SAFETY GUIDE 18–STRUCTURAL ACCEPTANCE TEST FOR CONCRETE PRIMARY REACTOR CONTAINMENTS

A. Introduction

General Design Criterion 1 requires that structures, systems, and components of nuclear power plants important to safety be tested to quality standards commensurate with the importance of the safety function to be performed. This guide describes an acceptable method of implementing this requirement with regard to the initial structural acceptance test for a concrete primary reactor containment to demonstrate its capability to withstand postulated pressure loads. The tests that demonstrate the leakage through the containment to be within acceptable limits are not covered by this guide.

B. Discussion

"Primary Reactor Containment" for a water-cooled nuclear power plant is the structure or vessel that encloses the components of the reactor coolant pressure boundary as defined in § 50.2(v) of 10 CFR Part 50, and serves as a leakage limiting barrier to radioactive materials released from the reactor coolant pressure boundary. The energy in the reactor coolant that might be discharged from the reactor coolant system into the primary reactor containment during a loss of coolant accident would cause a significant pressure load on the containment. An acceptance test is commonly used to confirm that the design and construction of the containment is adequate to withstand such pressure loading. The test demonstrates that the deflections of the containment's structural elements and the cracks of its surface concrete are within acceptable limits when the containment is pressurized.

During the test, the containment is pressurized in increments to allow an evaluation of its deflections as a function of internal pressure as the test proceeds. This procedure provides a means to depressurize the containment if its response deviates significantly from the expected response. The number of pressure increments is chosen to provide sufficient data points for the evaluation of the containment's response. The maximum test pressure adopted follows the practice employed for steel pressure vessels.

The radial and vertical deflections of the containment are measured at several locations around its circumference to determine the increase in tensile stresses including those due to possible initial out-of roundness of the nominally cylindrical containment. Strain and crack widths are measured and crack patterns are recorded at locations of predicted high stress to confirm the designer's stress analysis. Because the strain measurements can be correlated to deflection measurements obtained in previous tests on prototype[1] containments, strain measurements are not taken during subsequent acceptance tests of non-prototype containments.

Appropriate reports are prepared to confirm the design. These reports are used to evaluate any significant deterioration of the structure at some future date.

C. Regulatory Position

1. Concrete primary reactor containments should be subjected to an acceptance test which increases the containment's internal pressure from atmospheric pressure to at least 1.15 times the containment design pressure in four or more approximately equal pressure increments. The containment should be depressurized in the same number of increments. Measurements should be recorded at atmospheric pressure and at each pressure level of the pressurization and depressurization cycles. At each level, the pressure should be held constant for at least one hour before the deflections and strains are recorded. Crack patterns should be recorded at the maximum pressure level.
2. The radial deflections of the containment should be measured at several points along six equally spaced meridians. Vertical deflections of the containment should be measured at the apex and the springline of the dome. For cylindrical containments,

these points should be located as shown on Figure A. For cone-cylinder containments, these points should be located as shown on Figure B.

3. The radial and tangential deflections of the containment wall adjacent to the largest opening[2] should be measured at twelve points as shown on Figure C.

4. The pattern of cracks that exceed 0.01 inch in width should be mapped near the base-wall intersection, at mid-height of the wall, at the springline of the dome, and around the largest opening.[2] In prestressed containments, the crack pattern should be mapped also at the intersection between a buttress and the wall, at the intersection between the top ring girder and the wall, and on the top shelf of the ring girder. At each location, an area of at least 40 sq. ft. should be mapped.

5. In prototype containments, strain measurements in the concrete sufficient to permit a complete evaluation (i.e., triaxial strain distribution) should be determined at the following locations:
   a. in the wall at the top of the base mat on one meridian,
   b. in the wall at the largest opening, approximately 0.5t from the edge of the opening, (t being the wall thickness at the edge of the opening), and
   c. in the wall at the level of the springline of the dome on one meridian.

   These measurements should be made at three positions within the wall, i.e., near the inside face, at the mid-point, and near the outside face. The vertical and horizontal strains and the shear strains in the concrete should be measured under one prestressing anchor of a verticle tendon. This measurement should be made at a distance below the base plate of one-half the width of the base plate and at a distance normal to the wall approximately one and one-half tendon duct diameters measured from the center line of the tendon.

6. In non-prototype containments, strain measurements need not be made if strain levels have been correlated to deflection measurements during the acceptance test of a prototype containment.

7. Any reliable system of displacement meters, optical devices, strain gages, or other suitable apparatus may be used for the measurements.

8. The environmental conditions during the test should be measured in such a manner and to such an extent that will permit the evaluation of their contribution to the response of the containment. Atmospheric temperature, pressure, and humidity inside and outside of the containment should be monitored continuously during the test. In addition, the temperature inside and outside the containment should be measured at sufficiently long periods of time prior to the test to establish an average temperature of the wall for the evaluation of effects of temperature change on the deflection and strain measurements.

9. The environmental conditions under which the test may be conducted should be specified. The test should not be conducted under extreme weather conditions, such as snow, heavy rain, or strong wind.

10. If the test pressure drops for unexpected conditions to or below the next lower pressure level, the entire test sequence should be repeated. Significant deviations from the previous test should be recorded and evaluated.

11. If any significant modifications or repairs are made to the containment following the test, the test should be repeated.

12. The following information should be included in the Preliminary Safety Analysis Report:
    a. a description of the proposed acceptance test,
    b. the numerical values of the predicted response of the structure which will be measured,
    c. the tolerances to be permitted on the predicted response in the acceptance test, and
    d. The bases on which the predicted response and the tolerances were established.

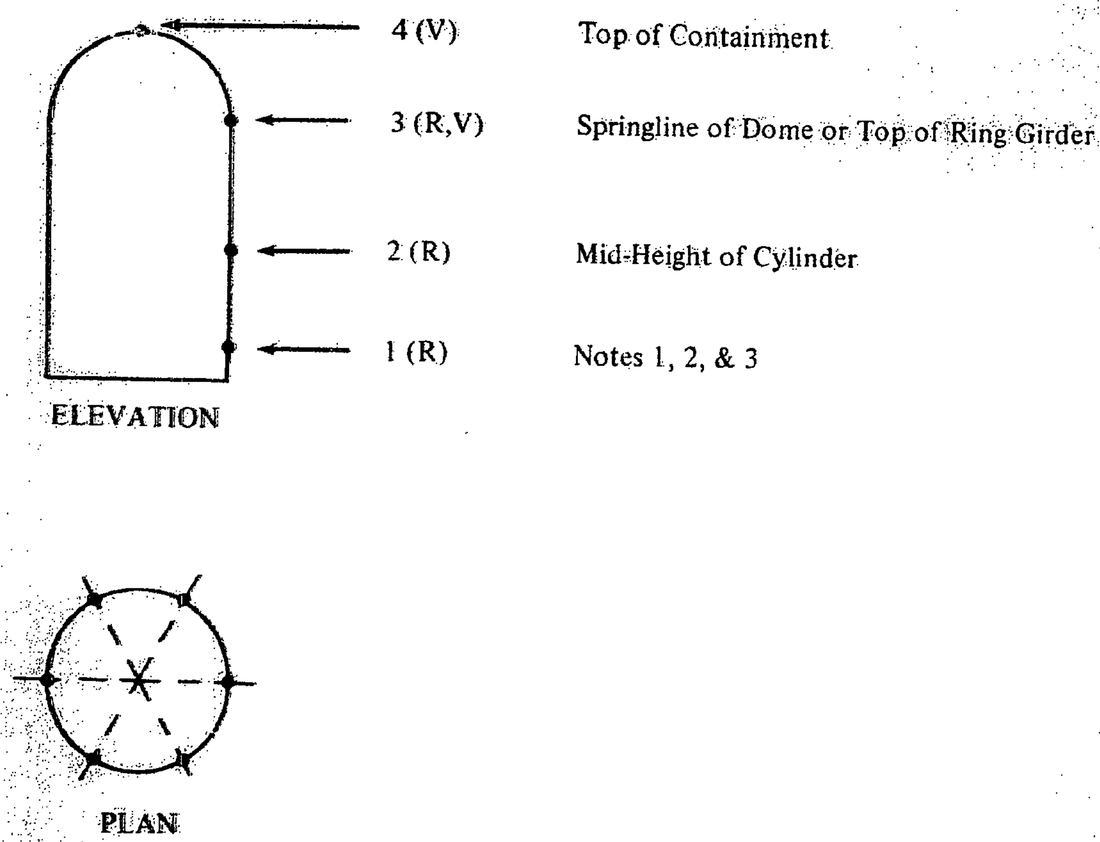
13. The following information should be included in the final test report:
    a. a description of the test procedure and the instrumentation,
    b. a comparison of the test measurements with the allowable limits (predicted response plus tolerance) for

deflections, strains, and crack width,

c. an evaluation of the estimated accuracy of the measurements,

d. an evaluation of any deviations, (i.e., test results that exceed the allowable limits), the disposition of the deviations, and the need for corrective measures, and

e. a discussion of the calculated safety margin provided by the structure as deduced from the test results.

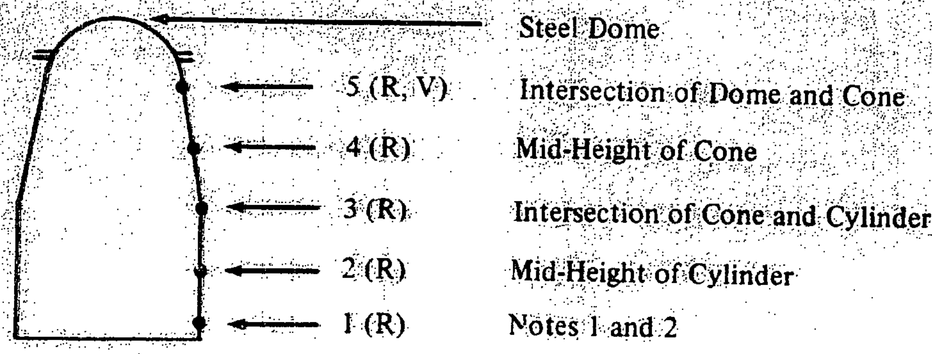


NOTES:

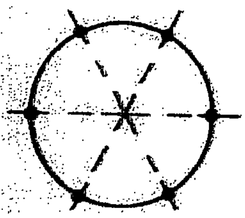
1. Radial (R) and Vertical (V) deflections should be measured at the points indicated by (R) and (V).
2. Where a rigid base/wall joint is used, Point 1 should be above the base of the wall a distance equal to three times the thickness of the wall at the location where the deflection is measured.
3. Where a non-rigid base/wall joint is used, Point 1 should be at the base of the wall.

CYLINDRICAL CONTAINMENTS

FIGURE A



ELEVATION



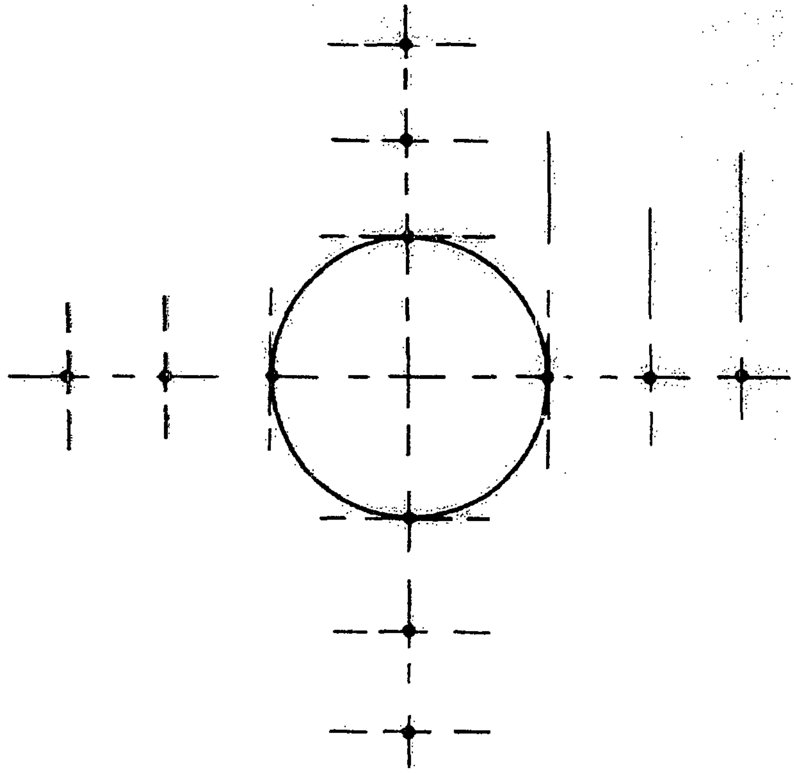
PLAN

NOTES:

1. Radial (R) and Vertical (V) deflections should be measured at the points indicated by (R) and (V).
2. Point 1 should be above the base of the wall a distance equal to three times the thickness of the wall at the location where the deflection is measured.
3. Test Points 2 and 4 may be adjusted to fall midway between floor locations.

CONE-CYLINDER CONTAINMENTS

FIGURE B



NOTES:

1. All points should be located symmetrically about the opening.
2. Radial and tangential deflections should be measured at each of the twelve points indicated.

LARGEST OPENING IN CONTAINMENT

FIGURE C

APPENDIX A

Prototype Concrete Primary Reactor Containments

The initial primary reactor containment that incorporates a new or unusual design feature is considered to be a prototype containment. Specific examples of design features that would be considered to be indicative of a prototype containment at this time are given below.

1. **Conventional Reinforced Concrete Containment**

   A concrete primary reactor containment is considered a prototype if it is the first design to incorporate any of the following features:

   a. A dome with a shape other than hemispherical,
   b. An opening larger than 0.2D,[3]
   c. Two opendings with a diameter greater than 0.15D that are separated by a distance less than 0.2D.
   d. A connection of the cylindrical wall to the bottom slab or to the dome by a sliding joint, a hinge, or a combination of hinge and sliding joint,
   e. A pattern of main reinforcing other than vertical straight bars and horizontal hoops,
   f. An intermediate interior floor connected to the wall, or
   g. Any other structural design features which may decrease the safety margins from that of a containment confirmed by an acceptance test.

2. **Prestressed Concrete Containment**

   A prestressed concrete primary reactor containment, with grouted or ungrouted tendons, is considered a prototype if it is the first design to incorporate any of the features below:

   a. A number of buttresses more or less than 6,
   b. Any buttresses in the dome,
   c. A pattern of tendons other than vertical tendons and hoop tendons in the wall, and 3 groups of tendons oriented at 120° in the dome,
   d. A prestressed dome with a shape other than ellipsoidal on top,
   e. A base other than a conventionally reinforced flat slab,
   f. A general containment shape different from a vertical cylinder,
   g. Individual tendons with ultimate strength larger than 500 tons,
   h. An opening larger than 0.2D,[3]
   i. Two openings with a diameter greater than 0.15D separated by a distance less than 0.2D,
   j. A connection of the cylindrical wall to the bottom slab or to the top dome by sliding joint, a hinge, or a combination of hinge and sliding joint,
   k. An intermediate interior floor connected to the wall, or
   l. Any other structural design features which may decrease the safety margins from that of a containment confirmed by an acceptance test.

[1] A prototype containment is one that incorporates a new or unusual design feature not yet confirmed by tests, as discussed in Appendix A.

[2] If the second largest opening is structurally loaded in a different manner from the largest opening, similar measurements and mapping should be made.

[3] D=internal diameter of the cylindrical part of the containment.

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