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GENERAL ELECTRIC

NUCLEAR SERVICES PRODUCTS DEPARTMENT (NSPD)

CLINTON PLANT UNIQUE ENCROACHMENTS FINAL TEST REPORT

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ABSTRACT

A series of 1/10 scale air blowdown tests was performed to determine the effect of the Clinton TIP platform, sump room and personnel hatch encroachments on pool response during a pool swell transient. Froude scaling (balance of gravity and inertia forces) was used in this simulation. The test series was conducted in the Pressure Suppression Test Facility (PSTF) drywell in order to obtain the 1.47 psia initial system pressure required by Froude scaling. Instrumentation consisted of drywell pressure measurements and high speed movies of the pool response.

This series of tests demonstrated that the pool response in the vicinity of the encroachment during the pool swell portion of a Design Basis Accident (DBA) in the Clinton plant is bounded by the clean pool response.

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1.0 INTRODUCTION/TEST OBJECTIVES

The Clinton plant unique encroachments pool swell tests, authorized by the Illinois Power Company (IPC), were conducted to determine the effect of the Clinton TIP platform sump room and personnel hatch encroachments on the pool swell transient. Specifically, the test were run to determine if the existing design load definition for pool swell in the clean pool bounds the expected pool swell loads in the vicinity of the encroachment during a design basis accident (DBA).

2.0 SUMMARY OF TEST RESULTS

The following is a summary of important results obtained during the test.

1) Pool peak surface velocities in the vicinity of all encroachments were less than the peak velocities in the clean pool.

2) Breakthrough in the encroached pool for all encroachments occur at a lower elevation than the design breakthrough elevation (18 feet) with all encroachments.

3) For all tests, the horizontal water ligament present in the Generic series A tests at the HCU floor elevation was not seen.

4) The pool response for tests run with the TIP platform/sump room encroachment were typically like the previous Generic Series B tests (Reference 1).

5) For all tests run with the personnel hatch encroachment - the surface of the water layer rising next to the containment wall was jagged and froth like at the elevation of the HCU floor.

3.0 TEST DESCRIPTION

3.1 TEST FACILITY

3.1.1 Test Tank and Drywell/Vent System

The tests described in this report were performed at the GE San Jose, California site in the drywell of the Pressure Suppression Test Facility (PSTF). The test tank which was mounted inside the PSTF drywell is a 1/10 linear Froude scale simulation of a 48 degree sector of a typical Mark III containment system as shown in Figures 3.1.a and 3.1.b. The test facility was designed in conformance with the Moody approach for the application of Froude scaling as described in Reference 2.

The test tank includes a drywell with a free volume of 44.8 ft^3 discharging into a weir annulus having 1/100 scale flow area per vent station and 2.6 in. width. The vent system and suppression pool represent a rectangular simulation of a 48 degree sector of the weir annulus and suppression pool including six vent cells with three horizontal vents in each cell. The horizontal vents are 1/10 scale in length (6 in.) and diameter (2.75 in.). All vents are parallel with 1/10 linear scale vent to vent spacing both vertically (5.4 in.) and horizontally (8.5 in.) within the suppression pool. The eighteen vents discharge into a 1/10 linear scale pool of depth 22.2 in., width 22.7 in., and length 51 in. The wetwell airspace volume is larger than its scaled value, which precludes pressurization of this compartment. This scaling compromise did not affect test results since negligible pressurization of the wetwell airspace volume would be expected to occur during the event modeled.

In order to scale the enthalpy flux into the bubble correctly, flow resistance was added in the vent system. This was performed by covering the weir annulus with a plate with 57 uniformly distributed 0.5 in. diameter holes which corresponds to an open flow fraction of 8.4%.

This test facility also included a blowdown line to admit air at atmospheric pressure into the drywell to drive the transient. A 2.25 inch orifice assembly was placed in the blowdown line to correctly scale the Clinton FSAR drywell pressurization rate. The valve in the blowdown line was controlled by a solenoid valve connected to a General Radio decade box (model No. 14324). The decade box was used to match the scaled Clinton FSAR drywell pressure. Other external piping connections were used for filling, draining and addition of water.

3.1.2 Plant Unique Encroachments

Two encroachment configurations were analysed in the Clinton plant unique tests. Table 3.1 gives a test matrix with the test numbers and associated encroachment configuration. The Clinton Nuclear Plant encroachments that were modeled are the TIP platform, sump room and personnel hatch. The TIP platform and sump room were considered to be a single encroachment for this test series.

3.1.2.1 Encroachment I - TIP Platform/Sump Room

The TIP platform and sump room are located on the drywell wall approximately 6.6 feet above the top vent centerline. The TIP platform extends 42.3% across the suppression pool, while the sump room only extends across 37.8%. The encroachment spans a 54° sector and is 6.5 feet in height.

The modeled encroachment had a radial extent of 42.3% (9.6 inches) for the TIP platform and 37.8% (8.6 inches) for the sump room. The length of the encroachment covered 4.43 cells and was 37.65 inches long. The height of the modeled TIP platform/sump room was 7.8 inches. The encroachment was attached to the simulated drywell wall in the corner of the suppression pool as shown in Figure 3.1.a.

3.1.2.2 Encroachment II - Personnel Hatch

The personnel hatch, which is geometrically similar to the equipment hatch is located on the drywell wall approximately 6.6 feet above the top vent centerline. The personnel hatch extends 24.4% across the suppression pool, but a 3 foot shelf is attached along the top edge of the personnel hatch making a total extent of 37.8%. The encroachment spans a 76° sector and is 6.5 feet in height. In addition, a 4.5 foot wide shield block spanning a 38° sector is attached to the top of the personnel hatch. This shield block is 18 feet high and attached to the drywell wall.

The modeled encroachment had a total radial extent (including shelf) of 37.8%, or 8.6 inches. The length of the encroachment covered 3 cells and was 25.5 inches long. Similarly, the length of the shield block covered 1 1/2 cells and was 12.75 inches long. The height of the modeled personnel hatch was 7.8 inches and the shield block was 21.6 inches high. The encroachment and shield block were attached to the simulated drywell wall in the corner of the suppression pool as shown in Figure 3.1.b.

3.2 TEST INSTRUMENTATION

3.2.1 Pressure Measurements

An absolute pressure gage was used to monitor the pressure in the drywell airspace in order to establish initial conditions. A Wallace and Tiernan (model GIA-1A-0015) 8.5 inch dial pressure gage with a 0 to 15.5 psia range in two revolutions was used for this purpose.

The drywell transient pressure response during the test was measured with a Validyne, variable reluctance, cavity type pressure transducer with a 0-20 psia range and a rated accuracy of ±1% full scale (model DP-15). The response was recorded by a Tektronix main frame storage oscilloscope (model 564).

3.2.2 High Speed Filming

High speed movies (at approximately 500 frames per second) were taken of each test run showing both a front view and side view of the pool swell transient. The camera was located outside the PSTF drywell and directed toward the front of the test tank. The distance from the camera to the drywell wall was approximately 9 feet. The camera was focused approximately 18 inches from the encroached side wall and six inches below the top of the tank as shown in Figures 3.1.a and 3.1.b. Lighting was obtained with a series of lamps located above the pool, under the pool and behind the clean side wall. The signal transmitted to open the blowdown valve was recorded as a red timing mark on the side of the film. Red timing marks were also made on the opposite side of the film every .01 seconds through the duration of the test.

To obtain a side view of the pool response a mirror was installed at an angle of 45° adjacent to the encroached side of the test tank. Grid lines were placed at 6 inch intervals on the front and side walls to aid in the reduction of the high speed movie data.

A bluing agent was added to the water to increase contrast between the liquid and bubble regions during the transient.

3.3 TEST OPERATION

Prior to running a test, the test facility, test instrumentation and test conditions were checked. The absolute pressure in the drywell was measured with an absolute pressure gage. This reading was used to insure that initial pressures were consistent with the targeted Clinton drywell pressure.

The initial drywell pressure and water level were then recorded by hand, lighting and instrumentation were turned on, filming was initiated (3 seconds before blowdown), and finally the valve in the blowdown line was opened and closed.

Following the test, a photograph was taken of the drywell pressure time history recorded on the storage oscillscope.

4.0 DATA ACQUISITION AND REDUCTION

Extensive data reduction was performed using the high speed movies. For each test run, the front and side views of the pool were used to manually develop surface elevation time histories. A third order polynominal curve fit of elevation versus time was utilized to generate a continuous elevation time history. The best estimate of velocity versus elevation was obtained by analytically differentiating the continuous elevation versus time histories.

The drywell pressure time history for each test was obtained from a photograph of the drywell pressure history recorded on the storage oscilloscope.

5.0 TEST RESULTS

5.1 INITIAL AND DRIVING CONDITIONS

Tests run with the two different encroachment configurations were executed with the same nominal initial conditions and with the scaled Clinton FSAR drywell pressurization rate calculated for a hypothetical Design Basis Accident (DBA).

The initial conditions for the tests are specified in Table 5.1. Figures 5.1.a and 5.1.b show the resultant drywell pressure response for the two sets of tests along with the target pressure time history.

5.2 BLOWDOWN DESCRIPTION

The transient is initiated by actuating a quick opening valve in the blowdown line to the drywell tank, admitting air at atmospheric pressure, and pressurizing the drywell. The correctly scaled drywell pressurization rate was obtained with the use of an orifice in the blowdown line. The drywell pressurizes until the pressure is high enough to drive the water initially in the weir annulus through the vents and into the suppression pool. As the water level in the weir drops to the top vent, the air is expelled through the vents and into the suppression pool where it forms a bubble. The bubble grows vertically and radially. This causes the pool level to rise until the bubble breaks through the surface.

5.3 POOL RESPONSE

5.3.1 Encroached Pool Response (Encroachment I)

The encroached pool response was examined with the side view film data. The test nominal conditions were examined by visual inspection and by comparing plots of pool surface velocity versus elevation.

The encroached pool response for the tests were in general repeatable. The slug initially lifted by the growing bubble thinned and dissipated through runoff to the containment wall.

Figure 5.2 shows profiles of the pool surface response in the encroached region for a typical test. The pool surface at the initial time (t=0) corresponds to vent clearing which occurs approximately 0.4 seconds after the blowdown is initiated. Initially, a spherical bubble is formed which grows vertically and radially until the bubble reaches the outer bottom edge of the encroachment. The bubble then grows vertically along the edge of the encroachment, initially lifting a slug of water 2"-4" thick. The curvature in the pool induced by the growing bubble causes water run off from the top of the bubble. As a result, the slug of water thins and eventually disappears approximately 1.8 feet above the initial pool height. During the bubble growth process, the bubble pushes the displaced water against the model containment wall. This results in a vertical layer of water on the containment wall which thins as the bubble grows. The top surface of this vertical ligament when it reaches the top of the test tank is highly curved. This is shown in Figure 5-3 which shows the surface and bubble profile in the encroached region at breakthrough and at the time the surface reaches the top of the test tank.

The pool surface response was also reduced via plots of pool surface velocity versus elevation. The pool surface velocity determined from the peak elevation is shown in Figure 5.4 and the pool surface velocity near the containment wall is shown in Figure 5.5.

The breakthrough elevation in the encroached pool occurs when the bubble grows vertically above the elevation of the top of the encroachment allowing venting of the bubble into the wetwell airspace.

The peak surface elevation at the time of breakthrough is 1.2 feet (12 feet full scale).

5.3.2 Encroached Pool Response (Encroachment II)

The side view of the film data was again used to examine the encroached pool response. The transient response for the tests was repeatable. The solid ligament initially carried by the growing bubble develops a high degree of surface curvature and disappears before reaching the elevation of the Clinton HCU floor for the tests with the Encroachment II configuration. The high degree of pool surface curvature seen early in the encroached pool swell transient together with the horizontal velocity imparted to the water by the shelf enhanced movement of the water to the containment wall.

Figure 5.6 shows the pool surface response for a typical test.

A vertical layer of water pushed against the containment wall by the bubble growth was seen in the film data (see Figure 5.7). The upper surface of this vertical layer was constantly changing due to the radial movement of water as discussed above. This produced a highly curved surface immediately adjacent to the containment wall near the top of the test tank. The radial movement of water to the containment wall also produced an increase in the pool surface velocity at the wall and a decrease in the velocity at the pool surface peak. Encroached pool surface velocities at the peak of the pool surface are shown in Figure 5.8 with velocities near the containment wall shown in Figure 5.9.

As with the Encroachment I configuration, breakthrough in the encroached pool occurs when the bubble grows vertically above the elevation of the top of the encroachment allowing venting of the bubble into the wetwell airspace. The peak surface elevation at the time of breakthrough is 1.3 feet.

Two tests of Encroachment II were run with the camera and lighting configuration focused on the pool response in the vicinity of the encroachment ledge. These tests were used to determine the velocity of the water surface approaching the ledge and the time required to engulf the entire ledge. The observed velocity of the surface impacting the ledge was 11 feet/sec. The impact duration ranged from 6 to 8 milliseconds. Figure 5.10 shows the pool surface profile prior to impact on the ledge and immediately after the pool surface traverses the elevation of the ledge.

5.3.3 Clean Pool Response

The clean pool response was quantified by the peak pool surface velocity. Figure 5.11 shows the peak pool velocities measured for tests run with Encroachment I. Figure 5.12 gives the clean pool peak surface velocity for the Encroachment II tests. The peak surface velocities measured for the Encroachment I tests were low relative to velocities measured in the Encroachment II and in the generic tests (Reference 1). This was attributed to the early lateral breakthrough circumferentially over the encroachment. This allowed early venting of the bubble in the clean pool to the wetwell airspace.

6.0 DISCUSSION OF RESULTS AND APPLICATION TO CLINTON

Examination of the Clinton film test data showed that the relatively thick, flat solid ligament of water above the bubble which was observed at the steam tunnel elevation during the Generic A Series Test (Reference 1) is not present. In general the pool surface approaching the Clinton HCU floor in the encroached pool region is highly curved and appears froth-like (see Figures 6.1 and 6.2).

Additional review of the test data and governing processes show that the encroached pool response is bounded by the response of the clean pool. The pool surface velocity in the vicinity of the encroachment is less than the velocity in the clean portion of the pool. Figure 6.3 gives a comparison of the peak surface velocities in the encroached and unencroached region of the pool during tests run with Encroachment I. These velocities were measured at the crown of the pool surface above the rising bubble. Figure 6.4 gives the same comparisons for the Encroachment II tests. Lower encroached pool surface velocities relative to the clean pool velocities were expected since pool swell is an inertia controlled process and the encroachment effectively lengthens the water slug which the bubble must lift. That is, instead of penetrating the 7.5 foot initial submergence, the bubble must now travel the radial length of the encroachment and then upwards to the pool surface. Newton's law shows that if the driving force doesn't change, yet the mass which is accelerated increases, the resulting acceleration, and hence velocity, must decrease. Therefore, an encroachment will decrease the local pool swell velocity.

The Clinton tests also showed that bubble breakthrough in the encroached region always occurred at or below a full scale height of 13 feet, which is below the design breakthrough elevation (18 feet above the initial pool surface in the actual plant).

Based on the test data, it is seen that the encroached peak pool surface velocities are always less than or equal to the clean peak pool surface velocities and the observed breakthrough elevations are below the design breakthrough elevation. Additionally, at the HCU floor elevation the encroached pool surface above the bubble is typically froth like and the water layer next to the containment wall highly curved.

Therefore, loads on structures at or near the HCU floor elevation in the encroached pool region will be bounded by the current design load for pool swell.

7.0 REFERENCES

1) E.J. McNamara et.al, "Mark III Encroachments Summary Report", November 1984, MDE 108-1184.

2) Moody, F.J., "Scale Modeling - Thermal Hydraulic Phenomena in Nuclear Containment", NUREG/CR-0014, Vol. 1, October 1980.

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TABLE 3.1

CLINTON PLANT UNIQUE ENCROACHMENTS TEST MATRIX

Test	Encroachment Configuration
F1	I
F2	I
F3	I
F1R*	I
F2R*	I
F3R*	I
R05**	I
F4	II
F5	II
F6	II
R06***	II
R07***	II

* F1R, F2R and F3R were run to improve on the quality of the film data seen in tests F1, F2 and F3.

** Test R05 was run using the same camera angle and mirror positioning used in the generic tests (Ref. 1) to facilitate comparisons with the Series B generic tests.

*** Tests R06 and R07 were run with a lighting and camera configuration which focused on the pool swell transient in the vicinity of the Encroachment II ledge.

TABLE 5.1

COMMON INITIAL CONDITIONS

	Range
Pool Temperature	50° - 62°F
Wetwell Airspace Temperature	54° - 66°F
Pool Height	22.2 inches
Wetwell Airspace Pressure	1.47 psia

Figure 3.1a. Test Tank and Simulated Clinton TIP Platform and Sump (Encroachment I)

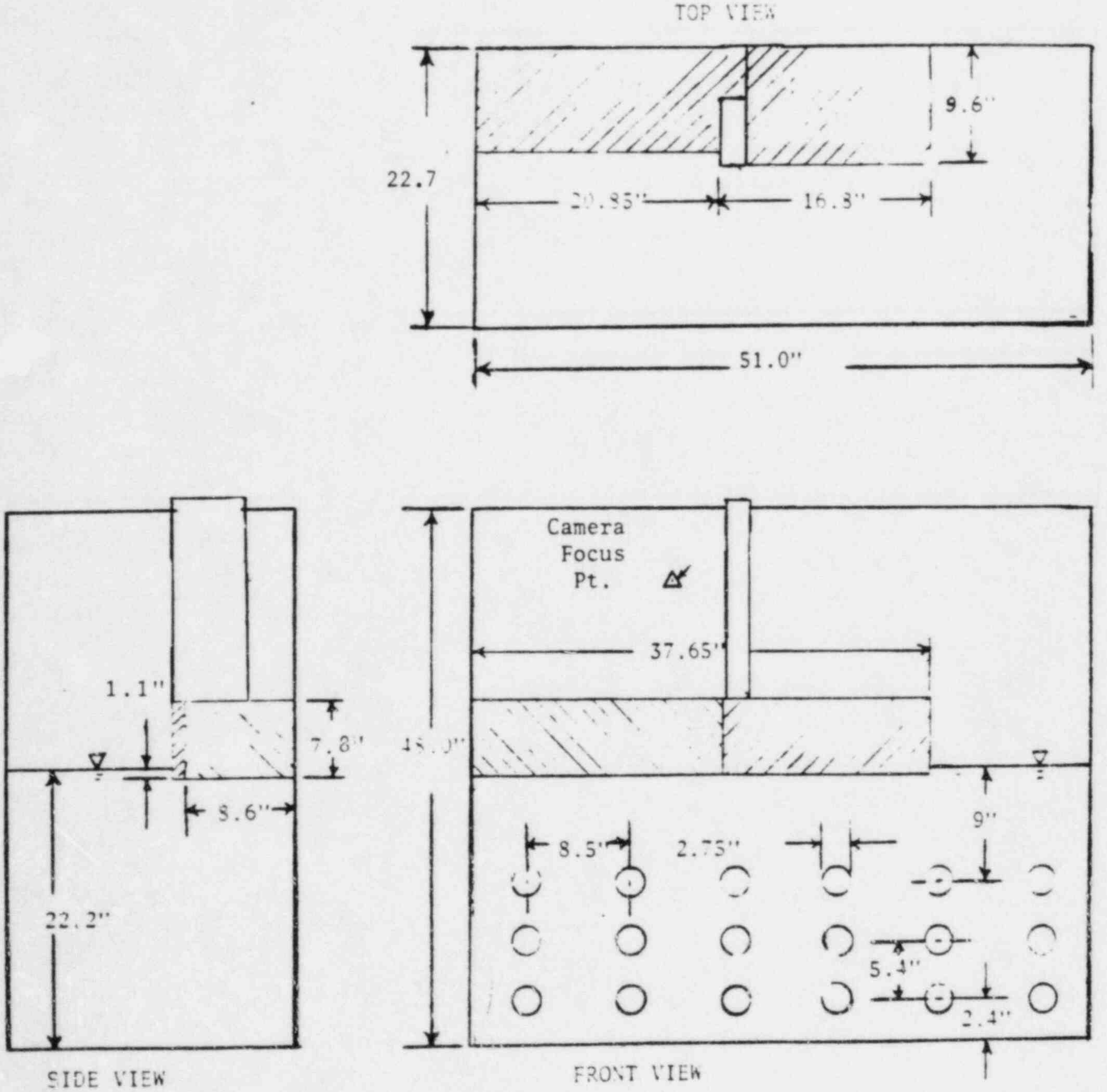

Figure 3.1b. Test Tank and Simulated Clinton Personnel Hatch (Encroachment II)