ASYMMETRIC LOCA BUBBLE POOL BOUNDARY LOAD

FOR MARK II

Prepared by: I. S. Uppal

March 1979

7903210057

ASYMMETRIC LOCA BUBBLE POOL BOUNDARY
LOAD FOR MARK II PLANTS

I. INTRODUCTION

During a design basis Loss of Coolant Accident (LOCA) event, the vent clearing process is followed by formation of a bubble at the vent exit as air and steam are purged from the drywell. The bubble formation and expansion cause loads on the pool boundary.

Reference 1 postulated that circumferential variations in the air flow rate due to drywell air/steam mixture variations would result in variations in the bubble pressure load on wetwell wall. Although large variations in the pressure and vent flow compositions are unlikely, reference 1 conservatively assumed all air vented on one-half of the drywell periphery and steam vented on the other.

A study was performed to ascertain the potential causes and effects of vent flow variations and the effect on bubble pressure load on the pool boundary. This study discussed in this document shows that significant vent flow variations in the Mark II drywell cannot occur and that the assumption, "all air vented on one-half of the drywell and steam vented on the other", is unrealistic. This report presents an alternate bounding asymmetric LOCA bubble pool boundary load for Mark II plants.

For the purpose of the study, asymmetric LOCA air bubble load during a postulated design basis (DBA) LOCA was investigated from the standpoint of the potential for non-uniformity in vent flow composition. The LOCA bubble load begins with vent clearing and ends when the pool swells to maximum height. A look at potential effects on composition variation in the Mark II drywell showed that:

1. Steam exits the break at sonic velocity causing turbulent conditions.

2. There are no major obstructions and compartments in the Mark II drywell.

3. Flow is diverted and mixed by drywell structures.

4. Marviken data supports good mixing.

5. Battelle tests (reference 2) support good mixing prior to vent clearing.

Even if steam is arbitrarily assumed to be moving as a front (reference 2) behind which the steam and air is being homogeneously mixed, the entire drywell air/steam mixture is homogeneous within 0.4 seconds. Using the Mark II Pool Swell Analytical Model (reference 3)

applied to separate vents located on opposite sides of the drywell, a maximum difference in LOCA vent bubble pressures was calculated to be less than 10 percent of the water clearing bubble pressure (psig), when vent flow composition is varied.

II. VENT FLOW COMPOSITION VARIATIONS

Non-uniform vent flow composition is recognized to be a potential cause of asymmetric vent air clearing. If the steam is not well mixed with the drywell air, some vents would receive higher steam concentrations than the others. The vents with higher steam concentrations could have lower bubble pressures than the vents with lower steam concentrations causing hypothetical asymmetric LOCA bubble load on the pool boundary.

Following a postulated DBA pipebreak, water and steam at ~ 1050 psia and ~ 550°F suddenly stream into the air filled drywell, which is initially at ~ 15.4 psia. Within one second after the break ~ 8200 lbm of the high energy fluid has flashed to steam, filling one-half of the drywell volume. By the end of the first second, drywell pressure has nearly doubled (to approximately 30 psia) and drywell temperature has increased by ~ 60 percent (to approximately 215°F). The rapid increase in the drywell pressure will accelerate the water initially standing in the downcomer vents into the suppression pool. A typical vent clearing time for Mark II plants is ~ 0.7 seconds. This vent clearing process is followed by the formation of a bubble at the vent exit as air and steam are purged from the vent system and the drywell. The bubble formation and expansion causes a load on the pool boundary. The LOCA bubble load begins at the time of vent clearing and ends at the time of maximum pool swell. Since the recirculation line break causes highest bubble loads, the recirculation line break is the DBA. Figure 1 presents the load sequence bar chart.

Almost immediately following a pipebreak, air and steam are homogeneously mixed due to the following reasons:

A. Steam and water at ~ 1050 psia and ~ 550°F suddenly stream into a drywell at ~ 15.4 psia and ~ 135°F. The steam exits from the break at sonic velocity (~ 1200 ft/sec). The high steam exit velocity and a high temperature differential (~ 415°F) between steam and air, cause highly turbulent flow which results in good mixing of steam with drywell air.

B. The steam, streaming out of the break at sonic velocity, will be diverted in various directions depending on the locations of structures and the break flow directions. This almost random diversion of steam flow will result in better mixing of steam with air.

C. The Mark II drywell is a relatively open space. There are no large solid obstructions except the reactor. Structures are relatively evenly distributed in the drywell and significant obstructions to flow do not exist. Thus, local drywell pressure variations are expected to be insignificant. For example, even if the drywell is assumed to be obstructed by a screen of 1 inch diameter pipes producing a 43.75 percent reduction of flow area, this produces a pressure loss, computed by the method in reference 4, of only .048 psi. A spatial pressure difference across the drywell (at the drywell floor elevation) of .048 psi is insignificant in comparison to the 15 to 30 psia in the drywell.

D. The Marviken wetwell is similar to the Mark II wetwell. Figure 2 shows that vent shafts are not symmetrically located at the header. Figure 3 shows pool bottom pressures as a function of time as measured by four pressure transducers during Marviken test 17 (reference 5). The locations of these transducers are shown in Figure 4. The maximum pool bottom pressure difference is approximately 7.5 percent of the maximum absolute pool bottom pressure. This difference is most probably caused by the asymmetric location of vent header inlets. Thus, it can be concluded that if vent flow variations occured, it did not affect the bubble pressures significantly.

E. Tests on a 1/64 scale model of a 1200 MW PWR-plant (reference 2), measured steam front velocity of 180 ft/sec, using fast response thermocouples installed at different distances from the site of the rupture. The shock wave velocity measured for this flow was 1115 ft/sec. Shock wave velocity in the Mark II is expected to be $\sim$ 1200 ft/sec. On the basis of comparison of shock wave velocity in the Mark II drywell with the shock wave velocity in the Battelle test, an assumption of steam front velocity of 180 ft/sec is conservative for Mark II. At 180 ft/sec the steam front will reach the farthest point in the Mark II drywell of the largest circumference in 0.4 seconds. Thus, within 0.4 seconds the steam is expected to be homogeneously mixed with the drywell air. At 0.4 seconds the Mark II vents are only about 23% cleared.

III. BOUNDING ASYMMETRIC LOCA BUBBLE LOAD

As stated above, steam is expected to very quickly mix homogeneously with drywell air after the LOCA. Note that all vents are initially filled with air so that the initial bubble formed will have essentially pure air. In an attempt to compute a reasonable bounding asymmetric LOCA bubble pressure load, two vents on opposite sides of the containment were exposed to different vent flow compositions produced by a specific break location.

For the purpose of this analysis, both vents are initially filled with air. The vent, near the break, is assumed to immediately be supplied with a homogeneous mixture of steam/air at the time of the LOCA. The far vent is assumed to be supplied with compressed air up to 0.4 seconds. After 0.4 seconds the far vent is also supplied with homogeneous air/steam mixture. Figure 5 shows the vent flow variation of the vents. For calculating a bounding asymmetric bubble load the following conservative assumptions were made:

A. The recirculation line is assumed to break at the lowest elevation. Break at a higher elevation will result in lower vent flow variations.

B. Two vents, one nearest to the break location and the other farthest from the break location, were selected for calculating potential asymmetric LOCA bubble loads. This is equivalent to assuming that vents in one-half of the wetwell have bubble pressures equal to vent nearest to the break (low) while the other half of vents have bubble pressures equal to the vent farthest from the break location (high).

C. The largest Mark II drywell geometry (drywell floor diameter of 91 feet) was used. This would maximize potential vent flow asymmetry.

D. Although a typical Mark II vent clearing time is ~ 0.7 seconds, for this analysis a vent clearing time of 0.6 seconds was assumed. For a given submergence, the assumption of lower vent clearing time results in higher vent water displacement during the 0.4 seconds homogeneous mixing time; consequently more vent space will be filled by air on one side of drywell and by the air/steam mixture on the other side. This increases vent flow variation.

E. The steam in the mixture is instantaneously condensed and does not contribute to bubble pressure. This increases the difference in bubble pressures.

Using these parameters, the maximum bubble pressure differences between the two vents is less than 10 percent of the bubble pressure (psia) at the time of vent clearing.

IV. CONCLUSION/RECOMMENDATION

The suggested assumption that all air vented on one-half of the drywell and zero air (or steam) vented on the other half, is overly conservative. Significant vent flow variations cannot occur in

the Mark II drywell. Based on the Battelle test, the steam/air mixture should homogeneously mix within $\sim$ 0.4 seconds of a LOCA in a Mark II drywell.

Using conservative assumptions, a maximum difference in LOCA vent bubble pressures was calculated to be less than 10 percent of vent clearing bubble pressure (psia). Therefore, for asymmetric LOCA load evaluations of the containment structure it is recommended that the local bubble pressure at the downcomer vents on one-half of the suppression pool be assumed to be 10 percent of the maximum LOCA vent clearing bubble pressure while the other half remains at zero gauge pressure. This load would be applied statically, together with the normal hydrostatic pressure, to the submerged portion of the containment.

REFERENCES

1. U.S. Nuclear Regulatory Commission, Draft of, "Mark II Containment Lead Plant Program Load Evaluation Report", NUREG-0487, October 1978.

2. T.F. Kanzleiter, "Experimental Investigation and Temperature Loads on a containment after a Loss of Coolant Accident", Nuclear Engineering and Design 38 (1976), pp 159-167, North-Holland Publishing Company. Battelle Institute, Frankfurt, Germany.

3. R.J. Ernst, et al, "Mark II Pressure Suppression Containment System: An Analytical Model of the Pool Swell Phenomena", General Electric Company, NEDE-21544-P, December 1976.

4. J.H. Perry, et al, "Chemical Engineer's Handbook", 4th edition, McGraw-Hill, New York, 1963, pp 5-35.

5. Marviken Full Scale Containment Pressure Response Tests, second series, Interim Report of Blowdown 17 Test Results (MXB-217), Marviken Power Station, Sweden (April 1976)

6. T.R. McIntyre, et al, "Mark II Pressure Suppression Test Program", General Electric Company, NEDE-13442-P, January 1976.

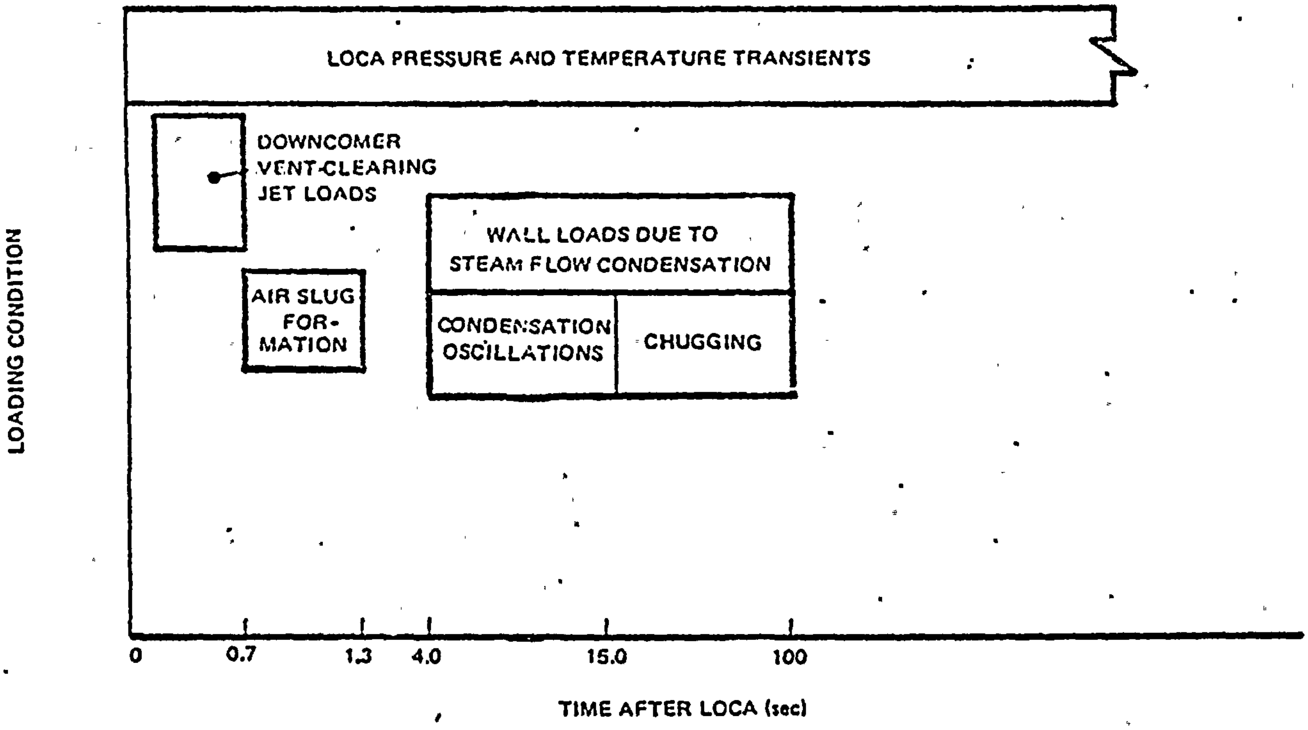


Figure 1 Structure Affected: Submerged Wetwell Walls
Accident Condition: Large Break

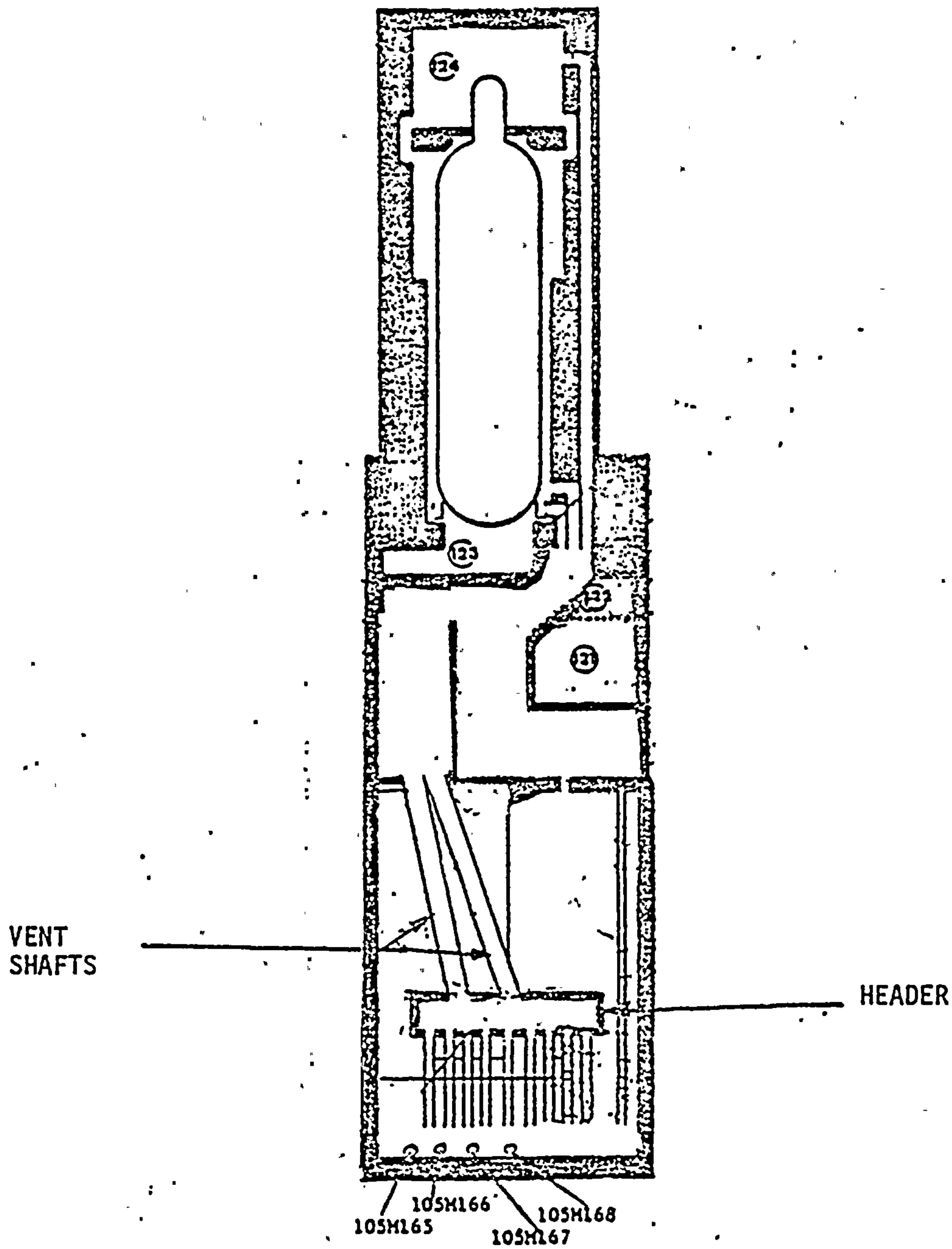
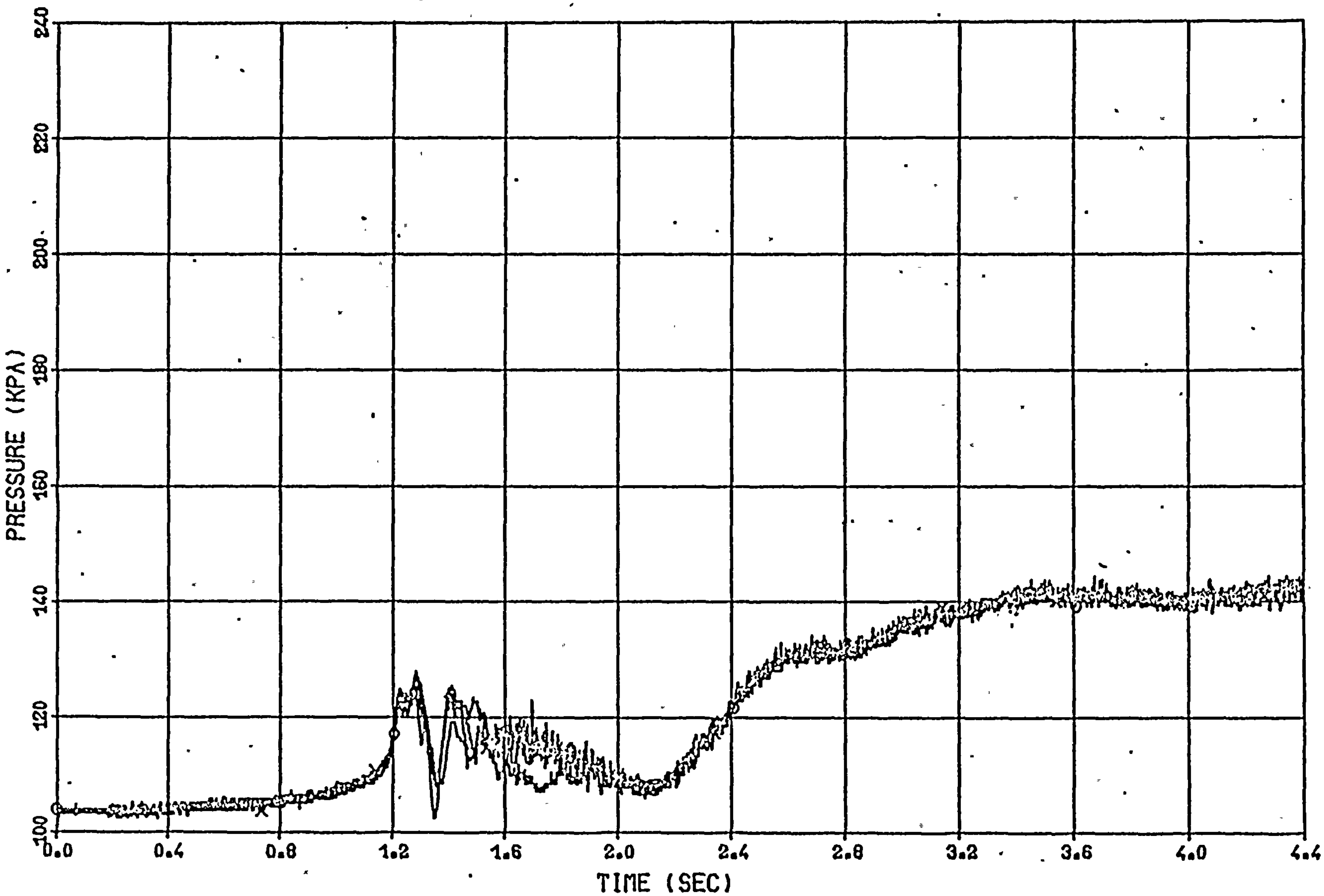


Figure 2: Pressure and differential pressure in the drywell and wetwell

BLOWDOWN 17

O 105M165 POOL BOTTOM
▲ 105M166 POOL BOTTOM
+ 105M167 POOL BOTTOM
X 105M168 POOL BOTTOM

Figure 3: Pool bottom pressure vs time at Marviken



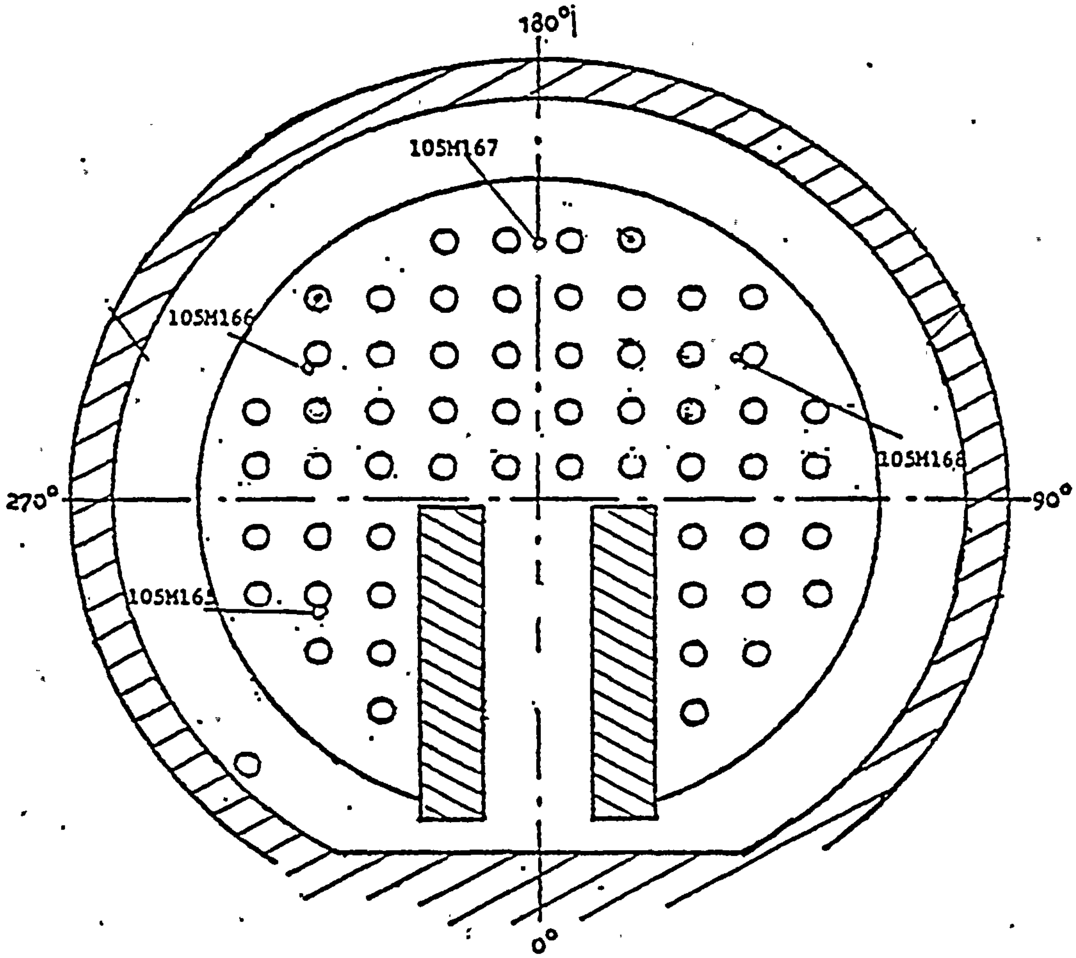


Figure 4: Locations of measurement points on the floor of Marviken wetwell.

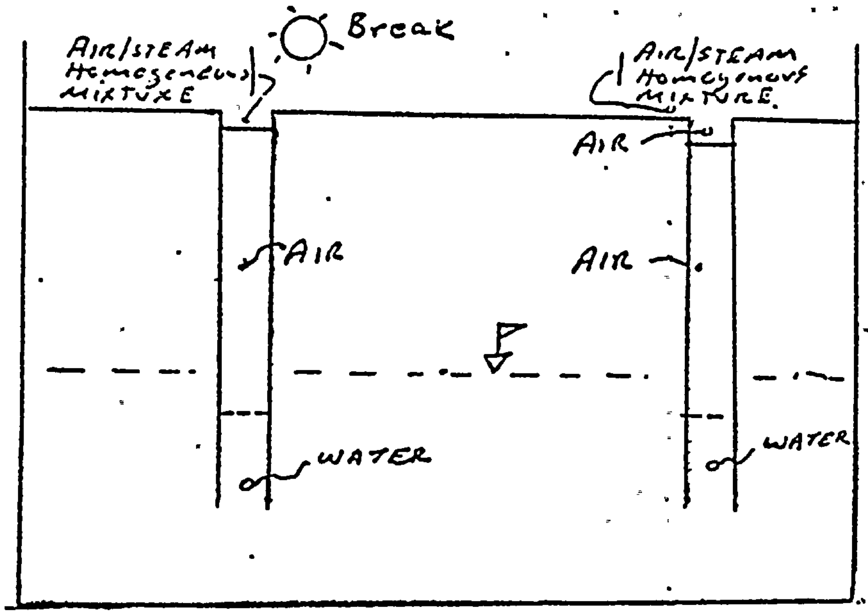


Figure 5: Vent Flow Composition Variation at 0.4 seconds after LOCA