U.S. ATOMIC ENERGY COMMISSION

2/5/73

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.35

INSERVICE SURVEILLANCE OF UNGROUTED TENDONS IN PRESTRESSED CONCRETE CONTAINMENT STRUCTURES

A. INTRODUCTION

General Design Criterion 53, "Provisions for Containment Testing and Inspection" of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," 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 an acceptable basis for developing an appropriate 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 guide is applicable to "typical" prestressed concrete containments with ungrouted tendons only, for which the number of tendons does not exceed: 200 in the dome (either three families of tendons 60° apart or two families of tendons 90° apart), 200 vertical (in wall), and 500 complete hoops (in wall).

For containments that differ from the "typical" containment described above, the model program presented in this guide should serve as the basis for development of a comparable surveillance program.

Surveillance of ungrouted wire and strand tendons of all sizes (up to an ultimate strength of approximately 1300 tons) and types should be considered (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 surveillance 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 a surveillance program is necessary because generally there is no permanent instrumentation installed in the containment that could continuously monitor its structural behavior.

When developing a surveillance program, the total containment tendon population should be divided into homogeneous subgroups, i.e., tendons having approximately the same probability of corrosion and a similar function in the overall structural capabilities and properties of the structure. Thus, for each structure the surveillance program should consider separately the groups of vertical, hoop, and dome tendons.

Consideration of homogeneous tendon subgroups (i.e., vertical, hoop, and dome) establishes a sampling base for determining loss of prestress, the main characteristic checked by the surveillance program.

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 prestressing force in a tendon may be checked by a liftoff or other equivalent test. 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:

a. Stress relaxation in the wire;
b. Temperature variation of the wire;
c. Shrinkage, creep, and temperature stresses in concrete;
d. Differential thermal expansion or contraction between the concrete and the tendon; and
e. Eventual deterioration of the wires (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 surveillance procedure oriented toward verifying that these limits are not 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. The original layout of tendons should address itself specifically to this problem. Any anchor architectural treatment or environmental protection 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:

a. Defects that can be found when the tendon is in its normally stressed condition;
b. Defects that can be found only after the tendon is tensioned to a higher value than the existing prestressing force; and
c. Defects that can be found only after the tendon is detensioned.

If the limits provided in C.5. and C.6. are exceeded or if abnormal material behavior is detected pursuant to inspection in accordance with C.7., then abnormal degradation of the containment structure, a boundary designed to contain radioactive materials, is indicated. In such cases, the reporting provisions of Safety Guide 16, "Reporting of Operating Information," should apply. Included in the report should be a description of the condition of the concrete (especially at tendon anchorages), the surveillance procedure, the tolerances on cracking, and the measures to be used when tolerances are exceeded.

C. REGULATORY POSITION

1. This guide should be applied to "typical" prestressed concrete containments having a shallow-domed roof on cyclindrical walls about 150 feet in diameter, an overall height of about 200 feet, and for which the number of tendons does not exceed: 200 in the dome (either three families of tendons 60° apart or two families of tendons 90° apart), 200 vertical (in wall), and 500 complete hoops (in wall). For containments that differ from the "typical" containment described above, this guide should serve as the basis for development of a comparable surveillance program, which will be evaluated on a case-by-case basis.

2. Each containment structure should be inspected in accordance with this guide independently from containments at any other site. Where identical containment structures are located on one site, where no environmental or other differences are apparent, and where they were constructed by the same contractor in the same manner at the same time (continuous construction), then every second containment structure need only be visually inspected in accordance with C.7.

3. Containments should be designed so that the prestressing anchor hardware is accessible for periodic inspection.

4. The surveillance measures identified in C.5., C.6. and C.7. should be performed 1, 2, and 3 years after the initial containment structural integrity test and every 5 years thereafter.

5. Selected tendons should be periodically subjected to liftoff or other equivalent tests to monitor loss of prestress. These tests should include the following:

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

b. A maximum test liftoff force 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.

c. Selected numbers and types of tendons periodically tested for loss of prestress:

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

(2) Five vertical tendons, randomly but representatively distributed,

(3) Ten hoop tendons (where more than one tendon comprises the total hoop, one tendon may represent the hoop), randomly but representatively distributed.

d. A measurement of the prestress force for each tendon tested in C.5.c., with acceptable limits being defined as not less than the predicted lower bound nor greater than the predicted upper bound forces at the time of the test.

e. An allowable limit of not more than one defective tendon out of 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 C.5.d., then the surveillance 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, abnormal degradation of the containment structure is indicated, and the Commission should be notified in accordance with C.8.

6. The physical condition of the tendon material should be checked as noted below.

a. Previously stressed tendon wires or strands from one dome tendon and two wall tendons (one from a vertical tendon and one from a hoop tendon) should be removed for testing and examination over the entire length to determine if evidence of corrosion or other deleterious effects are present. At each successive inspection the samples should be selected from different tendons.

b. 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 being of a maximum length practical for testing). If frequent stress cycling is suspected, tests simulating his condition should be conducted. Similarly, where as a result of the surveillance program a potentially corrosive atmosphere is suspected, accelerated corrosion tests should be made.

c. Failure below the guaranteed ultimate strength of any one of the three tendon material sample tests should be considered an indication of abnormal degradation of the containment structure, and the Commission should be notified in accordance with C.8.

7. Tendon anchorage assembly hardware (such as bearing plates, stressing washers, shims, wedges, and buttonheads) of all tendons inspected pursuant to C.5. and C.6. should be visually inspected. For those containments for which only visual inspections need be performed, as noted in C.2., the same numbers and types of tendons as noted in C.5.c. should be visually inspected 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. If the entire containment is pressurized for leak testing purposes, the visual inspection should be scheduled, if possible, to coincide with the leak test.

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. The method used for removing grease in order to permit visual inspection 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 even under unfavorable conditions so as not to conflict with operational requirements.

8. Any significant or critical deterioration of the containment revealed by the inservice surveillance program should be reported to the Commission as an abnormal occurrence in accordance with Safety Guide 16, "Reporting of Operating Information," except that the initial report may be made within 10 days of the completion of the tests, and the detailed report may follow within 90 days of the completion of the tests.