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SC ~~809-4~~ Reg Guide 1.35.1
SC 807-4
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Gilbert/Commonwealth engineers and consultants

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215-775-2600/Cable Gilasoc/Telex 836-431

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October 31, 1980

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Director, Division of Technical
Information and Document Control

Re: Comments on USNRC Regulatory Guides

Dear Sir:

Enclosed please find comments on:

1. Proposed Revision 3 to Regulatory Guide 1.35, "Inservice Inspections of Ungrouted Tendons in Prestressed Concrete Containments", dated April, 1979.

2. Proposed Regulatory Guide 1.35.1 "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments", dated April, 1979.

In order to provide the basis for certain specific comments on the Reg. Guide in item #1, it is necessary to discuss the similar provisions in Chapter CC-9000 of ASME Code Section III, Division 2. This is reflected in the attached information.

Very truly yours,

J. F. Fulton
J. F. Fulton
Structural Engineer

JFF:slg
Enclosures

cc: F. L. Moreadith
R. E. Pages
J. C. Herr
Hans Ashar (USNRC)
B. A. Erler

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COMMENTS ON

CC-9000 DRAFT OF ASME CODE SECTION III, DIVISION 2

AND

PROPOSED REVISION 3 TO NRC REGULATORY GUIDE 1.35 (DATED APRIL, 1979)

by J. F. Fulton

Some inconsistencies exist between the subject Reg. Guide and the latest draft of Article CC-9000, Inservice Inspection of Concrete Containments, of the ASME Code Section III, Division 2. The most significant difference between the two documents is in the tendon lift off force acceptance criteria. CC9222.2 of the ASME code has the dual requirements discussed below. Based on this discussion, changes to the subject Reg. Guide are proposed.

CC9222.2 (a)

This section requires that the average of the adjusted tendon lift off forces within each tendon group (the vertical, hoop, and dome tendons each constitute a group) be equal to or greater than the "minimum required prestress level for that type." The adjustment made to each tendon is to account for known differences in force between a specific tendon and the "average" tendon within the group. These differences occur because the tendons are not all necessarily stressed initially to the same force and because the elastic shortening losses are not the same. The "minimum required prestress level" is, for example, the minimum hoop prestress required in order to meet the containment design acceptance criteria. The hoop prestress level might be stated in terms of a kips per foot membrane hoop force or an external pressure. Regardless, either can be translated into a minimum required average hoop tendon force. Thus, criteria CC9222.2 (a) is for the purpose of directly establishing the safety of the containment.

CC9222.2 (b)

The criterion of CC9222.2 (b) is for the purpose of detecting abnormal force losses in the sample tendons. The occurrence of an abnormal force loss is cause for concern and investigation. However, the containment can still be safe even if such a loss were to occur for individual tendons. An abnormal force loss can be detected by comparing the measured lift off force for a specific tendon with the force predicted for the tendon at the time of the the test. However, a better assessment of the status of the tendon is obtained by plotting the lift off force on a graph of the predicted tendon force versus log time, starting at completion of stressing and extending to end of plant life. Thus, the actual rate of force loss can be compared with that predicted. CC9222.2 (b) provides that the lift off force is acceptable if it is equal to or greater than 95% of the "minimum required prestress at the time of the test".

It seems that the use of the above phrase "minimum required" is inappropriate. The word "predicted" should have been used. Nevertheless, the 95% value is intended to account for any inaccuracies in the individual predicted losses (steel relaxation, creep, and shrinkage) plus stressing equipment calibration and measurement errors. If the latter errors are assumed to not exceed 2% (as per CC 4464.1), the total error implied for predicted long term losses is 3% of the measured tendon force.

From CC9222.2, if a tendon lift off force is less than 95% of that predicted, the lift off forces in adjacent tendons are measured. CC9222.2 provides that: "If the average tendon force measurements of these three tendons is greater than the minimum required for these tendons, the inspection program shall proceed considering the event unique and acceptable". It appears that the "average" of the three forces is inappropriate since the purpose of CC9222.2 (b) is to detect abnormal force losses of individual tendons. This provision should read: "If the tendon force measurements for these two tendons is greater than 95% of their respective predicted values, the inspection program shall proceed considering the event unique and acceptable."

CC9222.2 further provides: "If that individual tendon is below 90% of the minimum required prestress level the cause shall be investigated and the tendon restressed to its' required prestress level." This should read: "If the force measured for an individual tendon is below 90% of that predicted for the time of the test, the tendon shall be completely detensioned and a determination shall be made as to the cause." Also, this requirement should be included as a part of CC9222.2 (b).

Finally, if criterion (a) and (b) are not met, CC9222.2 requires that an additional 4% sample of tendons are to be tested. According to CC9222.2, if the "total population of sampled tendons" meets the criteria given in (a) and (b), the prestressing system is considered to be acceptable. Actually, this doesn't make sense because if criteria CC9222.2 (b) is not met in the first 4% sample, it will not be met when included in the second 4% sample. However, the requirement for a second 4% sample does make sense in relation to criteria CC9222.2 (a). Moreover, increasing the sample size for the purpose of obtaining the average tendon forces of CC9222.2 (a) results in statistically more acceptable, and hence, more accurate value for these averages. Certainly, the sample size should be increased if the average measured tendon force obtained from the first 4% sample were slightly low with respect to its minimum required value.

Reg. Guide 1.35, Prop. Rev. 3

The provisions of the proposed Reg. Guide are more detailed than those in CC 9000, and in general the proposed revision is an improvement over the current Reg. Guide. However, the proposed revision needs to add the following provisions:

1. Preceding the requirements of section 7.1 (which parallel those of CC 9222.2 (b)), a criterion addressing the average tendon forces equivalent to that in CC 9222.2 (a) should be added. This is necessary since meeting the requirements of section 7.1 does not directly demonstrate that there is adequate prestress to maintain a safe containment. The requirements of section 7.1 only detect abnormal force losses in individual tendons. It should not be assumed that satisfying section 7.1 automatically satisfies CC9222.2 (a), even though in some cases it may.

2. A provision should be added for an additional 4% sample if the average of the measured tendon forces is less than that required. The provision should state that if the average measured tendon forces for the total sample (8%) are equal to or greater than that required, then the deficiency is the first 4% sample is considered as unique and acceptable. Such a condition could be reportable for the purpose of alerting the NRC, but the containment has been determined to be safe.

3. The proposed Reg. Guide requires that one wire is to be removed from each group of tendons for testing. The provision should be added that all detected broken wires are to be tested.

4. In the second paragraph on page 4 of the proposed Reg. Guide, it is not clear if the grease from <u>every</u> lifted off tendon is required to be tested for contaminants and water content. This should be clarified.

October 10, 1980

COMMENTS ON PROPOSED NRC REGULATORY GUIDE 1.35.1 (DATED 4/79)

BY J. F. FULTON

The proposed Reg Guide is a very worthwhile contribution. It will provide uniformity across projects in calculating the tendon losses which are used to establish individual predicted force-versus-log-time curves. When such curves are compared with measured lift off forces, abnormal force losses can be detected. The criteria for this comparison is given in section 7.1 of Proposed Revision 3 to Reg Guide 1.35.

The provisions of the subject Reg Guide have been applied to three projects in-house as part of an effort to update the tendon surveillances for these projects. The comments below result from this experience.

1. Measurement of Prestressing Force - Comparing the predicted elongation with that measured serves the same purpose as comparing the predicted tendon force with that calculated from the measured elongations. This procedure applies only to those tendons which are completely detensioned and retensioned.

A review of the stressing records of a recently post tensioned containment indicates that the measured and predicted elongations for the vertical tendons were within ±5%. However, many of the hoop and dome tendons exceeded ±5%, but all were within the ASME code allowable of ±10%. Therefore, it would be impractical to reduce the current 10% requirement to 5%.

The accuracy of the measured lift off force is affected by the accuracy of the stressing equipment, ability to read and interpolate between the pressure gauge marks, and ability to determine the precise point in which the tendon anchor head lifts off from the shims. CC 4464.1 of the ASME Code requires that the cumulative error due to these effects not exceed 2% of the force being measured. For a 170 - 1/4" diameter wire tendon the lift off force might be 1400 kips, and 2% of this is 28 kips. This

28 kip error is roughly 10% of the 40 yr. long term loss that is predicted for a tendon. Thus, the error in measuring the lift off force is not insignificant. In light of this, the Lower Limit established in the proposed Reg Guide should be redefined to include a 0.98 factor, which represents the 2% error.

2.2.2 Effect of Concrete Creep - The recommended formula for specific creep in Appendix A is acceptable; however, the recommended number of minimum observations is far too small and should be revised to include the number specified by ASTM C 512. The values for A and B appearing in the formula should be obtained from values of specific creep (at t_1, t_2, and t_3) picked off a linear regression fit to the creep data. The creep data consists of values measured at the times after loading specified in ASTM C 512. This revision is necessary because the creep data oscillates about a line of best fit and use of three data values at t_1, t_2, and t_3, rather than creep values off this line, produces erroneous values of A and B. The attached plot of some creep data illustrates this (concrete cylinders loaded at 180 days). From this data, the 40 yr. specific creep (micro inches per inch per psi) were calculated:

Cylinders	Linear Regression	Existing* App. A	Proposed** App. A
17/18	0.27	0.48	0.29
9/10	0.23	0.18	0.23

* A and B based on actual measured creep values at t_1, t_2, and t_3

**A and B based on creep values from linear regression line at t_1, t_2, and t_3

2.3 Losses Due to Tendon Degradation - An allowance in the design for broken wires affects only the number of tendons to be provided to satisfy the required prestress. If for a specific tendon to be sampled, a wire is actually broken, then the predicted force versus log time curve for this tendon should be reduced. Any discussion of broken wires in Reg Guide 1.35.1 should be limited to the statement that the predicted tendon force is a function of the number of effective wires in the tendon, and a broken wire is not considered to be effective. However, a wire with a buttonhead which has slips or splits exceeding the acceptance criteria is still considered to be effective.

3.0 Grouping of Tendons and Construction of Tolerance Band - Regarding the last sentence (underlined) of the second paragraph, the so-called concrete creep-steel relaxation interaction method of loss determination is, in theory, more accurate than the approach discussed in the Reg Guide. This is offered merely as a comment. There may be no significant difference in the predicted losses for concrete that is the least one year old at time of initial prestressing.

The following comments apply to the discussion under "Relaxation of Prestressing Steel". Regarding the statement that the predicted prestressing force can be considered to vary linearly as log time, it should be noted that this is true only after a sufficient length of time has transpired after post tensioning the containment. If the earliest predicted force is one year after the SAT, then this is usually sufficient.

Regarding the third paragraph, any allowance for broken wires that may have been incorporated into the design does not have any effect on establishing a Lower Limit curve for each sample tendon. The Lower Limit curve is based on this initial lock off force in the tendon minus its elastic shortening loss minus the upper bound of its long term losses. This Lower Limit should also be multiplied by 0.98 to reflect a possible measurement error of 2%, but this is discussed later. Reducing the Lower Limit by "an allowance for breakage" ignores the actual number of effective wires in the tendon, and it gives a predicted tendon face which is unconservatively low for purposes of comparing this force with a measured value.

Incorporation of Lift Off Force Measurement Error into Lower Limit - The two attached Predicted Force-versus-Time curves illustrate the significance of a 2% measurement error. One figure is for a 169 wire tendon; the other applies to a 90 wire tendon.

The Lower Limit line was established from upper bound losses as per the Reg Guide. If a 2% measurement error is applied to the Lower Limit curve, the 0.98 Lower Limit line results. From a discussion of the measurement accuracy of lift off forces with post tensioning vendors, a 2% error is realistic.

From the figures, it is seen that the force corresponding to a 2% measurement error is about the same as the upper bound loss tolerance. Thus, the Lower Limit should include the 2% measurement error. Its effect on the 90% Lower Limit line would not be as significant; consequently, the 2% error does not have to be applied to the 90% Lower Limit.

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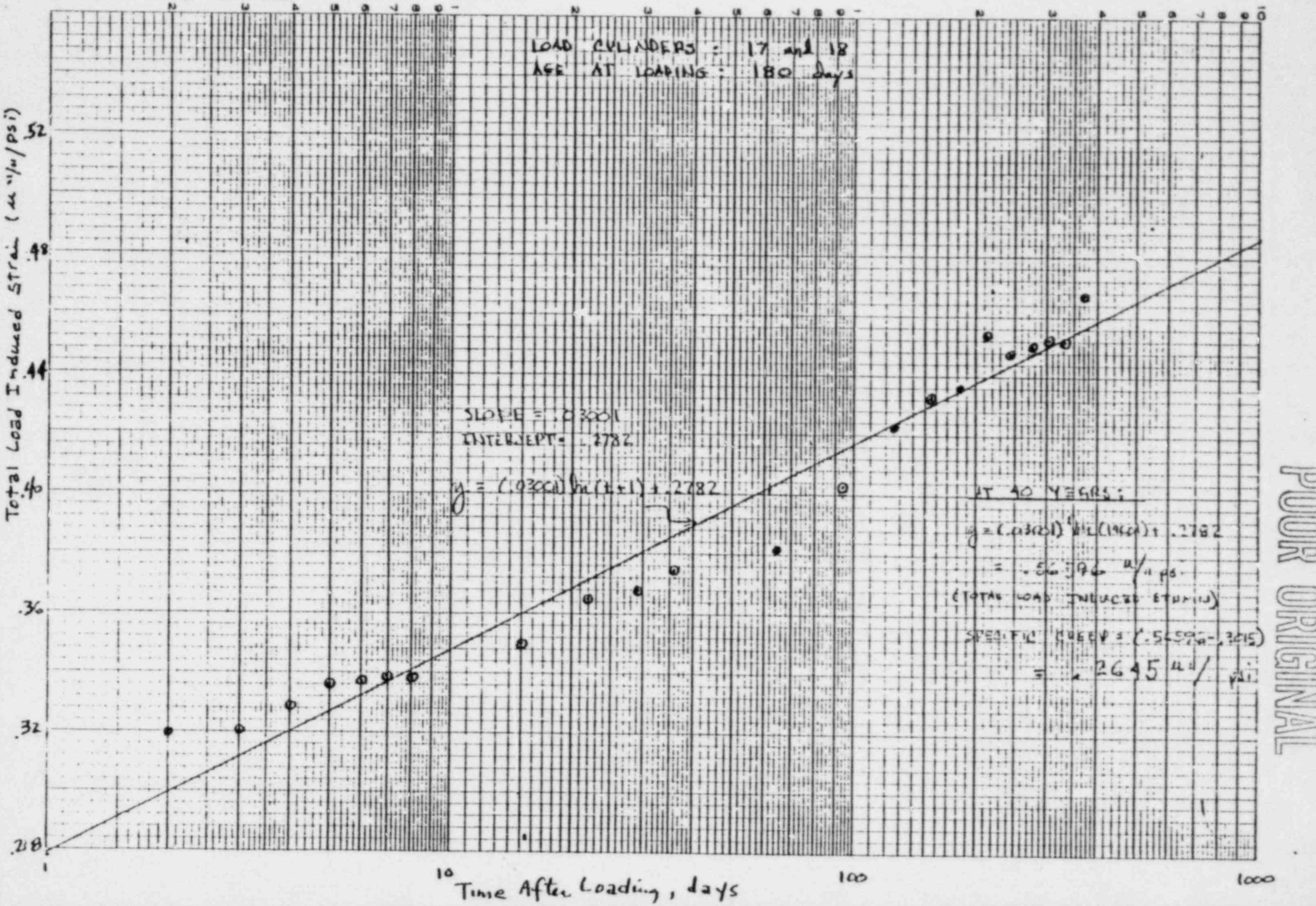

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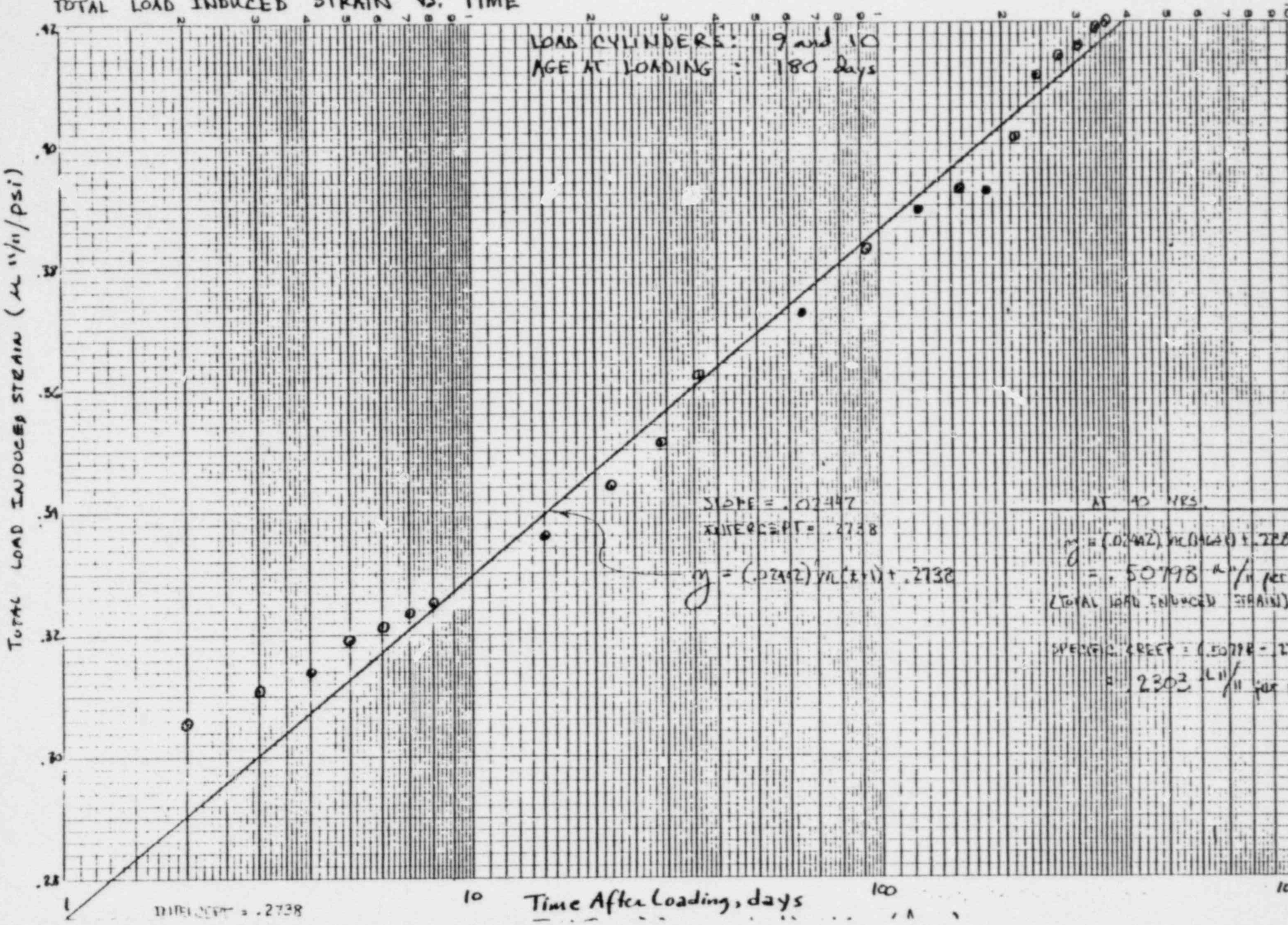
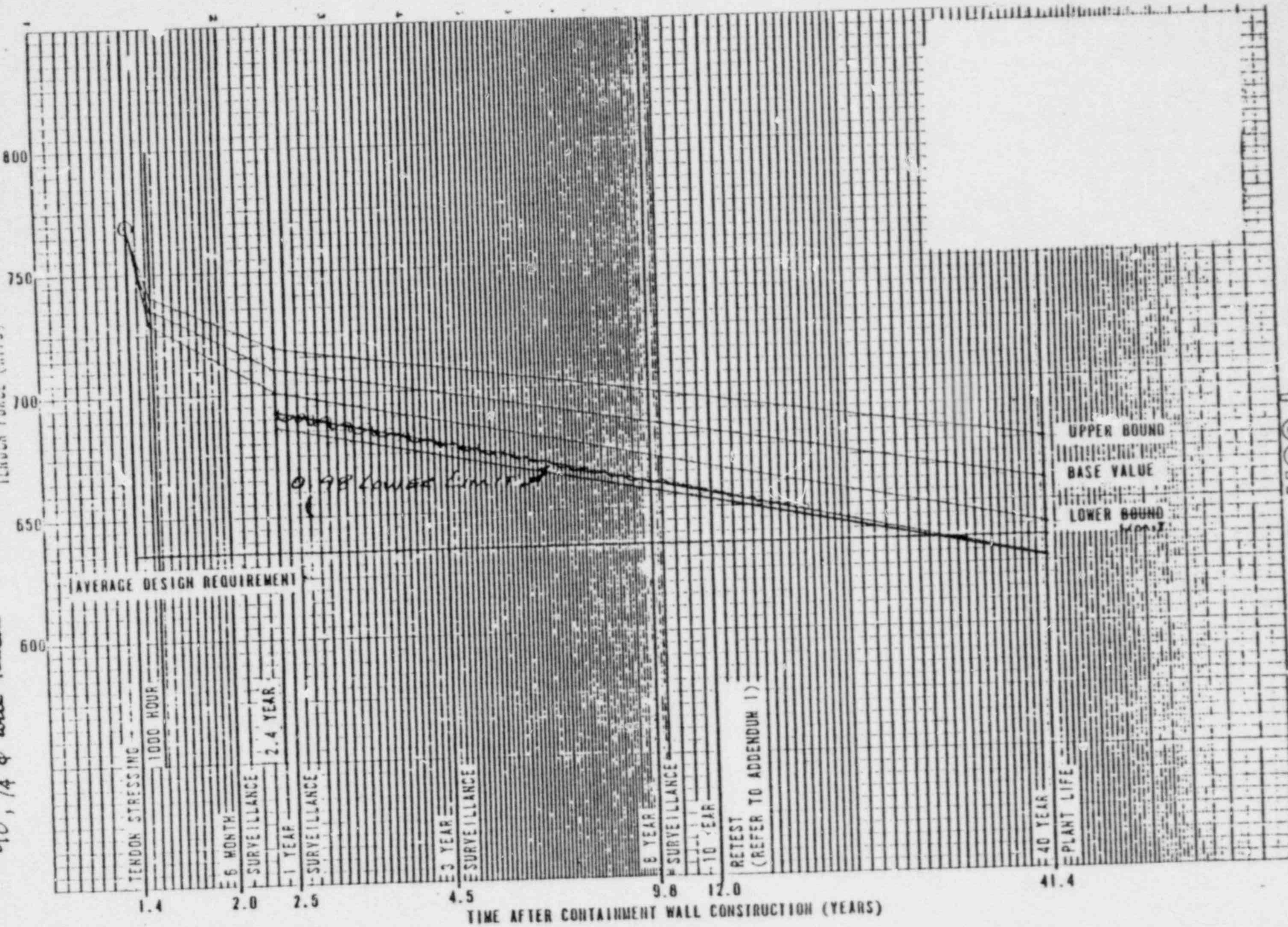
TOTAL LOAD INDUCED STRAIN VS. TIME





90, 1/4" φ wire tendon

169, 25mm wire tendon