MDE-19-0185
DRF-T23-598

# GENERAL ELECTRIC

## NUCLEAR SERVICES PRODUCTS DEPARTMENT (NSPD)

## GRAND GULF PLANT UNIQUE ENCROACHMENTS FINAL TEST REPORT


Prepared by: S. Mintz
S. Mintz
Containment Loads Engineering

Prepared by: S. Mintz for MN King
M.N. King
Containment Loads Engineering

Reviewed by: J.E. Torbeck
J.E. Torbeck, Tech. Leader
Containment Loads Engineering

Approved by: A.E. Rogers
A.E. Rogers, Manager
Application Engineering Services





GENERAL ELECTRIC

NUCLEAR ENERGY BUSINESS OPERATIONS
GENERAL ELECTRIC COMPANY • 175 CURTNER AVENUE • SAN JOSE, CALIFORNIA 95125

ABSTRACT

A series of 1/10 scale air blowdown tests was performed to determine the effect of the Grand Gulf encroachment 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 as 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 Grand Gulf plant is bounded by the clean pool response up to the design breakthrough elevation of 18 feet.

Based on film data from the Grand Gulf tests, solid water impact loads may occur above the current 18 foot design elevation, in the region affected by the encroachment.

TABLE OF CONTENTS

## 1.0 INTRODUCTION/TEST OBJECTIVES

The Grand Gulf plant unique encroachment pool swell tests, authorized by the Mississippi Power and Light Co., were conducted to determine the effect of the Grand Gulf encroachment on the pool swell transient. Specifically, the tests were run to determine if solid water impact occurs following a design basis accident (DBA) above the current design elevation of 18 feet in the vicinity of the encroachment.

## 2.0 SUMMARY OF TEST RESULTS

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

1) Peak pool surface velocities in the vicinity of the encroachment are less than the velocities in the clean pool.

2) Breakthrough in the encroached pool occurs at 12.5 feet above the initial pool surface which is a lower elevation than the design breakthrough elevation (18 feet).

3) Test film data of the encroached pool shows a solid ligament of water similar to the ligament in the Generic A Series tests (Reference 1) at the elevation of the Grand Gulf HCU floor. The ligament in the Grand Gulf test was characterized by more curvature radially and circumferentially and a smaller radial extent than seen in the Generic A Series Tests (Ref. 1). Due to this ligament, water impact may occur above the design elevation of 18 feet.

# 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 Figure 3.1.

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 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 d[illegible] 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 to drive the transient. A 2.29 inch orifice assembly was placed in the blowdown line to correctly scale the Grand Gulf 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 Grand Gulf drywell pressure ramp. Other external piping connections were used for filling, draining and addition of water.

### 3.1.2 Plant Unique Encroachment

The Grand Gulf Plant encroachment modeled is the TIP platform. The TIP platform is located in the Grand Gulf Plant on the drywell wall approximately 6.5 feet above the top vent centerline. The TIP platform extends 52% across the suppression pool at its centerline (10.7 ft radially) and is attached to the drywell along a 30.7° sector (22.2 feet circumferentially). Since the encroachment does not follow the curvature of the suppression pool, the TIP platform is modeled by conserving the total encroached area of the pool.

For the test configuration an effective radial extent was obtained by drawing a radial vector from the reactor center through the midpoint of the TIP platform centerline and an outer edge (see Fig. 3.2). The effective encroached radial extent of 11.0 ft (or 53.6% of the pool width) was measured along this vector. This corresponds to 12.12 inches in the test.

The effective circumferential length of the TIP platform used for the test was obtained by conserving the encroachment area. The number of encroached cells was calculated by dividing the circumferential length of the encroachment by the vent to vent spacing at the radial midpoint of the encroachment. The number of encroached cells was then used to determine the test encroachment circumferential length by multiplying the number of encroached cells times the cell spacing in the test facicity.

The effective circumferential length of the encroachment covered 1.70 cells or 14.5 inches. The bottom of the encroachment was submerged by 1.2 inches. The height of the encroachment was 12 inches.

## 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-005) 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. Encroached side and front views were obtained. The camera was focused approximately 18 inches from the encroached side wall and six inches below the top of the tank as shown in Figure 3.1. 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. Timing marks every .01 seconds were also specified as red marks on the opposite side of the film.

To obtain a side view of the pool response a mirror was installed at an angle of 45° adjacent to the encroached side of 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. This agent did not influence test results.

### 3.3 TEST OPERATION

Prior to running a test, the test facility, test instrumentation and test condition were checked to ensure proper test operating conditions. 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 Grand Gulf drywell pressure. A series of test operations was then followed to conduct the test. During these operations, the initial drywell pressure and water level were recorded, 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

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 by manually digitizing a photograph of the drywell pressure history recorded on the storage oscilloscope.

# 5.0 TEST RESULTS

## 5.1 INITIAL AND DRIVING CONDITIONS

Three matrix tests were executed with the same nominal initial conditions and using the Grand Gulf FSAR drywell pressurization rate.

The initial conditions for the three tests (E2, E3, E4) are specified in Table 5.1. Data from test E1 was not available since a temporary instrument malfunction prevented drywell pressure measurements from being recorded. Figure 5.1 shows the resultant drywell pressure response for each test along with the target pressure time history (which was determined from the Grand Gulf FSAR drywell pressure response).

## 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 atmosphere 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 reaches the top vent, the air is expelled through the vents and into the suppression pool. After the air has displaced the water in the top vent, it begins flowing into the suppression pool where it forms a bubble. The bubble grows vertically and radially. This causes the pool level to rise.

## 5.3 POOL RESPONSE

### 5.3.1 Encroached Pool Response

The pool response near the encroachment was examined with both the side and front views of the film data. The side view of the film data showed a ligament of water, initially on top of the vertically growing bubble which continued to rise up to the scaled elevation of the Grand Gulf HCU floor. The ligament was 2"-4" thick and extended radially 52% of the pool width (1.1 feet) from the containment wall. There were three regions, which could be identified on the ligament. The first region next to the containment wall (0-15% radial extent) was characterized by high curvature. Farther away from the containment wall, in the second region (15-40%), the ligament exhibited a flat upper surface. The third region (40-52%) also exhibited a curved top surface. Figure 5.2 shows a sketch of the ligament profile obtained from the side view film data at the elevation of the Grand Gulf HCU floor.

Examination of the front view film data showed circumferential curvature on the top of the encroached pool surface at the containment wall. This curvature was attributed to the higher clean pool surface velocities at the containment wall relative to the encroached pool velocities. Figure 5.3 shows a sketch of the circumferential ligament profile at the scaled elevation of the Grand Gulf HCU Floor.

The encroached pool swell transient up to the elevation of the Grand Gulf HCU floor is shown in Figure 5.4. The pool surface at the initial time (t=0) corresponds to vent clearing. Initially, a spherical bubble is formed which grows vertically and radially until the bubble reaches the bottom edge of the encroachment. The bubble then grows vertically along the edge of the encroachment, initially lifting a slug of water which it carries to the top of the test tank. During the bubble growth process, the bubble pushes the displaced water against the model containment wall. This results in a vertical layer of water at the containment wall which thins as the bubble grows. Figure 5.5 shows a photograph of the bubble and pool profiles at breakthrough and when the pool surface is at the top of the test tank.

The pool surface response was also measured by plots of pool surface velocity versus elevation. The peak encroached pool surface velocity, measured at the containment wall, is shown in Figure 5.6.

The breakthrough elevation in the encroached pool was defined as the elevation where the encroached bubble rises above the top of the encroachment allowing venting of the bubble to the model wetwell airspace. The pool surface at breakthrough was approximately 1.25 feet above the initial pool elevation.

### 5.3.2 Clean Pool Response

The clean pool response was quantified by the peak pool surface velocity. Figure 5.7 shows the peak pool surface velocities for the three matrix tests.

# 6.0 DISCUSSION OF RESULTS AND APPLICATION TO GRAND GULF

Examination of the Grand Gulf encroachment test film data indicated that solid water impact may occur on structures at or near the HCU floor elevation, above the encroached pool region. The film test data showed a solid ligament of water which rises to the elevation of the HCU floor in the encroached pool region. This ligament was characterized by more curvature radially and circumferentially next to the containment wall and a smaller radial extent than a similar ligament seen in the Generic A Series Test (Reference 1).

Additional review of the test data and governing processes show that the encroached pool response is bounded by the response of the clean pool up to the design elevation for breakthrough (18 feet).

Test data from the Grand Gulf encroachment tests show that the pool surface velocity in the vicinity of an encroachment is less than or approximately equal to the velocity in the clean portion of the pool. This is shown in Figure 6.1 which gives a comparison of the mean of the peak clean pool velocities with the peak encroached velocities. This was as expected since pool swell is an inertia controlled process and the encroachment effectively lengthens the water slug which the bubble must lift.

The Grand Gulf test also showed that bubble breakthrough always occurred at approximately 1.25 feet (12.5 feet full scale) which is significantly below the design breakthrough elevation (18 feet above the initial pool surface).

Based on this data, the encroached pool swell response up to the design breakthrough elevation of 18 feet is bounded by the design clean pool response. Structures above this elevation will require solid water impact loads to be defined.

REFERENCES

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

TABLE 5.1

COMMON INITIAL CONDITIONS

| | Range |
|---|---|
| Pool Temperature | 56° - 60°F |
| Wetwell Airspace Temperature | 60° - 64°F |
| Pool Submergence | 22.2 inches |
| Drywell Airspace Pressure | 1.47 psia |

PROPRIETARY

FIGURE 3.1 TEST FACILITY DESIGN SCHEMATIC

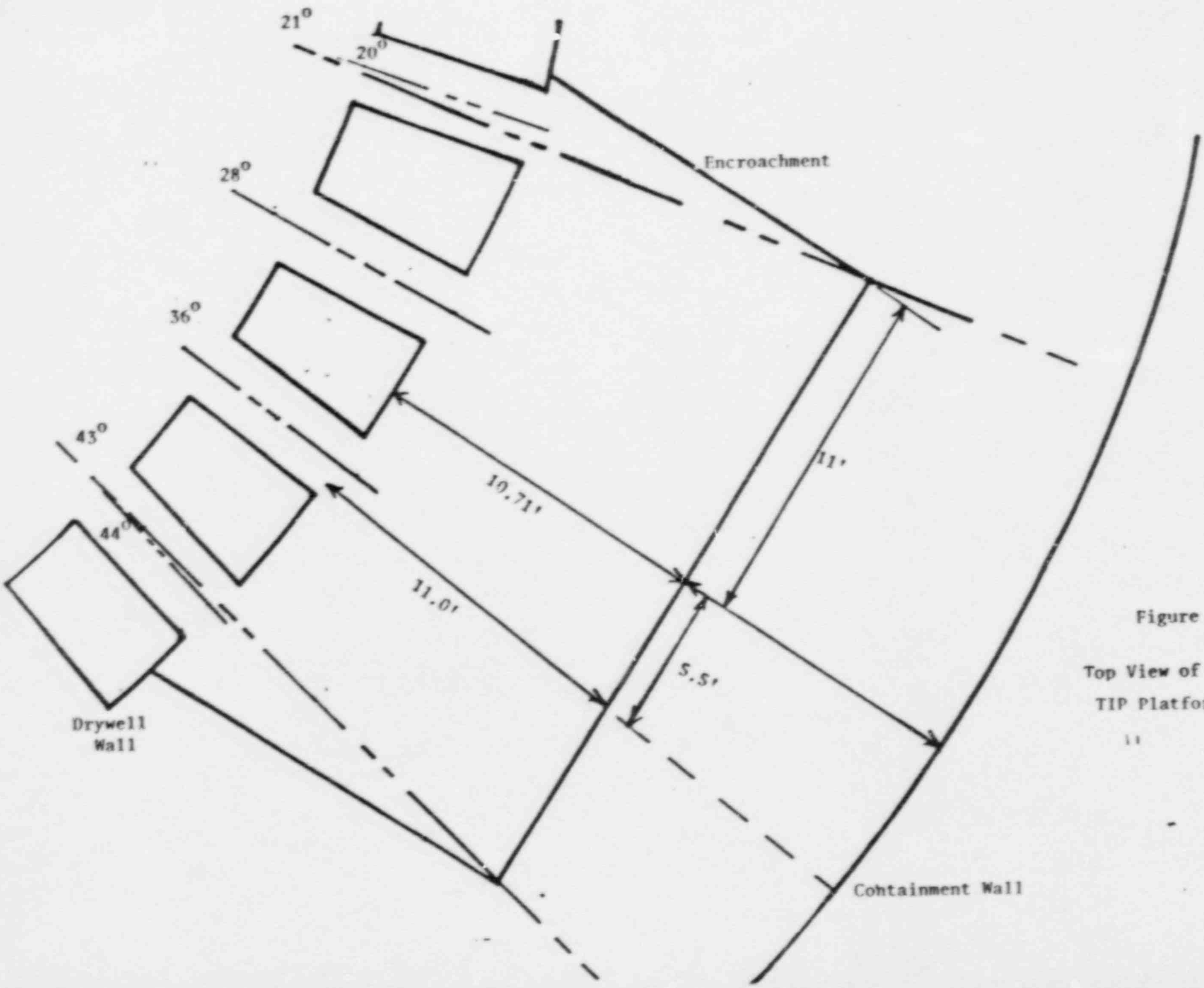



Figure 3.2

Top View of Grand Gulf
TIP Platform

PROPRIETARY

FIGURE 5.1 GGNS DRYWELL PRESSURES

PROPRIETARY

FIGURE 5.2 SKETCH OF THE WATER LIGAMENT AT THE HCU FLOOR

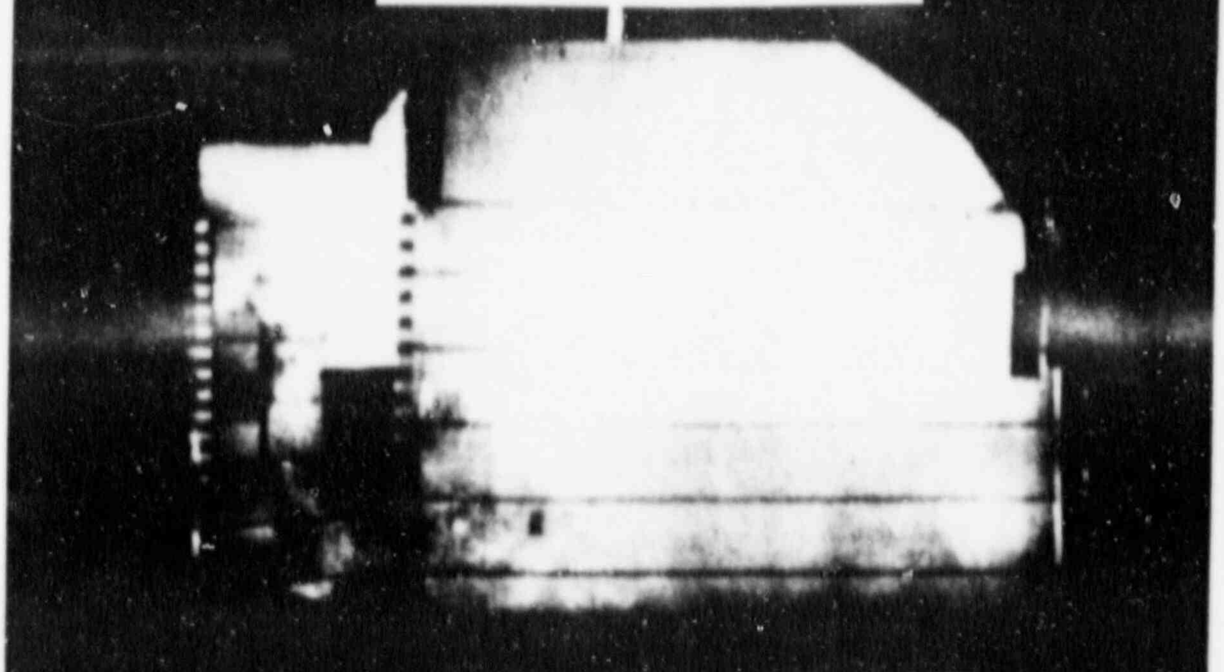
PROPRIETARY

FIGURE 5.3 SKETCH SHOWING THE CIRCUMFERENTIAL PROFILE OF THE POOL SURFACE AT THE ELEVATION OF THE HCU FLOOR

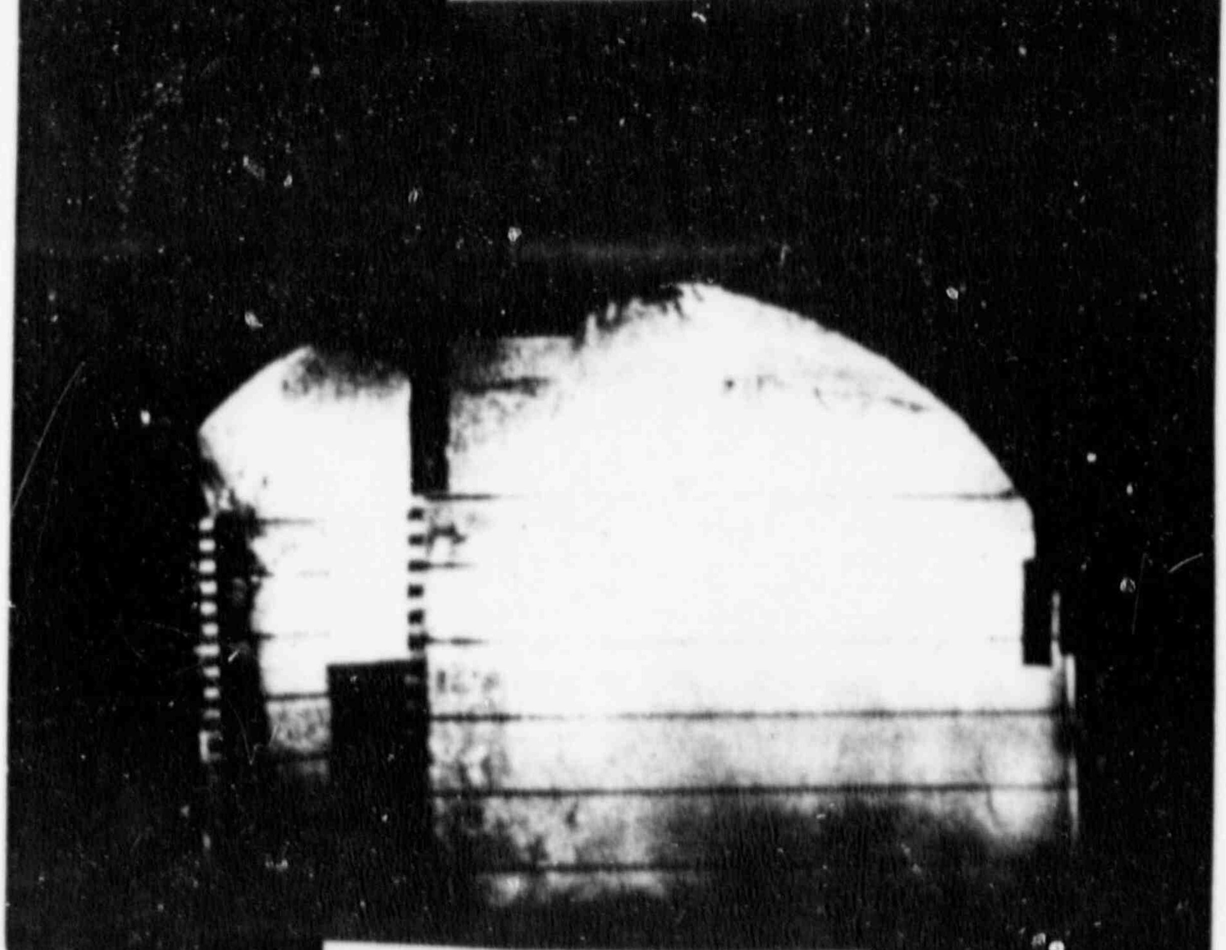
PROPRIETARY

FIGURE 5.4 TYPICAL POOL SURFACE RESPONSE IN THE GRAND GULF PLANT UNIQUE ENCROACHMENT TEST

Figure 5.5
Pool/Bubble Profiles



Breakthrough



Pool Exit

PROPRIETARY

FIGURE 3.6 PEAK ENCROACHED POOL SURFACE VELOCITIES

PROPRIETARY

FIGURE 5.7 PEAK POOL SURFACE VELOCITY IN THE CLEAN POOL

PROPRIETARY

FIGURE 6.1 PEAK ENCROACHED POOL VELOCITY VS. THE MEAN OF THE PEAK CLEAN POOL VELOCITIES

REGULATORY INFORMATION DISTRIBUTION SYSTEM (RIDS)

ACCESSION NBR:8504180120 DOC.DATE: 85/04/15 NOTARIZED: NO DOCKET #
FACIL:50-416 Grand Gulf Nuclear Station, Unit 1, Mississippi Power 05000416
AUTH.NAME AUTHOR AFFILIATION
DALE,L.F. Mississippi Power & Light Co.
RECIP.NAME RECIPIENT AFFILIATION
DENTON,H.R. Office of Nuclear Reactor Regulation, Director

SUBJECT: Forwards GE "Grand Gulf Plant-Unique Encroachments Final Test Rept," per 850307 commitment to perform addl tests w/facility-specific encroachment dimensions proprietary rept transmitted under separate cover.

DISTRIBUTION CODE: B001D COPIES RECEIVED:LTR 1 ENCL 40 ON SHELF SIZE: 2126
TITLE: Licensing Submittal: PSAR/FSAR Amdts & Related Correspondence

NOTES: 05000416
OL:06/16/82

| | RECIPIENT ID CODE/NAME | | COPIES LTTR | ENCL | RECIPIENT ID CODE/NAME | | COPIES LTTR | ENCL |
|---|---|---|---|---|---|---|---|---|
| | NRR/DL/ADL | | 1 | 0 | NRR LB4 BC | | 1 | 0 |
| | NRR LB4 LA | | 1 | 0 | KINTNER,L | 01 | 1 | 1 |
| INTERNAL: | ACRS | 41 | 6 | 6 | ADM/LFMB | | 1 | 0 |
| | ELD/HDS4 | | 1 | 0 | IE FILE | | 1 | 1 |
| | IE/DEPER/EPB | 36 | 1 | 1 | IE/DQAVT/QAB21 | | 1 | 1 |
| | NRR ROE,M.L | | 1 | 1 | NRR/DE/AEAB | | 1 | 0 |
| | NRR/DE/CEB | 11 | 1 | 1 | NRR/DE/EHEB | | 1 | 1 |
| | NRR/DE/EQB | 13 | 2 | 2 | NRR/DE/GB | 28 | 2 | 2 |
| | NRR/DE/MEB | 18 | 1 | 1 | NRR/DE/MTEB | 17 | 1 | 1 |
| | NRR/DE/SAB | 24 | 1 | 1 | NRR/DE/SGEB | 25 | 1 | 1 |
| | NRR/DHFS/HFEB40 | | 1 | 1 | NRR/DHFS/LQB | 32 | 1 | 1 |
| | NRR/DHFS/PSRB | | 1 | 1 | NRR/DL/SSPB | | 1 | 0 |
| | NRR/DSI/AEB | 26 | 1 | 1 | NRR/DSI/ASB | | 1 | 1 |
| | NRR/DSI/CPB | 10 | 1 | 1 | NRR/DSI/CSB | 09 | 1 | 1 |
| | NRR/DSI/ICSB | 16 | 1 | 1 | NRR/DSI/METB | 12 | 1 | 1 |
| | NRR/DSI/PSB | 19 | 1 | 1 | NRR/DSI/RAB | 22 | 1 | 1 |
| | NRR/DSI/RSB | 23 | 1 | 1 | REG FILE | 04 | 1 | 1 |
| | RGN2 | | 3 | 3 | RM/DDAMI/MIB | | 1 | 0 |
| EXTERNAL: | BNL(AMDTS ONLY) | | 1 | 1 | DMB/DSS (AMDTS) | | 1 | 1 |
| | LPDR | 03 | 2 | 2 | NRC PDR | 02 | 1 | 1 |
| | NSIC | 05 | 1 | 1 | PNL GRUEL,R | | 1 | 1 |

TAC 56303

TOTAL NUMBER OF COPIES REQUIRED: LTTR 52 ENCL 44

MISSISSIPPI POWER & LIGHT COMPANY
*Helping Build Mississippi*
P. O. BOX 1640, JACKSON, MISSISSIPPI 39215-1640

April 15, 1985

NUCLEAR LICENSING & SAFETY DEPARTMENT

U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D. C. 20555

Attention: Mr. Harold R. Denton, Director

Dear Mr. Denton:

SUBJECT: Grand Gulf Nuclear Station
Unit 1
Docket No. 50-416
License No. NPF-29
File: 0260/272/L-860.0
Humphrey Containment Concerns
AECM-85/0123

In a letter dated March 7, 1985 (AECM-85/0038) Mississippi Power & Light (MP&L) confirmed a verbal commitment to perform additional 1/10-scale tests with Grand Gulf Nuclear Station (GGNS) specific encroachment dimensions to help resolve the encroached pool issue. This letter also indicated that MP&L would submit the final test report to the NRC. This report, "Grand Gulf Plant Unique Encroachments Final Test Report", is enclosed with this letter. The attached is a non-proprietary version of the report. The proprietary version is being transmitted under separate cover by AECM-85/0124, dated April 15, 1985.

It should be noted that MP&L is continuing to work on the other activities associated with the encroached pool issue and remains committed to assuring that encroached pool swell does not adversely affect plant equipment or structures.

Yours truly,

L. F. Dale
Director

CWS/SHH:vog
Attachment

cc (See Next Page)

8504180120 850415 3pp
PDR ADOCK 05000416
P PDR


Member Middle South Utilities System

cc: Mr. J. B. Richard (w/a)
Mr. O. D. Kingsley, Jr. (w/a)
Mr. R. B. McGehee (w/a)
Mr. N. S. Reynolds (w/a)
Mr. G. B. Taylor (w/o)

Mr. James M. Taylor, Director (w/a)
Office of Inspection & Enforcement
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dr. J. Nelson Grace, Regional Administrator (w/a)
U. S. Nuclear Regulatory Commission
Region II
101 Marietta St., N. W., Suite 2900
Atlanta, Georgia 30323