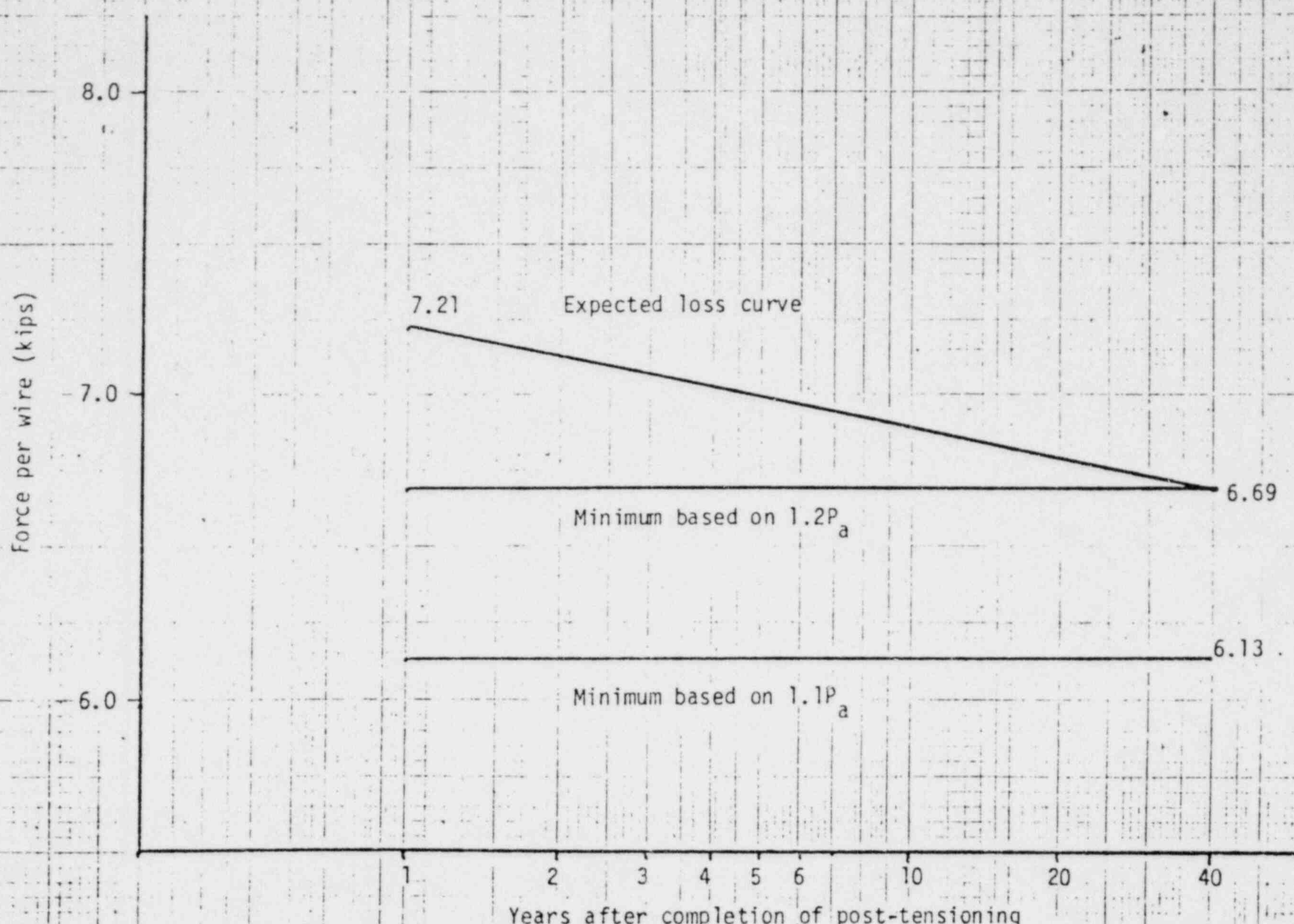


FIGURE 4-1 AVERAGE TENDON WIRE FORCE VERSUS TIME

5.0 SURVEILLANCE DATA REDUCTION

As shown in Section 3.0, the containment is designed based on the average tendon for the group. During tendon installation and tensioning it is not possible to anchor all the tendons at the same force level since it is only practical to use preselected sets of incremental shims. Also as illustrated in Section 3.0, there will be elastic losses and the tendons tensioned first will have lower force levels at completion of tensioning than those tensioned last. These two effects can be corrected for, since they are well defined. These corrections must be made so that the measured values will be typical of average conditions and also the general loss trend can then be established from one surveillance to the next.

To illustrate the concept of correcting (normalizing) lift-off readings, a containment which has only a total of 10 hoop tendons will be used. With this assumption the entire population will then be known (and is defined in Table 5-1). The first column lists the tendon number and also shows when it was tensioned in the sequence. The second column shows the initial lift-off values which are within ±30 kips with an average of 1500 kips. The third column shows the tendon forces after elastic losses which were determined by:

$$\begin{bmatrix}\text{Tendon Force}\\ \text{After Completion}\\ \text{Of Tensioning}\end{bmatrix} = \begin{bmatrix}\text{Actual}\\ \text{Lift-Off}\end{bmatrix} - \begin{bmatrix}\dfrac{N-(n+1)}{N}\end{bmatrix} L_{max}$$

where:

L_{max} = elastic loss based on maximum elastic strain in the concrete (kips/tendon)

N = total number of tendons

n = number of tendons tensioned prior to the one being considered

From Section 3.0, the maximum elastic loss was 8.7 ksi; therefore:

$L_{max} = (8.7)(.0491)(182) = 78$ kips

for a 182 wire tendon with a wire area of .0491 in^2.

The sixth tendon will be used for illustration:

$$\text{Tendon force} = 1530 - \frac{10-(5+1)}{10} 78 = 1499$$

The values in the fourth column were determined by assuming that 70% of the total wire relaxation and 55% of the concrete creep and shrinkage had occurred the first year. Using the sixth tendon, the relaxation is:

1st year relaxation loss = (.70)(.08)(initial lift-off)

= (.056)(1530) = 86 kips

The first year concrete creep and shrinkage loss is:

(.55)(14.5)(.0491)(182) = 71 kips

Total losses are: 86 + 71 = 157 kips

Subtracting this value from column 3 for tendon 6 results in a first year predicted value of:

(1499 - 157) = 1342 kips

Column 4 simulates a sample that might be found in a real containment if the sample were not affected by other items such as a ram calibration. Column 5 shows the normalizing factors which can be used to correct the actual tendon lift-off values to the average value. The normalizing factors were determined by:

$$NF = \frac{\begin{bmatrix}\text{Average}\\ \text{Lift-Off}\\ \text{All Tendons}\end{bmatrix} - \begin{bmatrix}\frac{N-1}{N}\end{bmatrix} \frac{L_{max}}{2}}{\begin{bmatrix}\text{Actual}\\ \text{Tendon}\\ \text{Lift-Off}\end{bmatrix} - \begin{bmatrix}\frac{N-(n+1)}{N}\end{bmatrix} L_{max}}$$

Using tendon 4 for illustration:

$$NF = \frac{\begin{bmatrix}1500\end{bmatrix} - \begin{bmatrix}\frac{10-1}{10}\end{bmatrix} \frac{78}{2}}{\begin{bmatrix}1530\end{bmatrix} - \begin{bmatrix}\frac{10-(3+1)}{10}\end{bmatrix} 78} = \frac{1465}{1483} = .988$$

Column 6 was determined by multiplying column 4 by column 5. Again, using tendon 4 for illustration:

(1326)(.988) = 1310 kips

All values of column 6 should have been 1310, but this would lead to normalizing equations which are extremely complicated and not justified. Column 6 illustrates that by normalizing any tendon, then it will be essentially typical of the average tendon in the containment and this is a necessary condition. The bandwidths for columns 4 and 6 are:

Column 4 - unnormalized bandwidth

$$\frac{(1365-1255)100}{(1365+1255)} = \pm 4.2\%$$

Column 6 - normalized bandwidth

$$\frac{(1314-1306)100}{(1314+1306)} = \pm.31\%$$

Significant errors may result if surveillance lift-off readings are not corrected for initial lift-off and elastic losses.

Table 5-2 shows the columns 4 and 6 information from Table 5-1 changed to force per wire. Lift-off can be stated in terms of tendon force, wire force or wire stress. Tendon force is not very good, since some tendons may not have the full amount of wire due to initial installation breakage and wire removal from previous surveillances. Wire force is more convenient than stress since it is directly obtained by dividing the tendon force by the number of wires.

Based on past experience, Bechtel has observed a bandwidth of about ±5% after the lift-off readings were normalized; however, this may increase in future surveillances. Figure 5-1 shows a condition which may exist in many containments after years of operation. If the expected loss curve and the minimum curve have the same value at end of life, then half the lift-off values will be above and the other half below the curve at end of life. Therefore, if each time a tendon falls below the curve, and if one or two additional tendon lift-offs are required, eventually all tendons will be needed for lift-off. Obviously this requirement would be ridiculous, since containments are designed for average tendon conditions.

A rational lift-off criteria is stated below:

1) All lift-off values must be corrected for initial installation conditions (actual anchorage force and elastic losses during initial post-tensioning and any other significant effects) so that the value is indicative of the average level of prestress.
2) The average of all corrected lift-off values shall be equal to or above the minimum required prestress.
3) Lift-off values shall be obtained on adjacent tendons for any tendon which is below 90% of the minimum required prestress.

Table 5-1 End Anchor Forces

1	2	3	4	5	6
Tensioning Sequence	Initial Lift-Off Value (kips)	Anchor Forces After Elastic Loss (kips)	Anchor Force After First Year (kips)	Normalizing Factor	Normalizing Force After First Year (kips)
1	1500	1430	1275	1.025	1307
2	1470	1408	1255	1.041	1306
3	1470	1415	1262	1.035	1306
4	1530	1483	1326	.988	1310
5	1500	1461	1306	1.003	1310
6	1530	1499	1342	.977	1311
7	1470	1447	1294	1.013	1311
8	1500	1484	1329	.987	1312
9	1530	1522	1365	.962	1313
10	1500	1500	1345	.977	1314
Average	1500	1465	1310	1.000	1310

Table 5-2 Wire Forces

Tendon	Wire Force After First Year (kips)	Normalized Wire Force After First Year (kips)
1	7.00	7.18
2	6.90	7.18
3	6.93	7.18
4	7.29	7.20
5	7.18	7.20
6	7.37	7.20
7	7.11	7.20
8	7.30	7.21
9	7.50	7.21
10	7.39	7.22

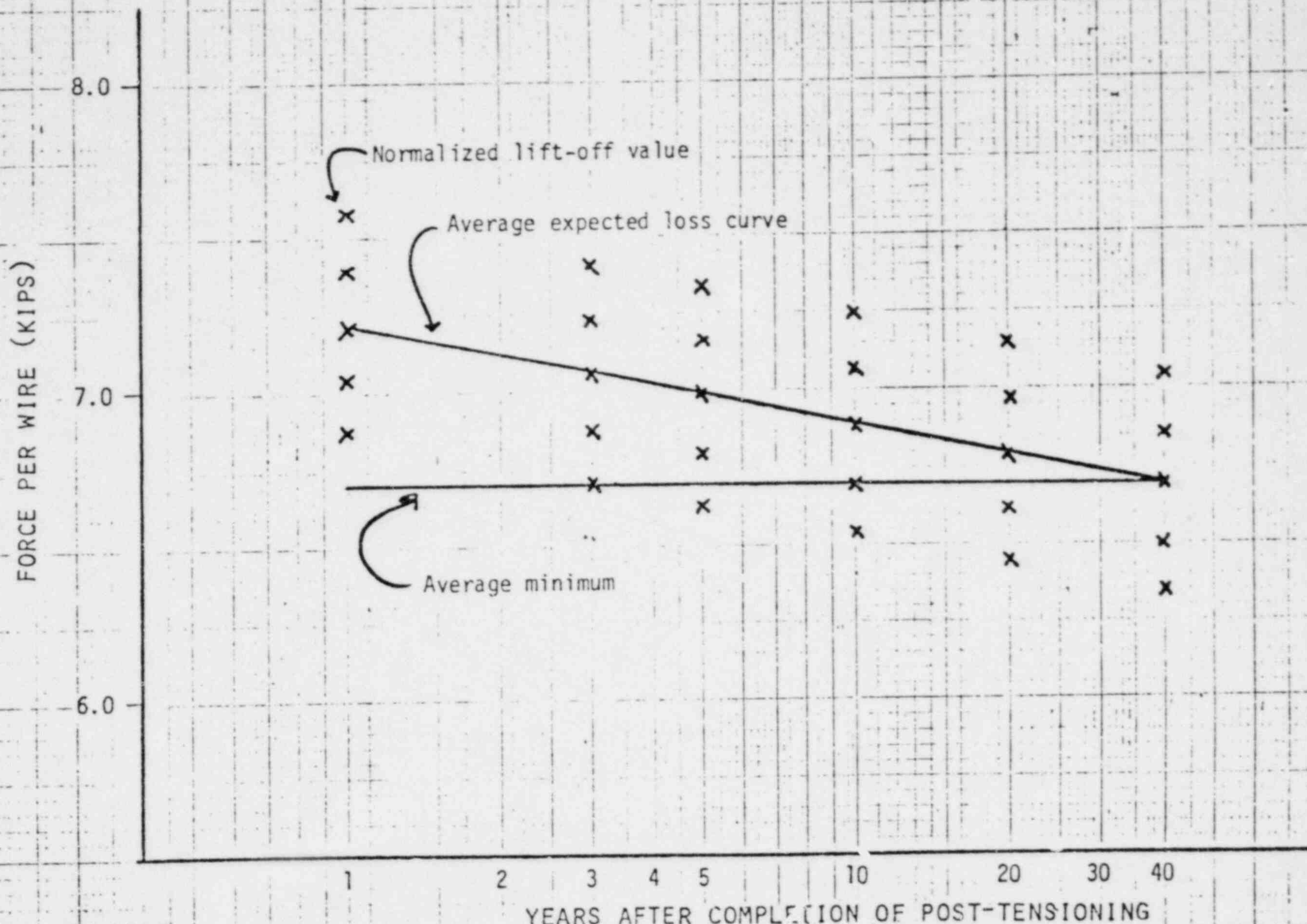


FIGURE 5-1 AVERAGE TENDON WIRE FORCE VERSUS TIME

6.0 REGULATORY GUIDE 1.35 AND NRC REQUIREMENTS

As mentioned in Section 1.0, Bechtel submitted comments to the NRC on Regulatory Guide 1.35 and the NRC responded. This correspondence is contained in Appendix A. The requirements for lift-off acceptance from Regulatory Guide 1.35 are summarized as follows:

a) "4.2 The maximum test liftoff force should be greater than the maximum in-service prestressing force."

b) "7.1 The prestress force measured for each tendon in the tests described in Regulatory Position C.4 should be within the limits predicted for the time of the test."

c) "7.2 There should be no more than one defective tendon in the total sample population. If one sample tendon is defective, an adjacent tendon on each side of the defective tendon should also be checked."

Comments on items a), b) and c) are as follows:

There does not appear to be a clear definition of the intent of item a). Item b) requires that tendon acceptance be based on a predicted value at the time of testing. This requirement is meaningless, since it now makes acceptance and the amount of tendons in the sample a function of the designer's ability to predict very small loss values. Losses are originally, conservatively based on testing, and using these losses, the minimum amount of prestress in the average tendon is determined. Therefore, the only thing important to public safety is the minimum required value.

As another example of the unimportance of the expected value, consider a containment which is over-designed and has more prestress than is absolutely necessary. This condition can be considered simulated in Figure 4-1. As shown, the acceptance should not be based on the expected loss curve, but must be based on the minimum value such as $1.1P_a$. Also, for a tendon to be acceptable, it must be within limits predicted at the time of test (surveillance) However, these limits are not clearly defined and, in fact, it may not be possible to define these limits. If they are too loose, then the criteria may be meaningless, and if they are too tight, the surveillance sample may increase by a large amount and, as stated in Section 5.0, significant problems may be coming by the end of life.

Regulatory Guide Section 7.2 infers that if a tendon lift-off does not meet the requirements of 7.1, then it is defective. This certainly appears to be a poor choice of terminology. A tendon may just fall slightly below some chosen value and be in very good condition. Also, if a low lift-off is determined due to excessive concrete creep and shrinkage, the tendon is certainly not defective, and if there is no evidence of corrosion, the ultimate strength has not changed; and therefore the word "defective" should be replaced with something more appropriate.

The valid and fully defined technique of determining containment surveillance lift-off acceptability summarized in Sections 4.0 and 5.0 will eliminate most of the problems previously defined. This technique was previously documented in the Bechtel letter to the NRC (see Appendix A).

The following summarizes the NRC response:

a) "It is the intent of the guide that the applicants construct a tolerance band bounded by two concurrent prestressing force curves against, i.e., ..."

b) "The practice indicated in your letter is not acceptable as it mixes up the initially determinable parameters (i.e., initial anchorage force, loss due to elastic shortening) with the parameters which cannot be determined so accurately and are time-dependent...."

c) "However, the criteria that you have suggested may be modified as follows:

   1) All curves of predicted tolerance bands should be corrected for initial installation conditions such as actual anchorage force and loss due to elastic shortening.

   2) All lift-off values should be within the corrected tolerance bands of respective tendons. Lift-off shall be obtained on adjacent tendons for any tendon lift-off value which is outside the limits predicted for the time of the test.

   3) The average of the lift-off values from all tendons in a particular region shall be equal to or above the minimum required prestress."

Item a) requires a band per tendon. Item b) states that the Bechtel technique is "not acceptable" since it mixes up parameters. The technique does not mix parameters as has been illustrated in this document. Item c) then states that curves should be corrected for initial installation conditions. If done correctly, this is essentially the same as Bechtel has proposed, except the curves are adjusted instead of the measurements. However, as was previously pointed out, the Bechtel technique is much better for determining the condition of the entire group of tendons since they can be directly compared with each previous measurement and the average required value. This is not possible with the NRC technique. Item c)2) is a major problem since it used predicted values to set acceptability and this is incorrect.

7.0 SUMMARY

This document has attempted to give an understanding of the design and requirements for a prestressed concrete containment post-tensioning system. Also, realistic acceptance criteria and methods of data presentation are defined. The major points are summarized below:

1) The required minimum level of prestress during surveillance may not be the same value as was used in the original design.
2) Surveillance lift-off measurements should be normalized to eliminate elastic loss and initial anchorage effects.
3) Acceptance should be based on the average lift-off of the sample since the original design was based on the average tendon.
4) Acceptance must be based on the minimum effective force required and not some arbitrary predicted value.

APPENDIX A

1) Bechtel Power Corp., letter from B. L. Lex to R. M. Minogue of NRC, dated May 6, 1976, subject, "Regulatory Guide 1.35, January 1976, Revision 2, 'In-Service Inspection of Ungrouted Tendons in Prestressed Concrete Containments' - Comments".

2) U.S. Nuclear Regulatory Commission, letter from M. Kehnemuyi to B. L. Lex of Bechtel Power Corp., dated July 27, 1976, subject, "Your Comments on Revision 2 of Regulatory Guide 1.35, dated May 6, 1976".

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May 6, 1976

Mr. Robert B. Minogue
Director
Office of Standards Development
Nuclear Regulatory Commission
Phillips Building
7920 Norfolk Avenue
Bethesda, MD 20014

Subject: Regulatory Guide No. 1.35, January 1976, Revision 2
'In-Service Inspection of Ungrouted Tendons in
Prestressed Concrete Containments' - Comments

Dear Mr. Minogue:

We submit the following information on in-service inspection of ungrouted tendons in prestressed concrete containment structures. Your Regulatory Guide 1.35, January 1976, Revision 2, states detailed surveillance requirements. However, in Section D, "Implementation", it states that the applicant may develop an acceptable alternative method.

We request your review of the following material on a generic basis for all future containments. In the following we attempted to comply with the intent of Regulatory Guide 1.35 and, in addition, we have considered the knowledge we have gained in past tendon inspections.

Attached for your information is a Summary of Tendon Surveillance Data for Bechtel designed containments in which we supplied technical guidance during in-service inspection.

I. TENDON LIFT-OFF FORCE ACCEPTANCE CRITERIA

The containments are originally designed for an average prestress force from all tendons in a particular region and our past experience has shown variation in lift-off for a group of tendons. Lift-off readings must be corrected to reflect the condition of an average tendon, therefore, we have normalized the lift-off readings to correct for initial elastic losses and also the initial actual tendon anchorage value, since all tendons cannot be anchored at the exact same value. After normalizing we have determined that the variation ... variation is due to measureme... variation as the containment ... ts will be above the required va... is an acceptable condition, prov... or equal to the required valu... following sketch.