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PROPOSED REGULATORY GUIDE 1.35.1

DETERMINING PRESTRESSING FORCES FOR INSPECTION OF PRESTRESSED CONCRETE CONTAINMENTS

A. INTRODUCTION

General Design Criterion 53, "Provisions for Containment Testing and Inspection," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires, in part, that the reactor containment be designed to permit (1) periodic inspection of all important areas and (2) an appropriate surveillance program. Regulatory Guide 1.35, "Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment Structures," describes a basis acceptable to the NRC staff for developing an appropriate inservice inspection and surveillance program for ungrouted tendons in prestressed concrete containment structures of light-water-cooled reactors. This guide expands and clarifies the NRC staff position on determining prestressing forces to be used for inservice inspections of prestressed concrete containment structures.

B. DISCUSSION

The inspections of prestressed concrete containment structures (with greased or grouted tendons) are performed with the objective of ensuring that the safety margins postulated in the design of containment structures are not reduced under operating and environmental conditions. Of particular concern in the case of prestressed concrete containment structures is the possible degradation of the prestressing tendon system due to corrosion.

This regulatory guide and the associated value/impact statement are being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. They have not received complete staff review, have not been reviewed by the NRC Regulatory Requirements Review Committee, and do not represent an official NRC staff position.

Public comments are being solicited on both drafts, the guide (including its implementation schedule) and the value/impact statement. Comments on the value/impact statement should be accompanied by supporting data. Comments on both drafts should be sent to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch, by JUN 22 1979

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The recommended inservice inspection programs of Regulatory Guides 1.35 and 1.90 are formulated to achieve this basic objective. The extent to which the programs can perform their intended function depends on the method of their implementation.

Review of reports of some of the inspections performed by licensees on greased tendons indicates that there are various ways (simple but imprecise) of combining the losses in prestressing forces, giving a wide band of tolerance in comparing the measured results. Such a practice is not acceptable to the NRC staff because a real and substantial degradation of the tendon system may remain undetected.

Regulatory Guide 1.35 recommends the comparison of measured prestressing forces with the predicted forces of randomly selected tendons. The predicted forces at a given time are based on the measurement of prestressing forces during installation minus the losses in the prestressing forces that were predicted to have occurred since that time because of material and structural characteristics.

As various complex interacting phenomena are involved in the prediction of these losses, the chance is small that the measured prestressing force will agree quite closely with the predicted value. Hence Regulatory Guide 1.35 recommends the determination of bounds (upper and lower) of prestressing force as a function of time. Revision 1 of Regulatory Guide 1.90 discusses this aspect briefly, as it is also relevant to the recommended inspection alternatives in that guide.

This supplementary guide is intended to clarify the NRC staff's position on the construction of tolerance bands for groups and subgroups of tendons so that the small-sample inspection program of Regulatory Guide 1.35 can provide better confidence in the integrity of prestressing tendons. The regulatory position of this guide recommends the factors that need to be evaluated and a method of using these factors in the construction of a tolerance band for a group of tendons having approximately the same time-dependent characteristics. The methods for evaluating the effects of these factors are discussed in this section of the guide.

The "Code for Concrete Reactor Vessels and Containments" (Ref. 1) enumerates the factors to be considered in determining the effective prestress (see Section CC-3542 of Ref. 1). However, it does not provide detailed consideration of these factors. The methods suggested here are based on a search of relevant literature and on information provided to the NRC staff by applicants and their contractors. A list of relevant references is provided in Appendix A. However, the listing of these references does not constitute a blanket endorsement by the staff of their content.

1. MEASUREMENT OF PRESTRESSING FORCE

In general, the requirements of Section CC-4464 of the Code (Ref. 1) are adequate for measuring and verifying the seating force. However, the allowable discrepancy of ±10% of the force calculated from the measured elongation and that obtained by a dynamometer or a pressure gage is excessive. If the load/elongation curve for the tendon system is based on a thorough evaluation of the prior tests using tensioning and measuring equipment similar to that proposed for use in construction, such a high discrepancy level is unwarranted. The NRC staff believes that this discrepancy level should not exceed ±5%. This recommendation is in agreement with the practice adopted by the American Concrete Institute (Ref. 2) and the Post-Tensioning Institute (Ref. 3).

During an inservice inspection, the liftoff (or load cell) measurements are compared against the initially measured forces. If the equipment used to make the measurements during the tensioning operation and during an inservice inspection have identical characteristics, the errors introduced by contributing factors such as reading accuracy or friction in the jacking system can be reduced to a minimum. The objective should be to use well-calibrated, accurate measuring equipment with sufficient sensitivity during both construction and inservice inspections to reduce the comparative errors due to measurement to a negligible amount.

2. DETERMINATION OF PRESTRESSING LOSSES

The losses in prestressing force after the application of the force can be classified as follows:

a. Initial losses due to:

- Slip at anchorages
- Friction between the tendon and the tendon duct at areas of contact
- Elastic shortening and effect of sequence of stressing the various tendons.

b. Time-dependent losses due to:

- Shrinkage of concrete
- Creep of concrete
- Relaxation of prestressing steel.

c. Other losses due to:

- Failure of tendon elements due to corrosion or material deficiency.
- Effects of variations in temperature.

These losses are discussed briefly in the following paragraphs together with the methods of determining their magnitude. The discussion pertains only to the prestressed concrete containment structures typically used for light-water reactors. For containments that operate at sustained high temperatures, the time-dependent characteristics need to be evaluated at correspondingly high temperatures.

2.1 Initial Losses

Loss due to slip at anchorages should be determined based on the prior experience and the testing history of the prestressing system to be used. The influence of slip at anchorages should be allowed for in the computation of initial prestressing forces.

Coefficients for determining the losses due to friction should be determined before the start of the installation and should be verified and modified (if necessary) during the construction. In comparing the liftoff (or load cell) forces for ungrouted tendons, friction loss need be considered only for the fixed ends of tendons that have been tensioned from one end. For the purpose of inspection (or monitoring) of ungrouted tendons, consideration of this loss can be avoided by comparing forces at tensioned ends.

If all tendons in a specific direction (hoop, vertical, etc.) are prestressed simultaneously, the loss of prestressing force due to elastic shortening (F_{LES}) can be given by:

$$F_{LES} = \frac{F_o}{A_{cn}E_c + A_sE_s + A_pE_p + A_\ell E_\ell + A_dE_d} \times E_pA_p$$

where

F_o is the initial seating force

A_{cn} is the net concrete area

A_s, A_p, A_ℓ, A_d are the areas of reinforcing steel, prestressing steel, liner, and duct, respectively

$E_c, E_s, E_p, E_\ell, E_d$ are the moduli of elasticity of concrete, reinforcing steel, prestressing steel, liner, and duct, respectively.

However, the number of tendons to be prestressed is large, and the prestressing operation is performed in a systematic sequence so that the structure is more or less symmetrically prestressed during the process. Thus the first tendons that are tensioned undergo a full loss due to the subsequent elastic shortening of the structure, while the tendons that are tensioned last undergo almost no loss due to elastic shortening. For all practical purposes, the loss of prestressing force due to elastic shortening can be estimated and accounted for by using the following linear relationship:

$$F^n_{LES} = \frac{n_r}{N} F_{LES}$$

where N represents the total number of tendons in a particular direction, n represents the sequential number of a randomly selected tendon to be tensioned in that direction, and n_r represents the number of tendons to be tensioned after the n^{th} tendon, i.e., $n_r = N - n$.

If the sequences of tensioning tendons in different directions are intermingled, the stresses produced in one direction by the tendons tensioned in the other directions must be considered.

Thus it is essential that the complete history of tensioning a tendon be recorded, including its seating force F_o, the number of tendons tensioned before and after it, and any provision to account for the slip at anchorages. The modified initial prestressing force F_i at the tensioned end can be calculated and recorded as:

$$F_i^n = F_o^n - F_{LES}^n - F_{LSA}$$

where F_{LSA} is the loss of prestressing force due to slip at anchorages.

2.2 Time-Dependent Losses

2.2.1 Effect of Shrinkage of Concrete

The schedule of construction of a typical prestressed concrete containmen is such that a substantial portion of the expected long-term shrinkage will have taken place before the structure is prestressed. Reference 4 develops formulas for predicting the long-term shrinkage based on the assumption that the shrinkage approximately follows the laws of diffusion and supports the formulas by experimental investigation. An appropriate extrapolation of these formulas (for the volume to surface ratio of the structure in excess of 24 in. (60 cm) and the contributing shrinkage as that occurring 100 days after the average time of construction of the structure) would yield a value of 100×10^{-6}, which is considered to be a reasonable value at a temperature of 70°F (21°C) and a relative humidity of 50%. The safety analysis reports of several plants[1] indicate that a 40-year shrinkage value of 100×10^{-6} has been used by the applicants.

This value, however, needs to be modified to account for the significantly higher shrinkage in a low-humidity environment and the significantly lower shrinkage in a high-humidity environment. Table 1 provides typical shrinkage values that could be used for computation of prestressing losses due to shrinkage.

[1]Turkey Point, Midland, Bellefonte, Three Mile Island.

2.2.2 Effect of Concrete Creep

One of the most significant and variable factors in the computation of time-dependent losses in prestressed concrete containment structures is the influence of concrete creep. Creep is thought to consist of two components: basic creep and drying creep. Drying creep, also sometimes termed stress-induced shrinkage, is thought to be due to the exchange of moisture between the structure and its environment. Its characteristics are considered to be similar to those of shrinkage, except that they represent an additional moisture movement resulting from the stressed condition of a structure. The amount of drying creep depends mainly on the volume to surface ratio of the structure and the mean relative humidity of the environment. For prestressed concrete containment structures having a volume to surface ratio in excess of 24 in. (60 cm), the relative influence of drying creep (compared to basic creep) is negligible as indicated by Figure 9 of Reference 4.

The significant parameters influencing the magnitude of basic creep can be summarized as follows:

1. Concrete mix: cement and aggregate type; proportion of cement, water, and aggregates; and the influence of admixtures.

2. Age at loading. The basic creep value is a function of the degree of hydration that has taken place at the time of loading.

3. The magnitude of the average sustained stress.

4. Temperature.

Almost all investigators support the assumption that basic creep varies linearly with the intensity of sustained stress, as long as the average stress level in the concrete is not greater than 40% of the ultimate strength of the concrete. The specific creep is thus defined as the ratio of total creep to the average stress intensity.

A literature review of the effect of temperature on basic creep (sealed or water-stored concrete specimens) is compiled in Reference 6. The average temperature of a prestressed concrete containment structure could vary between 40°F (5°C) and 100°F (38°C). Creep is shown to vary linearly with temperature in this range of temperatures. Hence if the creep is evaluated at approximately 70°F (21°C), it should represent overall deformation due to creep of concrete.

An acceptable method of determining basic creep at various times for a given concrete mix as a function of age at loading is provided in Appendix A to this guide. The method is based on concepts and equations derived by Hansen (Ref. 7) from a rheological model representing creep of concrete. Reference 8 uses the method of Reference 7 in determining long-term creep for a given concrete mix. Most investigators agree that there is no one formula that can be generally applicable in determining the long-term creep for various concrete mixes. Hence Appendix A recommends a method of predicting the long-term basic creep from the results of short-term creep tests. Other methods such as those described in References 9, 10, and 11 may be used if demonstrated to be appropriate for predicting long-term basic creep.

Short-term creep tests are generally performed during the construction of a nuclear power plant. The extrapolated creep values consistent with the average time of the loading of the structure may not be available during the preliminary design stages. A conservative estimate of creep values may be obtained from previous experience or from creep tests on similar concretes. However, these values should be modified to estimate the tolerance band for the prestressing force to be used for comparison of the measured prestressing forces during inservice inspections. The modifications should include the extrapolated creep values in light of the actual average age of the concrete at the time the containment is prestressed.

2.2.3 Effect of Relaxation of Prestressing Steel

The stress relaxation properties of prestressing steel vary with its chemical composition and thermal/mechanical treatment. Manufacturers should be able to supply the long-term loss in prestressing steel stress due to pure relaxation for the steel supplied. Section CC-2424 of Reference 1 requires a minimum of three 1000-hour relaxation tests for the prestressing steel proposed for use. There should be a sufficient number of data points in each of the three tests to extrapolate the 1000-hour pure relaxation data to the life of the structure. An appropriate model (Refs. 12, 13, 14) should be selected for the determination of the "best-fitting" line for the purpose of extrapolation.

2.3 Losses Due to Tendon Degradation

Most applicants make allowance for breakage of wires on an overall basis as well as on a localized basis. Such an allowance in the design of the containment would allow a breakage of few wires during construction without the need for replacing these wires. For a tendon with a few broken wires, care should be taken not to overstress intact wires to bring the tendon force to a prescribed value. Instead, the tendon should be extended to the same level as other similar tendons (without broken wires). The procedure will leave the tendon at a prestress level lower than the prescribed (generally 70% of GUTS) level. This is acceptable provided the design includes an allowance for the breakage of wires.

2.4 Effects of Variations in Temperature

Of particular importance for the purpose of comparing the prestress forces is the effect of differences between the average temperature of the structure during installation and that during inspections. Localized hot spots and temperature variations along the length of a tendon can cause variations in the force along the length of the tendon. The differences between the coefficients of expansion or contraction of concrete and steel can also cause modifications of tendon forces. These effects, as appropriate, should be considered in comparing the measured prestressing forces with the predicted forces.

3. GROUPING OF TENDONS AND CONSTRUCTION OF TOLERANCE BAND

The significant variable affecting the time-dependent prestressing force of tendons would be the effect of concrete creep. If the concrete mix characteristics and the curing conditions are assumed to be about the same during the entire period of construction of a containment structure, the parameters introducing variations in creep are (1) average compressive stress and (2) age of concrete at the time of prestressing. For example, in a shallow-dome containment structure, if the design requires that the meridional compressive stresses in the cylinder be half those in the hoop direction, the creep strains affecting the losses in prestressing would be proportional to their compressive stresses. Similarly, at the time of prestressing, the dome concrete might have aged three months, while the cylinder concrete might have aged six months or more. These parameters would affect the losses in prestressing forces in tendons and should be considered in grouping the tendons according to the similarity of their time-dependent characteristics and in prescribing the tolerance band for prestressing forces in these tendons.

These groups may be further subdivided into subgroups to account for the differences in initial prestressing forces (F_i) due to differences in instantaneous elastic shortening during transfer. To account for the differences in initial prestressing forces F_i, a tabulation of F_i for each tendon in a group may serve the same purpose as subgrouping. In short, the intent of any adopted procedure should be to track the individual prestressing forces as precisely as possible with the current state of the art in predicting these forces, so that, when a tendon is selected randomly during an inspection, its measured values can be compared with its prescribed band of tolerance.

It is recognized that each of the factors affecting the time-dependent characteristics of tendon forces are subject to variations. To account for these variations in prescribing the tolerance band, the following method is recommended:

Shrinkage. Table 1 provides the 40-year shrinkage strains in relation to the location of the structure. To allow for the associated uncertainty in the assumed values, it should be varied by ±20%. The shrinkage strains at any time between the time of prestressing (consider zero shrinkage at t = 10 days) and 40 years can be estimated by considering shrinkage strain to vary linearly with the logarithm of time.

Creep. The creep strains at any time after prestressing can be determined by the method of Appendix A. The high and low creep strains can be determined by increasing the extrapolated creep values by 25% and decreasing them by 15%, respectively (see Appendix B for illustrative example).

Relaxation of Prestressing Steel. Provide a ±15% variation in relaxation values obtained by extrapolation of 1000-hour tests.

The first inservice inspection needs to be performed one year after the Initial Structural Integrity Testing (ISIT) of the containment. Hence, the period of interest from the point of view of inservice inspection is between one year and 40 years after prestressing.

The upper and lower bounds for prestressing forces at one year and 40 years after prestressing can be found by adding up the low and high losses and subtracting them from F_i. For the purpose of constructing tolerance bands for various groups of tendons, it is sufficiently accurate to consider prestressing force to vary linearly with the logarithm of time.

If an allowance for the breakage of wires has been made in the design on an overall basis, a line may be drawn parallel to and below the lower bound line (see Figure 1, Appendix B) at a distance equal to the allowance. The lower line may be considered for comparison with the measured prestressing forces. This allowance should be made only if the actual initial tendon forces (F_i) are used for constructing the tolerance band. It is not recommended if a nominal value (i.e., F_o = 0.7 GUTS) is used or if the tendon force is transformed to a force in one prestressing element (wire or strand).

The upper line of the tolerance band is not critical from a safety point of view. However, this line allows the designer to establish a maximum variation line. If the prestressing of a tendon lies above this line, it is prudent to investigate the measurement technique and the pattern of losses in adjoining tendons.

C. REGULATORY POSITION

The following minimum standards should be followed in design and construction of prestressed concrete containment structures to ensure the appropriate implementation of inspection programs of Regulatory Guide 1.35 (revision 3).

1. CONSIDERATIONS FOR TENSIONING PRESTRESSING TENDONS

The procedure of Code (Ref. 1) Section CC-4464 should be followed in measuring loads and extensions during tensioning, as supplemented by the following:

a. A minimum of three readings of loads and extensions at approximately equally spaced levels of load should be recorded before the final seating of the tendon.

b. If the discrepancy between the measured extension at the final seating force and the extension determined from the average tendon force along the length of a tendon exceeds 5%, the cause of such discrepancy and the corrective actions taken should be recorded. The extension corresponding to the average tendon force may be determined by calculation or from a tendon load-extension diagram provided by the tendon manufacturer.

2. CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

2.1. The initial seating force (F_o) should be modified to allow for the following influences:

a. A known amount of slip at anchorage (if any)

b. A loss due to elastic shortening of the structure, including the effects of sequence of tensioning by the method discussed in Section B or by any other appropriate method.

c. Influence of wire breakage during construction. The extent of wire breakage should not exceed the allowance made in the design.

2.2. A range (high and low) of expected time-dependent losses at the end of the service life of the structure (generally 40 years), as well as those at one year after prestressing, should be established considering the variations in the following factors:

a. The extent of shrinkage of the structure contributing to the prestress losses. Table 1 may be used for the purpose in the absence of specific data.

b. The effect of creep deformation on prestressing force. The method of Appendix A or a similar method may be used to determine the creep deformation.

c. The effect of relaxation of stress in prestressing tendons. See Section B.2.2.3 for a recommended procedure.

3. GROUPING OF TENDONS

3.1. The basic grouping of tendons for the purpose of developing tolerance bands should consider:

a. the geometric configuration of tendons with respect to the structure, e.g., vertical, hoop, dome, inverted U, and

b. the similarity in time-dependent characteristics. This may involve dividing the above configuration groups into additional groups.

3.2. The basic groups may be divided further into subgroups to account for the differences in instantaneous elastic shortening during the transfer of prestressing force.

4. TOLERANCE BANDS

Tolerance bands for groups and subgroups of tendons should be constructed as discussed in Section B.

These tolerance bands should be used for comparison of measured prestressing forces with the forces predicted for the time of inspection.

D. IMPLEMENTATION

This proposed guide has been released to encourage public participation in its development. Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods to be described in the active guide reflecting public comments will be used in the evaluation of all (1) construction permit applications, (2) standard reference system preliminary design applications (PDA) or Type-2 final design applications (FDA-2), and (3) licenses to manufacture that are docketed after the implementation date to be specified in the active guide, except those portions of a construction permit application that:

a. Reference an approved standard reference system preliminary or final design (PDA or FDA) or an application for approval of such design.

b. Reference an approved standard duplicate plant preliminary or final design (PDDA or FDDA).

c. Reference parts of a base plant design qualified and approved for replication.

d. Reference a plant design approved or under review for approval for manufacture under a Manufacturing License.

This implementation date (to be specified in the active guide) will in no case be earlier than December 1, 1979.

TABLE 1

VARIATION OF SHRINKAGE STRAIN WITH RELATIVE HUMIDITY

Mean Daily Relative Humidity[a]-Annual, %	40-Year Shrinkage Strain[b]
Under 40	130×10^{-6}
40 to 80	100×10^{-6}
Above 80	50×10^{-6}

[a]Mean Daily Relative Humidities for various areas in the U.S. can be found from Map 46 of Reference 5.

[b]These values are applicable to containments in which inside operating temperatures do not exceed 120°F (49°C) and that are subject to the ambient outside environment. The maximum value of 130×10^{-6} may be substantially increased if the containment is exposed to a controlled dry high-temperature environment after completion of prestressing.

APPENDIX A

DETERMINATION OF BASIC CREEP STRAINS FOR PRESTRESSED CONCRETE CONTAINMENT STRUCTURES

Recommended creep formula

$$\frac{\varepsilon_c}{f_c} = A\alpha\left[1 - e^{-\frac{1}{30}(t - t_o)}\right] + B\log_{10}\frac{t}{t_o}$$

where

- t = time (after average time of concrete placement) when creep value is desired, days
- t_o = time of loading after average time of concrete placement, days
- f_c = average sustained concrete stress
- ε_c = creep strain at time t when the age of concrete at loading is t_o
- A,B are coefficients to be determined from tests
- α is a function of the degree of hydration that has taken place at time t_o. In absence of any other data, its value may be taken as follows:*

t_o	30	90	180	365
α	1.16	1.07	1.03	1.00

To determine the value of constants A and B, the following short-term creep tests are recommended:

Age at loading	Minimum Observations at			
t_o	t_o	t_1	t_2	t_3
30	30	90	150	210
90	90	150	210	270
180	180	240	300	360

*For concretes made of cements specified in Section CC-2221 of Reference 1.

The constants A and B should be determined from creep strains at t_1, t_2, and t_3. Use average of three values of A and B for long-term extrapolation.

The short-term creep tests should be performed according to the test method of Ref. 15. To make the creep test results representative of creep deformations in a containment structure, the referenced test method should be used with the following specific provisions:

a. Section 3.1: The length of specimens should be 16 ± 1/16 in. (40 ± 0.16 cm).

b. Section 3.2: The concrete mix should be the same as that proposed for use in the construction of the containment.

c. Section 3.3: Companion identical specimens corresponding to each t_o may be used to observe the deformations of unloaded specimens.

d. Section 4.2: Mass curing (sealed specimen) conditions should be used during storage and testing. (The method used for the "as cast" condition in Reference 16 is a good example.)

e. Section 5.1: Other specimens may be used for t_o in addition to those recommended in this Appendix.

f. Section 5.2: Load the specimens to maintain a sustained stress of 30% of the design compressive strength of concrete.

g. Section 6.1: Subtract the instantaneous elastic strain taken at time t_o from the subsequent total strain measurements to arrive at creep strain (ε_c).

APPENDIX B

CONSTRUCTION OF TOLERANCE BAND (EXAMPLE)

Consider the following values as obtained for time-dependent influences:

Time-Dependent Factors	Base Value at 40 Years	1 Year High	1 Year Low	40 Years High	40 Years Low
Shrinkage (ϵ_s) @ 70% Relative Humidity x 10^6 Variation: ±20%	100	72	50	120	80
Creep ($\frac{\epsilon_c}{f_c}$) x 10^6 for t_o = 180 days per psi	0.3	0.193	0.073	0.375	0.255
per kPa	2.05	1.32	0.50	2.56	1.75
Variation: +25% -15%					
Stress Relaxation of Prestressing Steel in % of F_i Variation: ±15%	7	5.8	4.2	8.1	5.9

APPENDIX B (Cont'd)

Prestressing Losses in % of F_i

Assume $E_{ps} = 28 \times 10^3$ ksi (193×10^3 MPa)

$f_{ps} = 168$ ksi (1.158×10^3 MPa)

Time-Dependent Factors	Base Value at 40 Years	1 Year High	1 Year Low	40 Years High	40 Years Low
Shrinkage $\varepsilon_s \times \frac{E_{ps}}{f_{ps}} \times 100$	1.7	1.2	0.8	2.0	1.3
Creep for $f_c = 1500$ psi (10350 kPa) $\frac{\varepsilon_c}{f_c} \times f_c \times \frac{E_{ps}}{f_{ps}} \times 100$	7.5	4.8	1.8	9.4	6.4
Stress Relaxation of Prestressing Steel	7	5.8	4.2	8.1	5.9
Total Losses	16.2	11.8	6.8	19.5	13.6
Remaining Prestressing Force in Tendon[1]	0.84 F_i	0.88 F_i	0.93 F_i	0.8 F_i	0.86 F_i

[1]These values are used for constructing the tolerance band in Figure 1.

F_i = Initial Prestressing Force at an Anchorage Considering Losses Due to Anchorage Takeup, Instantaneous Elastic Shortening, and Friction

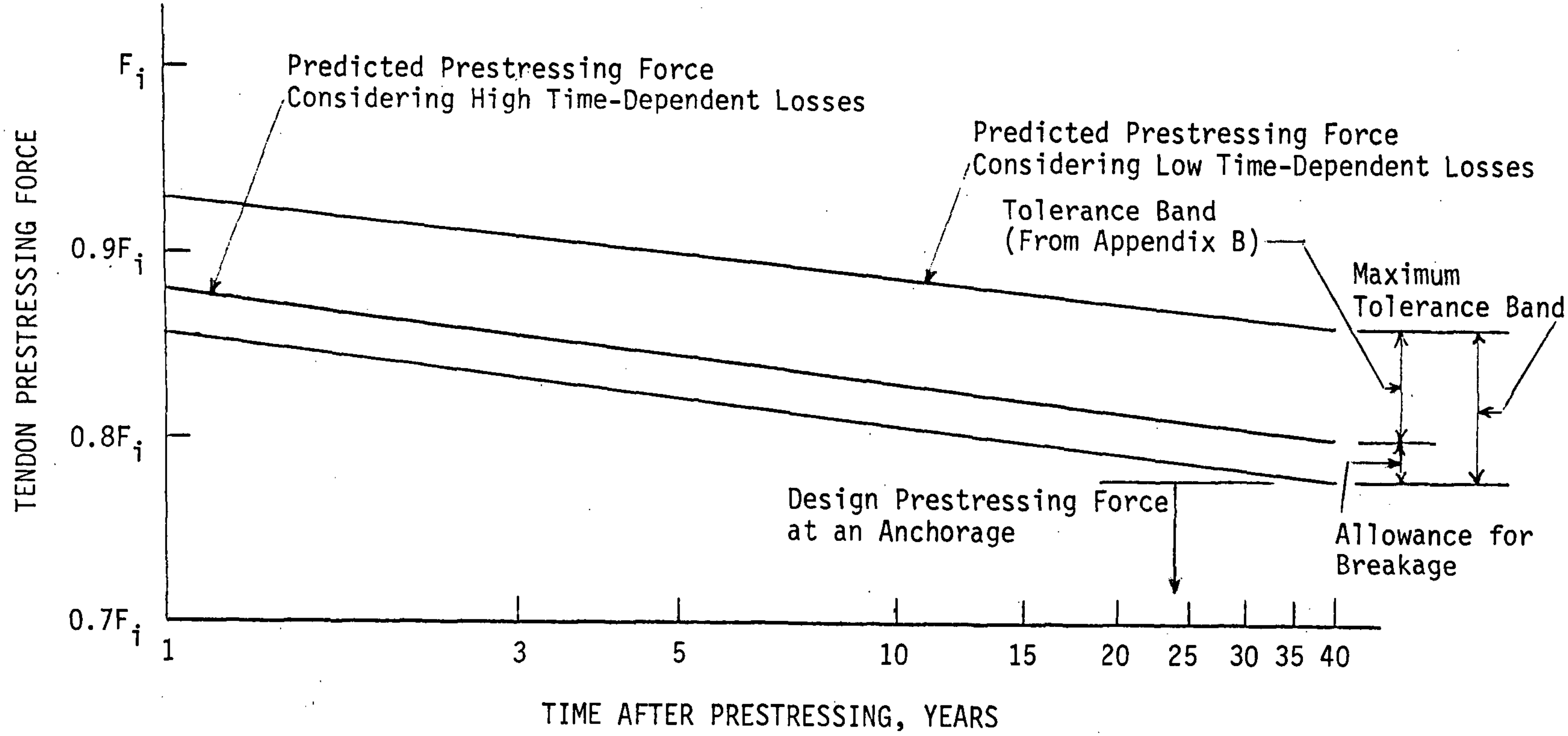

Figure 1. Tolerance Band of Acceptable Prestress

REFERENCES

1. "Code for Concrete Reactor Vessels and Containments," American Concrete Institute Committee 359 and American Society of Mechanical Engineers Subcommittee on Nuclear Power, 1977.

   Copies may be obtained from the American Society of Mechanical Engineers, 345 E. 47th St., New York, N.Y. 10017 or from the American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, Michigan 48219.

2. "Building Code Requirements for Reinforced Concrete," American Concrete Institute Committee 318, 1977.

   Copies may be obtained from the American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, Michigan 48219.

3. Post-Tensioning Manual, Published by the Post-Tensioning Institute, 1976.

   Copies may be obtained from the Post-Tensioning Institute, 301 West Osborn, Suite 3500, Phoenix, Arizona 85013.

4. Hansen, T. C., Mattock, A. H., "Influence of Size and Shape of Member on the Shrinkage and Creep of Concrete," Journal of the American Concrete Institute, February 1966, Proceedings Vol. 63.

   Copies may be obtained from the American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, Michigan 48219.

5. Baldwin, J. L., "Climates of the United States," published by the U.S. Department of Commerce, Washington, D.C., December 1974.

   Copies may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

6. Geymayer, H. G., "Effect of Temperature on Creep of Concrete, A Literature Review," Paper 31 of ACI SP-34, "Concrete for Nuclear Reactors," Vol. 1.

Copies may be obtained from the American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, Michigan 48219.

7. Hansen, T. C., "Creep and Stress Relaxation of Concrete," Swedish Cement and Concrete Research Institute, Stockholm, 1960.

Copies may be obtained from the Swedish Cement and Concrete Research Institute, Royal Institute of Technology, Stockholm, Sweden.

8. "Report on Recommended Concrete Creep and Shrinkage Values for Computing Prestressing Losses," by Schupack and Associates. This non-proprietary report is filed in the NRC Public Document Room as Appendix 5J of the Preliminary Safety Analysis Report for the Three Mile Island Nuclear Power Station, Unit 2, Docket No. 50-320.

A copy may be obtained from the Public Document Room, U.S. Nuclear Regulatory Commission, 1717 H Street, NW., Washington, D.C.

9. Jordann, I. J., England, C. L., Khalifa, M. M. A., "Creep of Concrete: A Consistent Engineering Approach," Journal of the Structural Division of the American Society of Civil Engineers, March 1977.

Copies may be obtained from the Publications Office, American Society of Civil Engineers, 345 E. 47th St., New York, N.Y. 10017.

10. Cinlar, E., Bazant, Z. P., Osman, E., "Stochastic Process for Extrapolating Concrete Creep," Journal of the Engineering Mechanics Division of the American Society of Civil Engineers, December 1977.

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Copies may be obtained from the address in Reference 9.

11. Chaung, J. W., Kennedy, T. W., Perry, E. S., "An Approach to Estimating Long-Term Multiaxial Creep Behavior from Short-Term Uniaxial Creep Results," Union Carbide Report #2864-3, Department of Civil Engineering, University of Texas at Austin, June 1970, TID 25795.

    Copies may be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

12. Magura, D. D., Sozen, M. A., Siess, C. P., "A study of Stress Relaxation in Prestressing Reinforcement," Prestressed Concrete Institute Journal, April 1964.

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DRAFT VALUE/IMPACT STATEMENT

1. THE PROPOSED ACTION

1.1 Description

Inspections of prestressed concrete containment structures are performed using Regulatory Guides 1.35 and 1.90. The proposed action is directed toward providing guidance for determining the prestress forces in prestressing tendons that can be compared with the measured liftoff force during each inspection.

1.2 Need for the Proposed Action

In implementing Regulatory Guide 1.35, it was found that licensees are not interpreting the acceptance criteria of that guide in an appropriate manner. This was evidenced by a comment letter from Bechtel Corporation. During conversations with PG&E on the approval of the technical specifications for the Trojan Nuclear Power Plant, the need to clarify the acceptance criteria and to provide guidance in methods of constructing a tolerance band became apparent. The concept was also discussed with the ASME Section XI Working Group on Inspection of Concrete Pressure Components during various occasions.

1.3 Value/Impact of the Proposed Action

1.3.1 NRC

The guide will provide a consistent basis for review of applications for plants containing prestressed concrete containment structures, primarily in the area of technical specification requirements for inspection of those containments. It will help clarify the intent of some of the provisions of Regulatory Guides 1.35 and 1.90. The guide should facilitate the review and evaluation of the pertinent inspection programs and reduce the time for these efforts in the affected NRC offices.

1.3.2 Industry

It is expected that the guidance provided will help licensees to monitor the tendon forces with better accuracy and thus increase the effectiveness of the inspection programs. It will help keep licensees' records of tendon forces in order. The overall cost impact (increase/decrease) should be negligible.

1.3.3 Public

The action will result in better control of the inspection program. Thus it will provide more confidence in the integrity of prestressed concrete containment structures.

1.3.4 Occupational Exposure

The action will not increase the occupational exposure.

1.4 Decision on the Proposed Action

Guidance should be provided on determining the prestress forces to be used for comparing the measured liftoff forces during each inspection.

2. TECHNICAL APPROACH

2.1 Technical Alternatives

An alternative proposed (and presumably used) in lieu of the method described in the proposed action is as follows:

1. Based on the average instantaneous elastic-shortening losses, time-dependent losses, and friction losses, establish an average required prestress at 40 years in kips/ft.

2. Depending on the tendon spacing, establish the minimum required prestress per tendon and subsequently per wire at the jacking end.

3. When a tendon is randomly selected for liftoff testing, adjust its measured liftoff force to transfer its actual elastic-shortening loss and actual number of effective wires to the condition of the average (hypothetical) tendon. The adjustment (or normalization) factors would vary from inspection to inspection.

4. On an individual tendon basis, the adjusted (normalized) wire force should be compared with the minimum required prestress per wire.

2.2 Discussion and Comparison of Technical Alternatives

The proposed position assumes that the containment (including its prestressing) is designed to the minimum requirements of the Code (ASME Section III, Division 2) as well as to other additional criteria set up by the jurisdictional and regulatory agencies. Once the tendons are installed, the inservice inspection program should monitor their integrity and reliability and detect tendencies toward degradation.

The proposed alternative, on the other hand, is directly design related. If the prestressing force provided is (say) 20% greater than the minimum required prestress, its acceptance criteria would allow at least 20% degradation of the tendon system before any evaluations or investigations are undertaken. Also, the procedure assumes that the average prestressing force of randomly selected tendons always represents the average tendon force of the group population. Moreover, the variation of the tendon force with time is not considered in the proposed alternative.

2.3 Decision on Technical Approach

The proposed alternative is likely to give a wide band of tolerance for comparing the measured prestressing force. Thus it could result in the acceptance of tendons that are not performing adequately or are degraded.

The method proposed in Regulatory Guide 1.35.1 alleviates the deficiencies of the proposed alternative and provides guidance as to the methods of predicting the time-dependent parameters and in constructing a reasonably narrow tolerance band for comparing the measured prestressing force. The position is keyed to the acceptance criteria of Regulatory Guide 1.35 in such a way that improper performance of the tendon system can be detected earlier in the life of the structure.

3. PROCEDURAL APPROACH

3.1 Procedural Alternatives

Potential SD procedures that may be used to promulgate the proposed action are:

- Regulation
- Regulatory guide
- ANSI standard endorsed by a regulatory guide
- Branch position
- NUREG report

3.2 Value/Impact of Procedural Alternatives

The matter is not of sufficient importance to justify issuance of a regulation.

There is no ANSI standard prepared or proposed at this time.

No branch position exists on this subject.

A NUREG report and a regulatory guide are the two viable alternatives. As a NUREG report, the content would be perceived as informational, rather than as a statement of an NRC position.

3.3 Decision on Procedural Approach

A regulatory guide supplementary to Regulatory Guide 1.35 should be prepared.

4. STATUTORY CONSIDERATIONS

The guide will be numbered as Regulatory Guide 1.35.1 and will principally supplement the regulatory positions of Regulatory Guide 1.35. Hence the statutory considerations discussed in the value/impact statement for revision 3 of that guide are applicable to this guide.

5. RELATIONSHIP TO OTHER EXISTING OR PROPOSED REGULATIONS OR POLICIES

Regulatory Guides 1.35 and 1.90 are related to verifying the continued structural integrity of prestressed concrete containment structures. The proposed action (Regulatory Guide 1.35.1) clarifies and expands the regulatory positions of these guides, thus making the implementation of these guides more effective.

6. SUMMARY AND CONCLUSION

A regulatory guide (numbered 1.35.1) should be prepared to provide guidance for constructing a tolerance band for prestressing levels in prestressed concrete containment structures.

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