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NUCLEAR REGULATORY COMMISSION
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REGULATORY GUIDE DISTRIBUTION LIST (Division 1)

SUBJECT: REVISION 3 OF REGULATORY GUIDE 1.35, "INSERVICE INSPECTION OF UNGROUTED TENDONS IN PRESTRESSED CONCRETE CONTAINMENTS," AND REGULATORY GUIDE 1.35.1, "DETERMINING PRESTRESSING FORCES FOR INSERVICE INSPECTION OF PRESTRESSED CONCRETE CONTAINMENTS"

The subject regulatory guides have been revised to reflect (1) public comments, (2) insights gained by the survey and study of actual inservice inspections (NUREG/CR-2719), and (3) consideration of Subsection IWL, "Requirements for Class CC Concrete Components of Light-Water Cooled Power Plants," of Section XI of the ASME B&PV Code, published January 1989.

The NRC staff will use the provisions of the guides as indicated in Section D, "Implementation," of the guides.

A sample technical specification incorporating the provisions of the regulatory guides is under development and will be available after August 1990. A copy of the sample technical specification will be available upon request from the plant project managers in the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

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Office of Nuclear Regulatory Research

U.S. NUCLEAR REGULATORY COMMISSION

Revision 3
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REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

**REGULATORY GUIDE 1.35
(TASK SC 810-4)**

INSERVICE INSPECTION OF UNGROUTED TENDONS IN 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. This guide describes a basis acceptable to the NRC staff for developing an appropriate inservice inspection and surveillance program for ungrouted tendons[1] in prestressed concrete containment structures of light-water-cooled reactors.

The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Part 50, which provides the regulatory basis for this guide. The information collection requirements in 10 CFR Part 50 have been cleared under OMB Clearance No. 3150-0011.

B. DISCUSSION

Following the issuance for public comment of the proposed Revision 3 of this regulatory guide (Task SC 810-4) and of the accompanying proposed Regulatory Guide 1.35.1 (Task SC 807-4) in April 1979, the NRC Office of Research awarded a contract to Oak Ridge National Laboratory (ORNL). The contract work included evaluating actual inspections performed by licensees, the methods of implementing Revision 2 of this guide, and the opinions and problems of utilities, A/Es, vendors, etc., related to Revision 2 of this regulatory guide. The contractor also considered the pertinent portion of the January 1982 draft version of "Inservice Inspection of Concrete Pressure Components," developed by a Working Group of ASME Section XI, in making final suggestions for modifying this guide. These suggestions were published in NUREG/CR-2719.[2]

This guide has been revised to reflect public comments, suggestions from ORNL, and additional staff review.

Regulatory Position 1 provides general information on the applicability of the guide, frequency of inservice inspections, and inspections when there are two containments at a site.

Regulatory Position 2 delineates the method of determining sample size and emphasizes random sampling. If random sampling can not be assured, it is acceptable to select representative samples from

[1]For the purpose of this guide, a tendon is defined as a separate continuous multiwire or multistrand tensioned element anchored at both ends to an end anchorage assembly.

[2]NUREG/CR-2719, "Evaluation of Inservice Inspections of Greased Prestressing Tendons," by J. R. Dougan, Nuclear Regulatory Commission, September 1982. Available for sale from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, or from the National Technical Information Service, Springfield, VA 22161.

between the pairs of buttresses and from various heights. The samples for each inspection may be selected any time prior to the inspection. Since inspections can be performed when the plant is operating, there may be certain areas where inspection of a randomly selected tendon might result in some radiological exposure to the inspecting personnel. The position provides for substituting a readily accessible tendon for such a tendon.

Regulatory Position 3 describes the areas and extent of visual examinations during each inspection.

Regulatory Position 4 presents the criteria for performing prestress monitoring tests.

Regulatory Position 5 states the extent and scope of tendon material testing.

Regulatory Position 6 lists items that should be considered in the inspection of sheathing filler grease. In order to assess the potential grease leakage, a recommendation is made to compare the amount of sheathing filler grease removed with that being replaced.

Regulatory Position 7 discusses the individual criteria for evaluating inspection results as follows:

In Regulatory Position 7.1, prestress monitoring criteria have been developed to ensure that any signs of systematic tendon force degradation are detected and investigated. Acceptance of 95% of the predicted force for two tendons out of three in Regulatory Position 7.1.3 is a slightly relaxed criterion from Revision 2 of the guide. It should be recognized, however, that the primary objective is to compare the measured tendon forces against the predicted forces at the time of the lift-off testing. Regulatory Guide 1.35.1 provides guidance on establishing the predicted forces.

A provision has been added to check the average of measured forces against the minimum required force in an average (hypothetical) tendon in a group. This provision is added as a result of a suggestion from the contractor (ORNL) and public comments. It should be recognized that each individual tendon force (measured) will have to be modified to reflect the condition of an average tendon. The contributing modifying factors would be the difference in installation forces and in the elastic shortening losses, assuming the time-dependent characteristics remain essentially the same for the group of tendons.

The loss of prestress from creep and shrinkage of concrete and stress relaxation of the tendon steel are time-dependent and are predicted on such a basis. The predicted tendon force may be represented by a sloped line in a semi-logarithmic graph. The trend of the actual effective tendon force is obtained by joining the points on the graph representing the measured tendon forces in two or more surveillances of the same tendon or tendons in a group. By extending the trend line, one can determine when the effective tendon force will be below the minimum required.

Regulatory Position 7.2 provides a means of tracking elongations during lift-off testing. The 10% tolerance in elongations at specific loads of retensioned tendons should include the effect of differential friction (from fully greased vs. coated tendons) and errors attributed to calibration, measurement procedures, and equipment.

Regulatory Position 7.4 provides detailed guidance on the results of the grease examination.

The incident of tendon anchor head failures at Farley demonstrated that the free water in grease was the main source of hydrogen for hydrogen stress cracking of high-hardness anchor heads. High-hardness anchor heads are used in large-size tendon systems (i.e., ≥750 tons). Since the small-size (≤750 tons) tendons have not exhibited such characteristics, two limits for water are provided. It should be recognized that these limits are not the threshold limits for distress in anchor heads. When these limits are exceeded, it is advisable to detension the tendon and look for cracks on the shim side of the anchor heads.

An assessment of a base number for filler grease has been proposed for new grease in ASME Section III, Division 2, and for new and old grease in ASME Section XI. The grease used in many operating plants tends to have a low base number (≤5). The newer grease formulations tend to have base numbers in excess of 20. Hence, two acceptance limits have been provided.

At least two plants that implemented the detailed grease examination criteria experienced problems with the void limit of 5%. Further inquiry into the matter revealed that when the injection pressure was very high (twice the pressure used during installation of grease), the amount of grease replaced was 10 to 15% higher than that removed. The staff discourages this practice, as there is a likelihood of tearing the sheathing joints at such pressures, opening a way for grease to seep into the concrete. Hence, Regulatory Position 7.4 has been revised to reflect this consideration.

The NRC staff encourages operating plant licensees to review their existing tendon inservice inspection programs and evaluate them from the standpoint of operating convenience, safety improvements, and cost reduction potential.

The NRC staff recognizes that in some older plants (plants operating before the initial issuance of Regulatory Guide 1.35 in 1974), adopting all provisions of this revised guide may not be feasible without extensive retrofitting. In such cases, licensees are advised to present their revised inservice inspection programs with any necessary exemptions from the specific provisions of this guide. If licensees adopt this Revision 3 to Regulatory Guide 1.35, it should be adopted in its entirety, not just segments of the guide.

C. REGULATORY POSITION

1. GENERAL

1.1. The inservice inspection program described in this guide should be used with the following types of prestressed concrete containment structures:

a. Prestressed concrete containments having a shallow-dome roof on cylindrical walls with the cylinder prestressed in hoop and vertical directions and the dome prestressed by three families of tendons at 60°.

b. Prestressed concrete containments having a hemispherical-dome roof on cylindrical walls with two families of inverted U tendons placed at 90° to each other and hoop tendons located in the cylinder and dome.

1.2. For containments that differ from these two types, the program described should serve as the basis for the development of a comparable inservice inspection program.

1.3. The inservice inspection should be performed 1, 3, and 5 years after the initial structural integrity test (ISIT) and every 5 years thereafter.

1.4. Containments should be designed and constructed so that the prestressing anchor hardware is accessible for inservice inspection.

1.5. All containment structures with ungrouted tendons should be inspected in accordance with this guide. However, the liftoff force comparison may be performed as shown in Figure 1 if any two containments at the same site are shown to satisfy all three of the following conditions:

a. The containments are identical in all aspects such as size, tendon system, design, materials of construction, and method of construction.

b. Their ISITs were performed within two years of each other.

c. There is no unique situation that may subject either containment to a different potential for structural or tendon deterioration.

For both containments, the visual and filler grease inspection should be performed according to Regulatory Positions 3 and 6 at frequencies described in Regulatory Position 1.3.

2. SAMPLE SELECTION

2.1. For the inspections at 1, 3, and 5 years, 4% of the population of each group (vertical, hoop, dome, and inverted U) of tendons should be selected randomly with a minimum of four tendons from each group. The sample size from any group need not exceed ten.

2.2. If the inspections performed at 1, 3, and 5 years indicate no abnormal degradation of the post-tensioning system, 2% of the population of each group (vertical, hoop, dome, and inverted U) of tendons or five tendons, whichever is less, may be selected for the subsequent inspection with a minimum of three tendons for each group.

2.3. The fraction obtained as a percentage of a tendon population should be rounded off to the nearest integer.

2.4. The tendons to be inspected should be randomly selected from each group during each inspection. However, to develop a history and to correlate the observed data, one tendon from each group should be kept unchanged after the initial selection, and these unchanged tendons should be identified as control tendons.

2.5. If, owing to plant operating conditions, a randomly selected tendon from a group cannot be inspected during a scheduled inspection, another sample from the group should be randomly selected. The tendon that was selected but not inspected should be inspected during the following plant shutdown and accepted (or rejected) on an individual tendon basis.

2.6. Tendons, except the control tendons, that had been inspected and found intact during previous inspections should be excluded from the group population during subsequent inspections.

3. VISUAL INSPECTION

3.1. The exterior surface of the containment should be visually examined to detect areas of large spall,[3] severe scaling, D-cracking in an area of 25 square feet or more, other surface deterioration or disintegration, or grease leakage.

3.2. Tendon anchorage assembly hardware (such as bearing plates, stressing washers, shims, wedges, and buttonheads) of all tendons selected as described in Regulatory Position 2 should be visually examined. For those containments for which only visual inspections need be performed, tendons selected as described in Regulatory Position 2 should be visually examined to the extent practical without dismantling load-bearing components of the anchorage or removing grease caps.

3.3. Bottom grease caps of all vertical tendons should be visually inspected to detect grease leakage or grease cap deformations. Removal of grease caps is not necessary for this inspection.

[3]The terms "large spall," "severe scaling," "D-cracking," "deterioration" and "disintegration" are as defined in the American Concrete Institute publication, ACI 201.1R-68, "Guide for Making a Condition Survey of Concrete in Service." The publication can be obtained from the American Concrete Institute, Redford Station, Detroit, Michigan 48219.

3.4. Concrete surrounding visually inspected tendon anchorages should also be checked visually for indications of abnormal material behavior.

4. PRESTRESS MONITORING TESTS

Tendons selected as described in Regulatory Position 2 should be subjected to liftoff or other equivalent tests to monitor their prestress. Additionally, the tests should include the following:

4.1. One tendon, randomly selected from each group of tendons during each inspection, should be subjected to necessary detensioning in order to identify broken or damaged wires or strands.

4.2. The simultaneous measurement of elongation and jacking force during retensioning should be made at a minimum of three approximately equally spaced levels of force between zero and the lock-off force.

5. TENDON MATERIAL TESTS AND INSPECTIONS

5.1. A previously stressed tendon wire or strand from one tendon of each group should be removed for testing and examination over its entire length to determine if evidence of corrosion or other deleterious effects is present. At each successive inspection, the samples should be selected from different tendons. The tendon selected may be the same as that selected for detensioning. In addition, all wires or strands identified as broken should be removed for tensile testing and visual examination.

5.2. Tensile tests should be made on at least three samples cut from each removed wire or strand, one at each end and one at mid-length. The samples should be the maximum length practical for testing and the gauge length for the measurement of elongation should be in accordance with the relevant ASTM specification. The following information should be obtained from each test:

1. Yield strength
2. Ultimate tensile strength
3. Elongation at ultimate tensile strength

6. INSPECTION OF FILLER GREASE

A sample of sheathing filler grease from each of the sample tendons should be taken and analyzed according to the following national standards.

1. To determine water content, ASTM D95, "Standard Test Methods for Water in Petroleum Products and Bituminous Materials by Distillation."[4]
2. To determine reserve alkalinity, ASTM D974, "Standard Test Methods for Neutralization Number by Color-Indicator Titration."[4,5]
3. To determine the concentrations of water-soluble chlorides, ASTM D512, "Standard Test Methods for Chloride Ion in Water."[4]
4. To determine nitrates, ASTM D3867, "Standard Test Methods for Nitrite-Nitrate in Water"[4] (formerly ASTM D992).
5. To determine sulfides, APHA 428, "Standard Methods for Examination of Water and Waste Water."[6]

In addition, the amount of sheathing filler grease removed and replaced should be compared to assess grease leakage within the structure.

7. EVALUATION OF INSPECTION RESULTS

7.1. The prestressing force measured for each tendon in the tests described in Regulatory Position 4 should be compared with the limits predicted for the time of that test. Regulatory Guide 1.35.1 provides further information on the determination of these limits.

7.1.1. If the measured prestressing force of the selected tendon in a group lies above the prescribed lower limit, the liftoff test is considered to be a positive indication of the sample tendon's acceptability.

7.1.2. If the measured prestressing force of a selected tendon in a group lies between 95% of the prescribed lower limit and 90% of the prescribed lower limit, two additional tendons, one on each side of the first tendon, should be checked for their prestressing forces. If the prestressing forces of each of the second and third tested tendons are above 95% of the prescribed lower limits for the tendons, all three tendons should be restored to the required level of integrity and the tendon group should be considered acceptable.

7.1.3. In Regulatory Position 7.1.2, if the prestressing force of any two adjoining tendons falls below 95% of the prescribed lower limits of the tendons, additional lift-off testing should be done to detect the cause and extent of such occurrence. The condition should be considered reportable.

7.1.4. If the measured prestressing force of the selected tendon lies below 90% of the prescribed lower limit, the defective tendon should be fully investigated and a determination should be made as to the extent and cause of such occurrence. Such an occurrence should be considered a reportable condition.

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[4]ASTM Standards can be obtained from the American Society of Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

[5]Modified by Note 3 of Table CC-2422-1 of the ASME B&PV, Section III, Div. 2, 1982 Winter Addenda.

[6]APHA Standards can be obtained from the American Public Health Association, 1015 Eighteenth Street NW., Washington, DC 20036.

7.1.5. If the average of all measured tendon forces for each group (corrected for average condition) is found to be less than the minimum required prestress level (as defined in the plant's Technical Specifications) at anchorage location for that group, the condition should be considered reportable.

7.1.6. If from consecutive surveillances the measured prestressing forces for the same tendon or tendons in a group indicate a trend of prestress loss larger than expected and the resulting prestressing forces will be less than the minimum required for the group before the next scheduled surveillance, additional lift-off testing should be done to determine the cause and extent of such occurrence. The condition should be considered reportable.

7.2. During detensioning and retensioning of tendons (Regulatory Position 4.2), if the elongation corresponding to a specific load differs by more than 10% from that recorded during installation of the tendons, an investigation should be made to ensure that the difference is not related to wire failures or slip of wires in anchorages. A difference of more than 10% should be considered reportable.

7.3. Failure in the tensile test at a strength or elongation value less than the minimum requirements of the tendon material should be considered reportable. Other conditions that indicate corrosion (metal reduction) found by visually examining wire or strands should be considered reportable.

7.4. Reportable conditions for sampled sheathing filler grease include:

a.	Water content	Exceeding 10% by wt
b.	Chlorides	Exceeding 10 ppm
c.	Nitrates	Exceeding 10 ppm
d.	Sulfides	Exceeding 10 ppm
e.	Reserve alkalinity (Base numbers)	Less than 50% of the installed value or less than zero when the installed value was less than 5

f. Amount of grease replaced exceeds 5% of the net duct volume, when injected at the original installation pressure.

g. Grease leakage detected during general visual examination of the containment exterior surface.

h. Presence of free water.

8. REPORTING TO THE NRC

The reportable conditions listed in Regulatory Positions 7.1.3, 7.1.4, 7.1.5, 7.3, or 7.4 could indicate a possible abnormal degradation of the containment structure (a boundary designed to contain radioactive materials). Any such condition should be reported to the NRC in accordance with the recommended reporting program of Regulatory Guide 1.16, "Reporting of Operating Information—Appendix A Technical Specifications."

The NRC staff recognizes that for some containment designs, adoption of all provisions of this guide may not be feasible. In those cases, licensees should present alternatives for those provisions of the guide they are unable to implement.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant or licensee proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described herein will be used in the evaluation of inservice inspection and surveillance programs for the following nuclear power plants using prestressed concrete containments with ungrouted tendons:

1. Plants for which the construction permit or design approval is issued after July 31, 1990.
2. Plants for which the licensee voluntarily commits to the provisions of this guide.

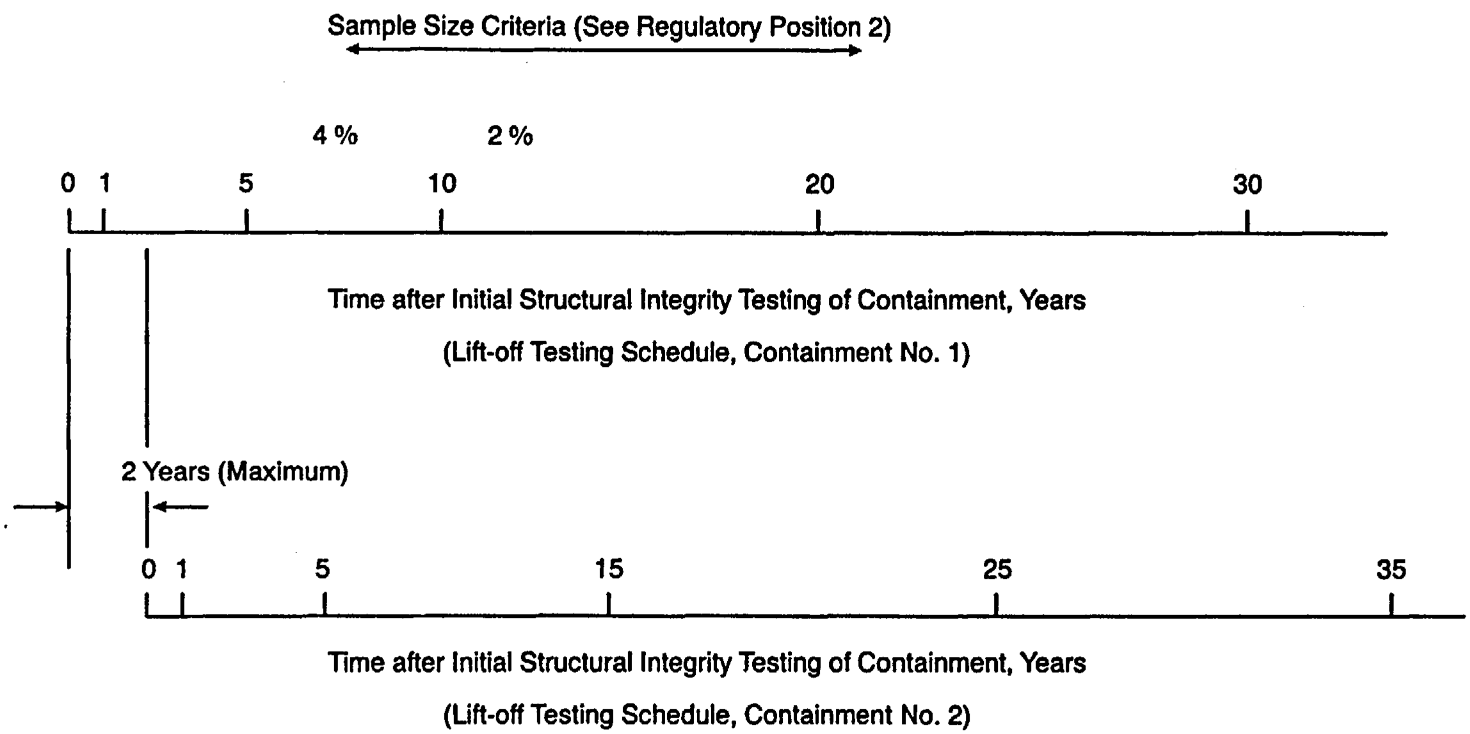

Figure 1. Schedule of Lift-off Testing for Two Containments at a Site
(See Regulatory Position 1.5)

REGULATORY ANALYSIS

A separate regulatory analysis was prepared for this Revision 3 to Regulatory Guide 1.35. The regulatory analysis is contained in NUREG/CR–4712, "Regulatory Analysis of Regulatory Guide 1.35 (Revision 3, Draft 2)—In-Service Inspection of Ungrouted Tendons in Prestressed Concrete Containments" (February 1987), and is available for inspection or copying for a fee in the Commission's Public Document Room, 2120 L Street NW., Lower Level, Washington, DC. NUREG/CR–4712 is also for sale at the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013–7082, and at the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

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