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Structural Integrity Test of Prestressed Concrete Containment

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ABSTRACT

Structural Integrity Test(SIT) of Prestressed Concrete Containment is performed at a pressure of at least 1.15 times the containment design pressure to demonstrate the quality of construction. At the specified pressure level, the pressure is held constant for an hour prior to measuring the deflections. Displacements, temperatures, and pressures are recorded at atmospheric pressure prior to starting pressurization and at the specified pressure stages. Concrete cracks exceeding 0.01 inch(0.25 mm) in width and 6 inch(150 mm) in length are mapped. The SIT of Ulchin Nuclear Power Plant Unit 3 Containment was conducted as non-prototype containment in May, 1997. The integrity test met the Code requirements.

1. PURPOSE

The Structural Integrity Test(SIT) is performed in accordance with ASME Boiler and Pressure Vessel Code SECTION III DIVISION 2, CC-6000 to verify the structural integrity of the containment after the containment is complete with all relevant constructions. The Local Leakage Rate Test should precede the. SIT, followed by the Integrated Leakage Rate Test.

2. ACCEPTANCE CRITERIA

Prestressed Concrete Containment shall meet following acceptance criteria for the structural integrity test.

a. Yielding of conventional reinforcement shall not develop as determined from analysis of crack width, strain, or displacement data.
b. No visible signs of permanent damage to either the concrete structure or the steel liner shall be detected.
c. Deflection recovery at maximum measured displacement within 24 hr after complete depressurization shall be 80% or more.
d. If the maximum predicted displacement is exceeded by more than 30%, displacement recovery within 24 hr shall be greater than 90%.

3. CONTAINMENT GENERAL DESCRIPTION

The containment building houses and supports the reactor and reactor coolant system. It's principal function is to control the release of radioactivity from the reactor coolant system. The containment provides biological shielding during normal operation and in the event of a Loss Of Coolant Accident(LOCA), a leaktight boundary following and accident inside the containment and a barrier against external missiles.

Ulchin Nuclear Power Plant unit 3 containment is a prestressed concrete shell structure composed of a right circular cylinder with a hemispherical dome and is founded on a flat circular foundation base slab. The entire structure is lined on the inside with steel plate that acts as a leaktight membrane.

The cylindrical portion of the containment is prestressed by a unbonded type post tensioning system consisting of horizontal and inverted "U" tendons. There are three buttresses equally spaced around containment and each tendon is anchored at buttresses 240° apart.

The dome portion is prestressed by a post-tensioning system consisting of horizontal tendons up to a 45° vertical angle and of two groups of inverted "U" tendons oriented 90° to each other. (Refer to Figure 2.)

The overall dimensions and characteristics of the Ulchin unit 3 containment are as follows :

- o Thickness of Basemat : 12'-0"
- o Diameter of Basemat : 160'-0"
- o Inside Diameter of Containment : 144'-0"
- o Inside Height of Containment : 219'-0"
- o Thickness of Containment Wall : 4'-0"
- o Design Pressure : 57.0 psig(4.01 kgf/㎠)
- o 115% Containment Pressure : 65.6 psig(4.61 kgf/㎠)
- o Design Concrete Strength : 5,500 psi(385 kgf/㎠)

4. TEST PROCEDURE

4.1 Preparation

A general inspection of the accessible interior and exterior surface of the containment structure and components should be performed to uncover any evidence of structural deterioration. Stage I concrete mapping is made at 0 pisg.(Refer to Figure 4)

4.2 Pressurization

a. Atmospheric air is used for the test medium. Maximum pressurization rate shall not exceed 5 psi/hr.
b. At every 5 psig pressure change and the test pressure, all displacement are recorded and evaluated with the predicted displacements.
c. At the following pressures, pressurization is held at least 1 hour and concrete crack mappings are made at the selected locations.
   o 10psig, 25psig, 35psig, 45psig, 57psig, 65.6psig
d. While containment pressure is held at 10 psig, designated personnel enters inside the containment for walkdown and inspections.

7. TEST RESULT

UCN unit 3 SIT was conducted from May 13, 1997 to May 22, 1997(including ILRT). For pressurization, 6 temporary air compressors were used and average pressurization rate was 3 psi/hr. The summarized test results are as follows.(Refer to Table 1)

a. The overall structure exhibited elastic behavior as predicted.

b. No visual signs of permanent damage to either the concrete structure or the steel liner were detected.

c. Maximum crack increase at the test pressure was 0.007 inch in comparison with the allowable crack width 0.046 inch.(Area 7)

d. Some displacements exceeded maximum predicted displacements by more than 30%, but displacement recovery rates within 24 hr were greater than 90%. (Equipment Hatch Area)

e. Major reasons of differences between predicted displacements and actual displacements in some areas are assumed the difficulties of structural analysis in varied section areas which have large penetrations and corresponding reinforcements.

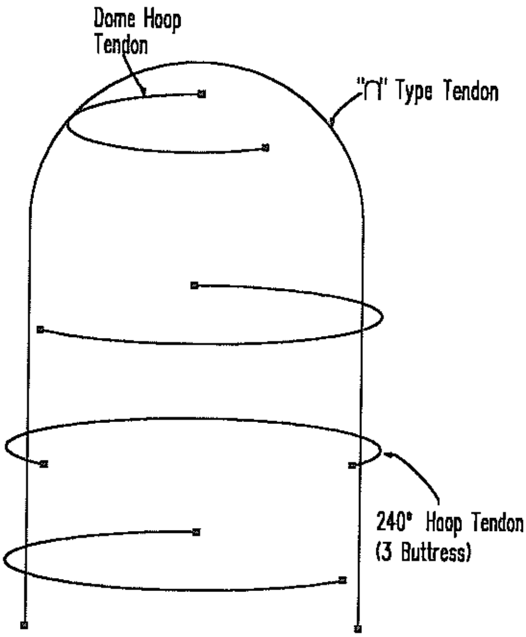


Figure 2. Post Tensioning System

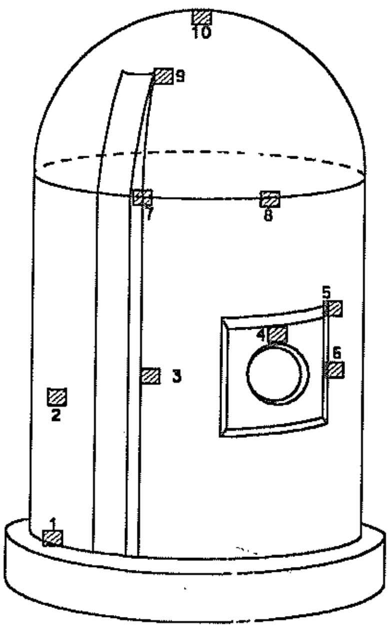


Figure 3. Crack Mapping Area

Table 1. Displacement Results

1. Radial Displacement(Average of same elevation displacements)

No	Level	Displacement at 66.01psig	Predicted Displacement	Rate(%)	Displacement at 0 psig	Recovery Rate	Remarks
1	El 106'	0.208	0.180	115.56	0.016	92.30	
2	El 128'	0.225	0.240	93.75	0.017	92.44	
3	El 150'	0.224	0.230	97.39	0.014	93.75	

2. Diametrical Displacement(Average of same elevation displacements)

No	Level	Displacement at 66.01psig	Predicted Displacement	Rate(%)	Displacement at 0 psig	Recovery Rate	Remarks
1	El 177'	0.314	0.460	68.26	0.039	87.58	
2	El 203'	0.366	0.460	79.57	0.049	86.61	
3	El 216'	0.343	0.430	79.77	0.037	89.21	

3. Vertical Displacement
 - Dome

No	Transducer	Displacement at 66.01psig	Predicted Displacement	Rate(%)	Displacement at 0 psig	Recovery Rate	Remarks
1	V1	0.132	0.350	37.71	0.000	100.00	
2	V2	0.347	0.350	99.14	0.049	85.88	
3	V3	0.322	0.340	94.71	0.004	98.76	
4	V4	0.340	0.340	100.00	0.017	95.00	
5	V5	0.322	0.320	100.63	0.015	95.34	
6	V6	0.300	0.320	93.75	0.016	94.67	Avr. 94.94

 - Shell

No	Transducer	Displacement at 66.01psig	Predicted Displacement	Rate(%)	Displacement at 0 psig	Recovery Rate	Remarks
1	V7+V11	0.202	0.170	118.82	0.040	80.20	
2	V8+V12	0.233	0.170	137.06	0.014	93.99	
3	V9	0.092	0.170	54.11	0.000	100.00	
4	V10	0.117	0.170	68.82	0.000	100.00	Avr. 93.55

4. Equipment Hatch Displacement
 - Horizontal(El 152'-10")

No	Transducer	Displacement at 66.01psig	Predicted Displacement	Rate(%)	Displacement at 0 psig	Recovery Rate	Remarks
1	E1	-	0.305	-	-	-	Fallen
2	E2	0.150	0.190	78.95	0.013	91.33	
3	E3	0.091	0.132	68.94	0.013	85.71	
4	E4	0.117	0.139	84.17	0.008	93.16	
5	E5	0.250	0.193	129.53	0.000	100.00	
6	E6	0.284	0.307	92.51	0.024	91.55	Avr. 92.35

 - Vertical(azimuth 287°)

No	Transducer	Displacement at 66.01psig	Predicted Displacement	Rate(%)	Displacement at 0 psig	Recovery Rate	Remarks
1	E7	0.058	0.013	446.15	0.000	100.00	
2	E8	0.061	0.017	358.82	0.003	95.08	
3	E9	0.079	0.022	359.09	0.004	94.93	
4	E10	0.025	0.033	75.76	0.008	68.00	
5	E11	-	0.048	-	-	-	Fallen
6	E12	0.126	0.120	105.00	0.005	96.03	Avr. 90.80

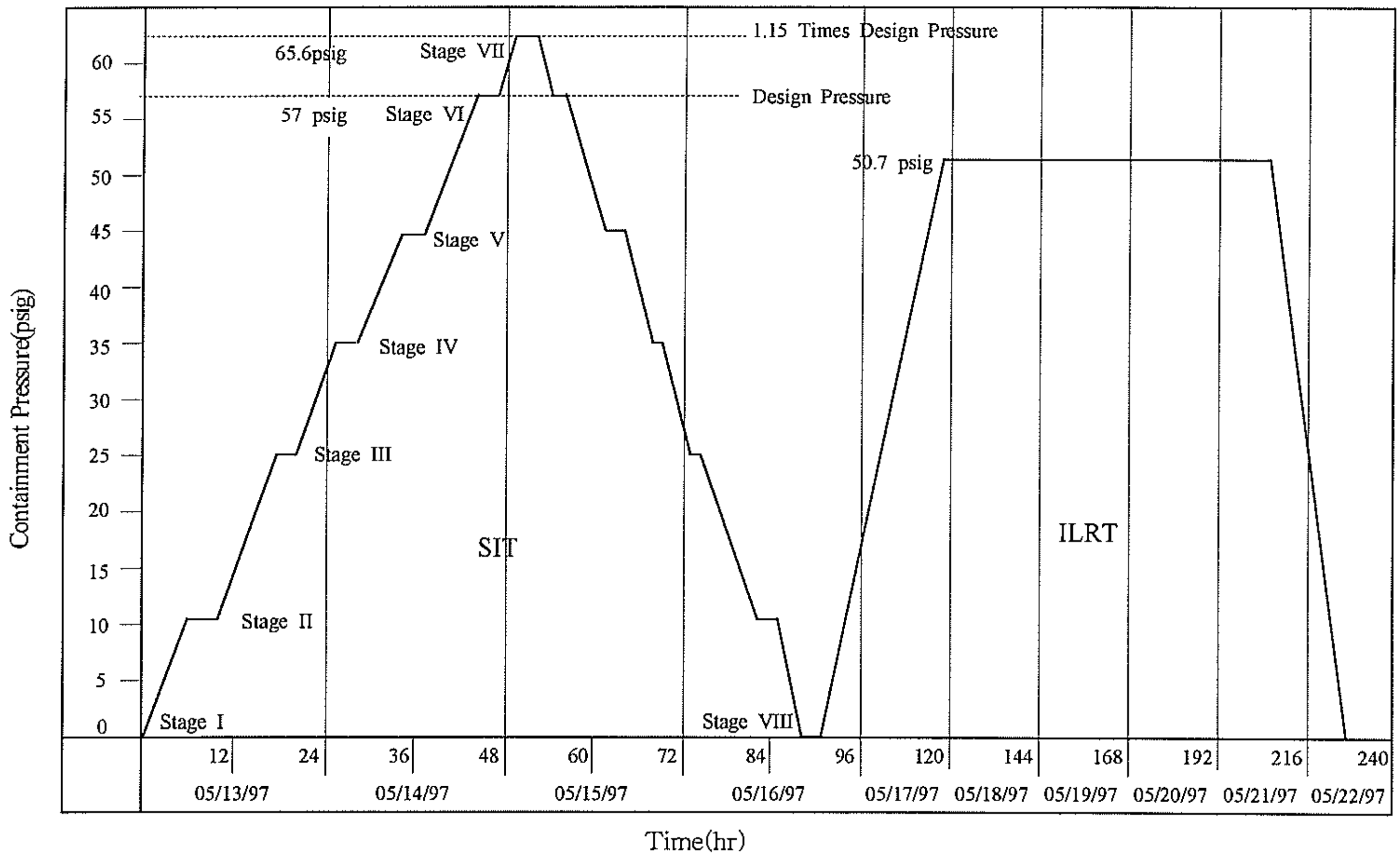
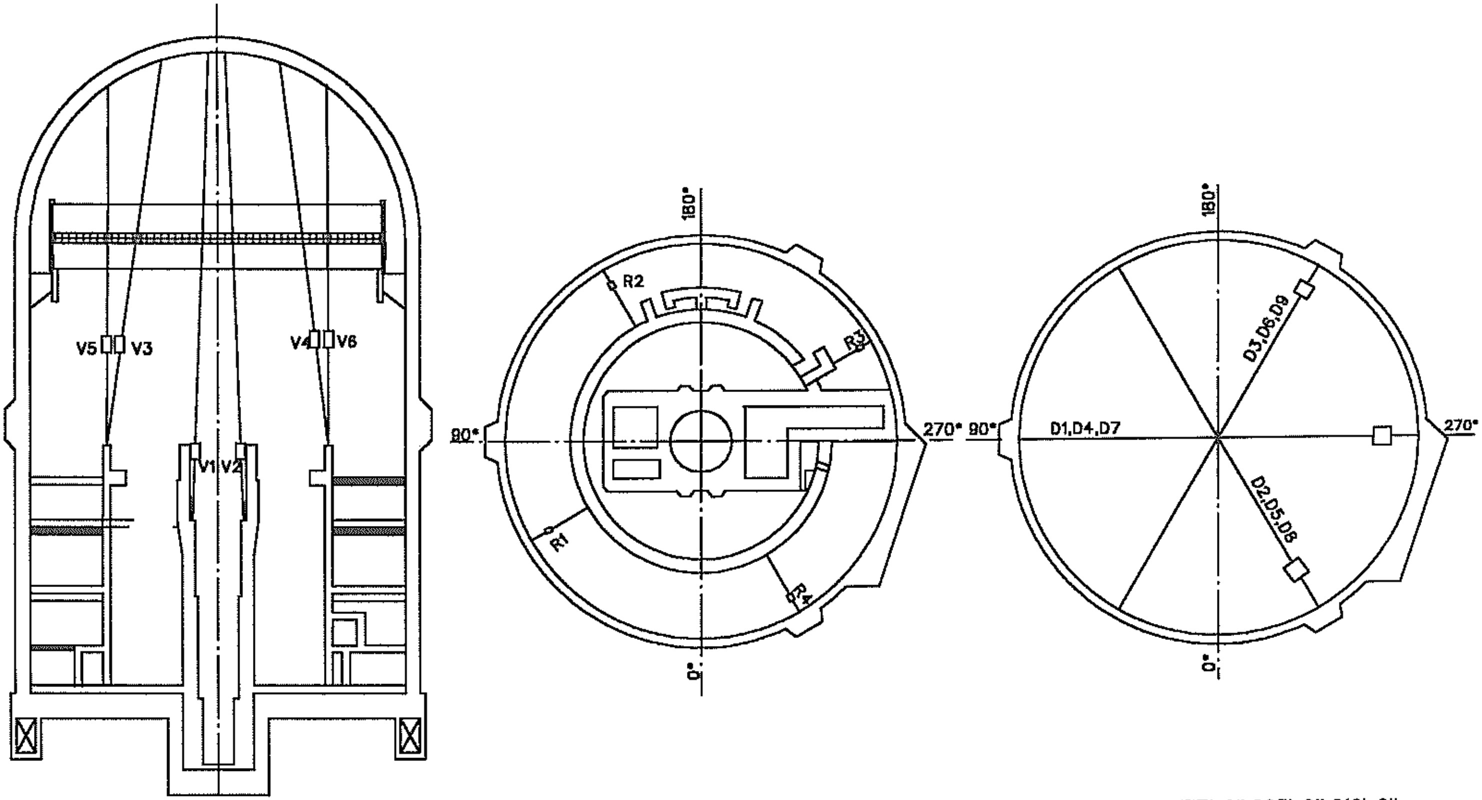


Figure. 4 Structural Integrity Test Schedule



VERTICAL DISPLACEMENT TRANSDUCERS

PLAN @ EL. 106'-0"

RADIAL DISPLACEMENT TRANSDUCERS

PLAN @ EL. 177'-0",203'-0",216'-0"

DIAMETRICAL DISPLACEMENT TRANSDUCERS

Figure 5. DISPLACEMENT TRANSDUCER LOCATION

4.3 Depressurization

a. Maximum depressurization rate shall not exceed 5 psi/hr.

b. At every 5 psig pressure changes, all displacement are measured and recorded.

c. When the containment pressure decreases to 0 psig, the recovery rates are calculated. Final concrete crack mapping and general inspections are performed inside and outside the containment structure and components.

5. INSTRUMENTATION

Pressures, displacements and temperatures shall be measured and recorded to calculate deflections of the containment.

5.1 Pressure

Two Digital pressure gauges are installed to measure the pressure of inside and outside the containment. The Gauges have to be calibrated prior to and after the test.

5.2 Displacement

Displacement measuring transducers are installed directly on the containment liner plate and concrete structure. Displacements are measured by taut wires stretched across the containment. 47 locations are selected to measure displacements of containment.

- o Radial displacement : 12, Diametrical displacement : 9
- o Vertical displacement : 12, Equipment Hatch displacement : 14

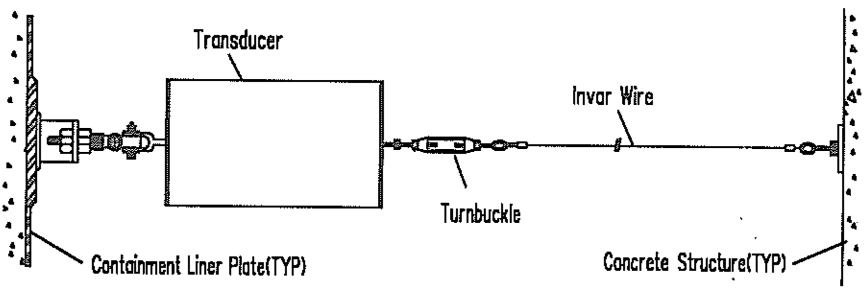


Figure 1. Transducer Installation Arrangement

5.3 Data Acquisition System

The system consists of scanning, measuring and recording equipments capable of processing inputs from taut wire displacement transducers and digital pressure gauges, and recording data.

6. CRACK MAPPING

Cracks exceeding 0.01 inch(0.25 mm) in width and 6 inch(150 mm) in length are measured and the maximum crack width increase is 0.046 inch. For the locations of the required crack mapping areas, refer to Figure 3.

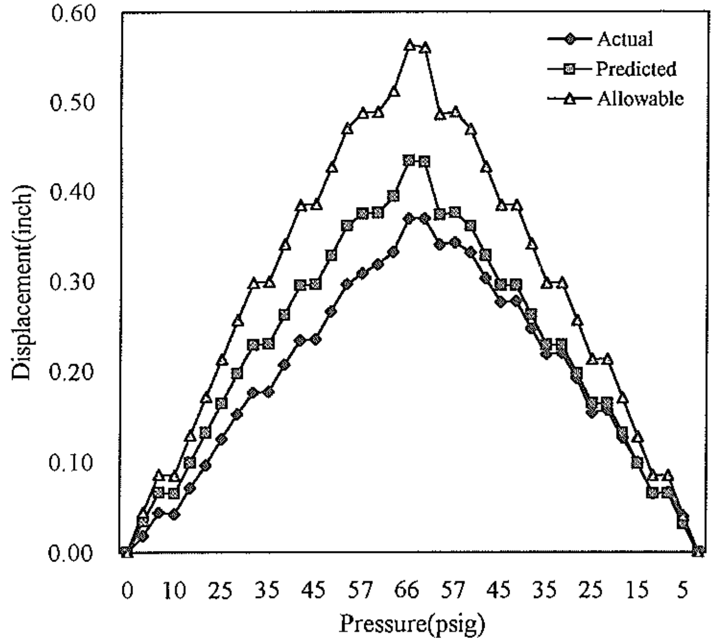


Figure 6. Displacements Comparison (for example)

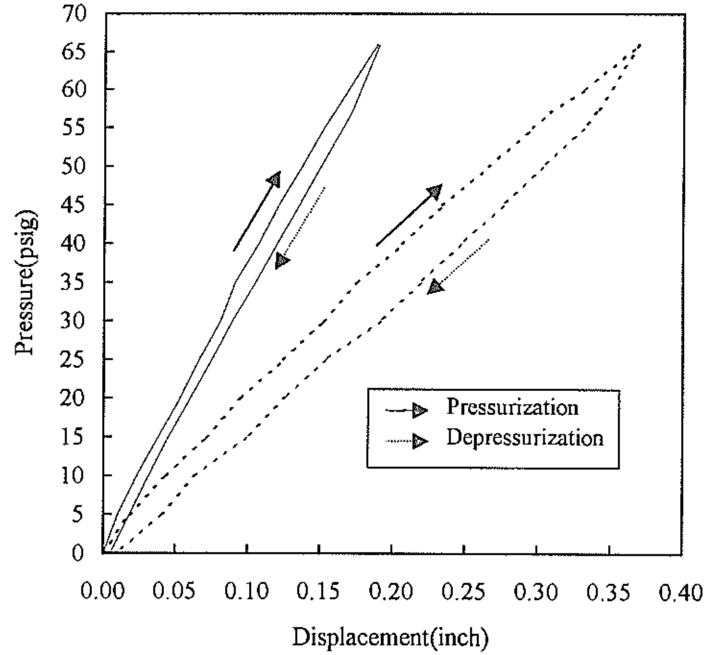


Figure 7. Typical Diagram of Displacement