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REGULATORY GUIDE 1.35

INSERVICE INSPECTION OF UNGROUTED TENDONS IN PRESTRESSED CONCRETE CONTAINMENT STRUCTURES

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, "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 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.

B. DISCUSSION

This revision is the result of comments received on Revision 1, June 1974, and additional staff review.

The recommendations of this guide are applicable to "typical" prestressed concrete containments having a shallow-domed roof on cylindrical walls about 150 feet in diameter, an overall height of about 200 feet, and the following tendons: approximately 200 in the dome (either three families of tendons 60° apart or two families of tendons 90° apart), 200 vertical in the wall, and 500 hoop tendons in the wall. In addition, these recommendations are applicable to containments having a hemispherical dome-shaped roof on cylindrical walls about 150 feet in diameter, an overall height ranging from 200 to 240 feet, and the following tendons: 70 to 90 inverted U tendons[1] arranged in two families of tendons 90° apart and 150 to 180 hoop tendons in the cylinder and dome.

Inservice inspection of ungrouted wire and strand tendons of all sizes (up to an ultimate strength of approximately 1300 tons) and all types should be performed (e.g., tendons with parallel wires, with one or several strands, and with different systems of anchors). Materials for all components should satisfy the requirements of applicable American Society for Testing and Materials (ASTM) material standards. The inservice inspection program should cover the anchor hardware and the corrosion-preventing filler (grease). To the fullest extent practical, it should also cover the ducts that contain the tendons. Such an inservice inspection program is necessary because generally there is no permanent instrumentation installed in the containment that could continuously monitor its structural behavior.

When an inservice inspection program is being developed, the total containment tendon population should be divided into homogeneous subgroups consisting of tendons having approximately the same probability of corrosion and similar functions in the overall structural capabilities and properties of the structure. Thus, for each structure the inservice inspection program should consider separately the groups of vertical, inverted U, hoop, and dome tendons. This will permit a sampling base to be established for determining loss of prestress, the main characteristic checked by the inservice inspection program.

*Lines indicate substantive changes from previous issue.

[1] A tendon, both ends of which are anchored at the bottom of the base of the cylindrical walls and which approximately follows the configuration of the containment in the vertical plane passing through the anchor points.

If some tendons are expected to be subject to greater prestress losses than the rest, this should be taken into account in selecting samples.

The inservice inspection programs outlined in this guide are applicable to all containments with ungrouted prestressing systems regardless of plant geographical location.

The prestressing force in a tendon may be checked by a liftoff or other equivalent tests. One of the main objectives of the test is to discover any brittle, damaged, or broken wires. Any eventual decrease in the prestressing force is due to the simultaneous interaction of several time-dependent factors such as:

1. Stress relaxation in the wire;

2. Temperature variation of the wire;

3. Shrinkage, creep, and temperature deformations in concrete;

4. Differential thermal expansion or contraction between the concrete and the tendon; and

5. Reduction in cross section of the wires, including possible fracture, due to corrosion.

A liftoff test does not separate the effects of these factors, and corrosion, the factor of greatest concern, cannot be isolated. Therefore, tolerance limits for the loss of prestressing force, including the effects of possible corrosion, should be established, and the inservice inspection program should be oriented toward determining whether these limits are exceeded. However, it should be noted that only gross deterioration of the prestressing system can be detected.

Many hoop tendons are anchored on buttresses partially located inside the auxiliary building adjacent to the containment. Since these anchors are not easily accessible, especially during operation of the facility, they present a special problem for liftoff tests. In the original layout of tendons, this problem should be specifically considered. Any architectural treatment or environmental protection of the anchors should be removable without damage to the anchor.

Defects that an inspector might uncover during visual inspection of the anchorage assembly should be separated into three groups:

1. Defects that can be found when the tendon is in its normally stressed condition;

2. Defects that can be found only after the tendon is tensioned to a higher value than the existing prestressing force; and

3. Defects that can be found only after the tendon is detensioned.

C. REGULATORY POSITION

1. General

1.1 The inservice inspection program described in this guide is applicable to the following types of prestressed concrete containment structures:

1.1.1 Prestressed concrete containments having a shallow-domed roof on cylindrical walls about 150 feet in diameter, an overall height of about 200 feet, and the following tendons:[2] approximately 200 in the dome (either three families of tendons 60° apart or two families of tendons 90° apart), 200 vertical in the wall, and 500 hoop tendons in the wall (herein designated ("typical") and

1.1.2 Prestressed concrete containments having a hemispherical dome-shaped roof on cylindrical walls about 150 feet in diameter, an overall height ranging from 200 to 240 feet, and the following tendons: 70 to 90 inverted U tendons[1] arranged in two families of tendons 90° apart and 150 to 180 hoop tendons in the cylinder and dome (herein designated "hemispherical 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 All containment structures with ungrouted tendons should be inspected in accordance with this guide. However, if it can be shown by the applicant that identical containment structures are located on one site, that no environmental or other differences are apparent, and that they were constructed by the same contractor in the same manner at the same time (continuous construction), every second containment structure need only be visually inspected as described in regulatory position C.3.

1.4 Containments should be designed so that the prestressing anchor hardware is accessible for periodic examination.

1.5 The inservice inspection should be performed 1, 3, and 5 years after the initial containment structural integrity test and every 5 years thereafter.

[2]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. Sample Selection

2.1 Samples for the inspection at 1, 3, and 5 years should be selected as follows:

2.1.1 "Typical" containments:

2.1.1.1 Six dome tendons, two located in each 60° group (i.e., three families of tendons) and randomly distributed to provide representative sampling, or three located in each 90° group (i.e., two families of tendons).

2.1.1.2 Five vertical tendons, randomly but representatively distributed.

2.1.1.3 Ten hoop tendons randomly but representatively distributed.

2.1.2 "Hemispherical dome" containments:

2.1.2.1 4% of the U tendon population with the result rounded off to the nearest integral number of tendons, but no less than four.

2.1.2.2 4% of the hoop tendon population with the result rounded off to the nearest integral number of tendons, but no less than nine.

2.2 If the inspections described in regulatory position C.2.1 indicate that there are no problems with prestressing tendons in containment structures, the samples for the subsequent inspections may be selected as follows:

2.2.1 "Typical" containments:

2.2.1.1 If there are three dome groups, one from each group; if there are two dome groups, one from each dome group plus one additional dome tendon selected at random.

2.2.1.2 Three vertical tendons randomly but representatively distributed.

2.2.1.3 Three hoop tendons randomly but representatively distributed.

2.2.2 "Hemispherical dome" containments:

2.2.2.1 2% of the U tendon population with the result rounded off to the nearest integral number of tendons, but no less than two.

2.2.2.2 2% of the hoop tendon population with the result rounded off to the nearest integral number of tendons, but no less than three.

2.3 If some tendons are subject to greater prestress losses than others, this should be considered in the sample selection. For each inspection, the tendons should again be selected on a random but representative basis so the sample group will change somewhat each time. However, to develop a history and for correlating the observed data, one tendon from each group may be kept unchanged after the initial selection.

3. Visual Inspection

Tendon anchorage assembly hardware (such as bearing plates, stressing washers, shims, wedges, and buttonheads) of all tendons selected as described in regulatory position C.2 should be visually examined. For those containments for which only visual inspections need be performed, tendons selected as described in regulatory position C.2 should be visually examined to the extent practical without dismantling load-bearing components of the anchorage. The surrounding concrete should also be checked visually for indications of abnormal material behavior. The visual examination of the concrete should be scheduled during integrated leakage testing while the containment is at its maximum test pressure.

The method used for removing grease in order to permit visual examination of the stressing washers, shims, wedges, and bearing plates should neither increase the effects of corrosion nor damage the steel (for instance, scratch it) and should be usable under operating conditions.

4. Prestress Monitoring Tests

Tendons selected as described in regulatory position C.2 should be subjected to liftoff or other equivalent tests to monitor loss of prestress during each inspection. These tests should include the following:

4.1 The simultaneous measurement of elongation and jacking force with properly calibrated jacks. Allowable elongations, jacking loads, allowable tolerances, and the effects of influences such as temperature should be established prior to the tests.

4.2 The maximum test liftoff force should be greater than the maximum inservice prestressing force. The liftoff test should include an unloading cycle going down to essentially complete detensioning of the tendon to identify broken or damaged wires or strands.

5. Tendon Material Tests and Inspections

5.1 Previously stressed tendon wires or strands from one tendon of each type (i.e., for "typical" containments, one dome, one vertical, and one hoop tendon; for "hemispherical dome" containments, one U tendon and one hoop tendon) should be removed for testing and examination over the 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.

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). If frequent stress cycling is suspected, tests simulating this condition should be conducted. Similarly, where the inservice inspection program indicates the possibility of a potentially corrosive atmosphere, accelerated corrosion tests should be made.

6. Inspection of Filler Grease

The method used for checking the presence of sheathing filler grease should account for (1) the minimum grease coverage needed for different parts of the anchorage system including, for example, buttonheads; (2) the influence of temperature variations, especially the lowest temperature likely to occur between two successive inspections; (3) the procedure used to uncover possible voids in grease in the trumpet; and (4) requirements imposed by grease specifications, qualification tests, and acceptability tolerances.

7. Acceptance Criteria

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.

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. If both of these tendons are acceptable as defined in regulatory position C.7.1, the inservice inspection program should proceed considering the single deficiency as unique and acceptable. However, if either adjacent tendon is defective or if more than one tendon out of the original sample population is defective, the occurrence should be considered as unacceptable.

7.3 Failure in the tensile test should not occur at a strength value less than the guaranteed ultimate strength of the tendon material. Failure below this value in any tendon material sample should be considered as unacceptable.

8. Reporting to the Commission

If the acceptance criteria of regulatory position C.7 are not met or if abnormal material behavior is detected as described in regulatory positions C.3 and C.6, a possible abnormal degradation of the containment structure (a boundary designed to contain radioactive materials) is indicated. Such an occurrence should be reported to the Commission.[3] The report should include a description of the tendon condition, the condition of the concrete (especially at tendon anchorages), the inspection procedure, the tolerances on cracking, and the measures to be used when tolerances are exceeded.

D. IMPLEMENTATION

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

This guide reflects current NRC practice. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, this guide will be used by the NRC staff in evaluating construction permit and operating license applications for plants whose construction permits are docketed after the date of publication of the guide.

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[3]The report to the Commission should be made in accordance with the reporting program summarized in Regulatory Guide 1.16, "Reporting of Operating Information - Appendix A Technical Specification."