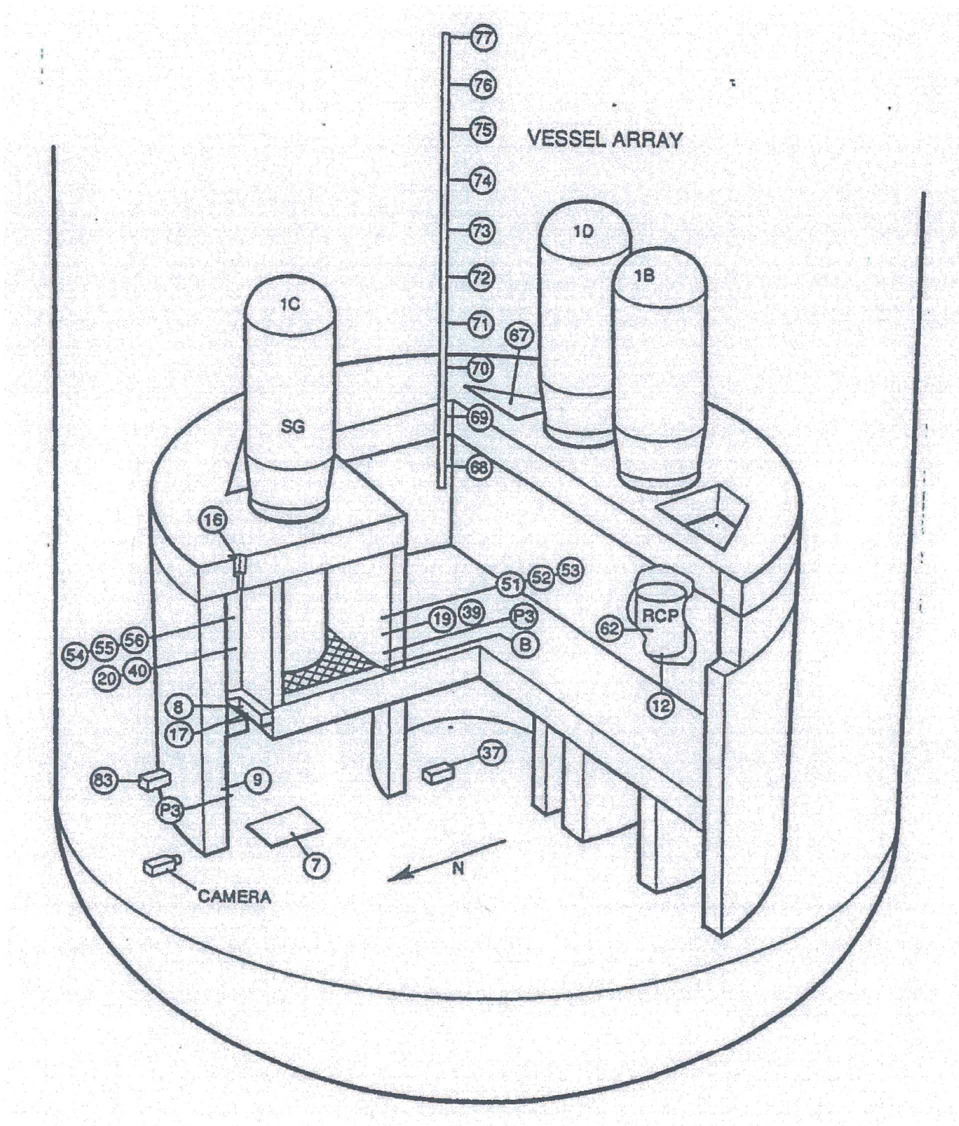

Figure 2-13 **Isometric view of the subcompartment structures inside the Surtsey 1/10 scale vessel**

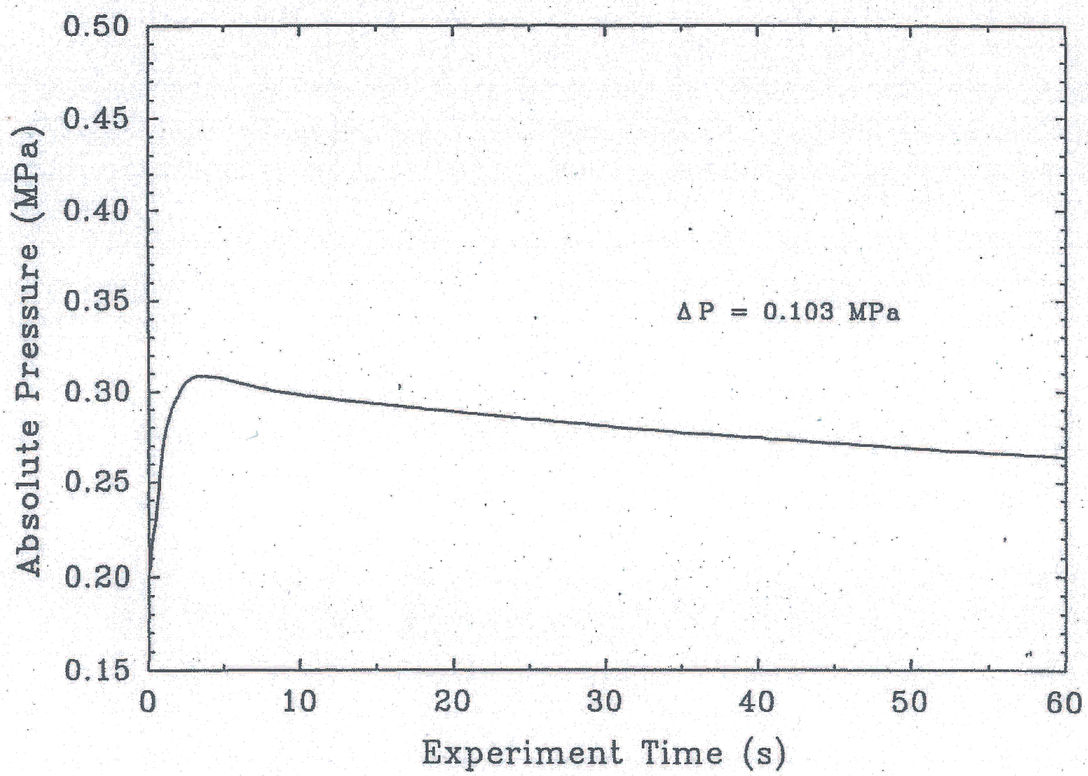

Figure 2-14 Surtsey vessel pressure versus time for Test IET-5

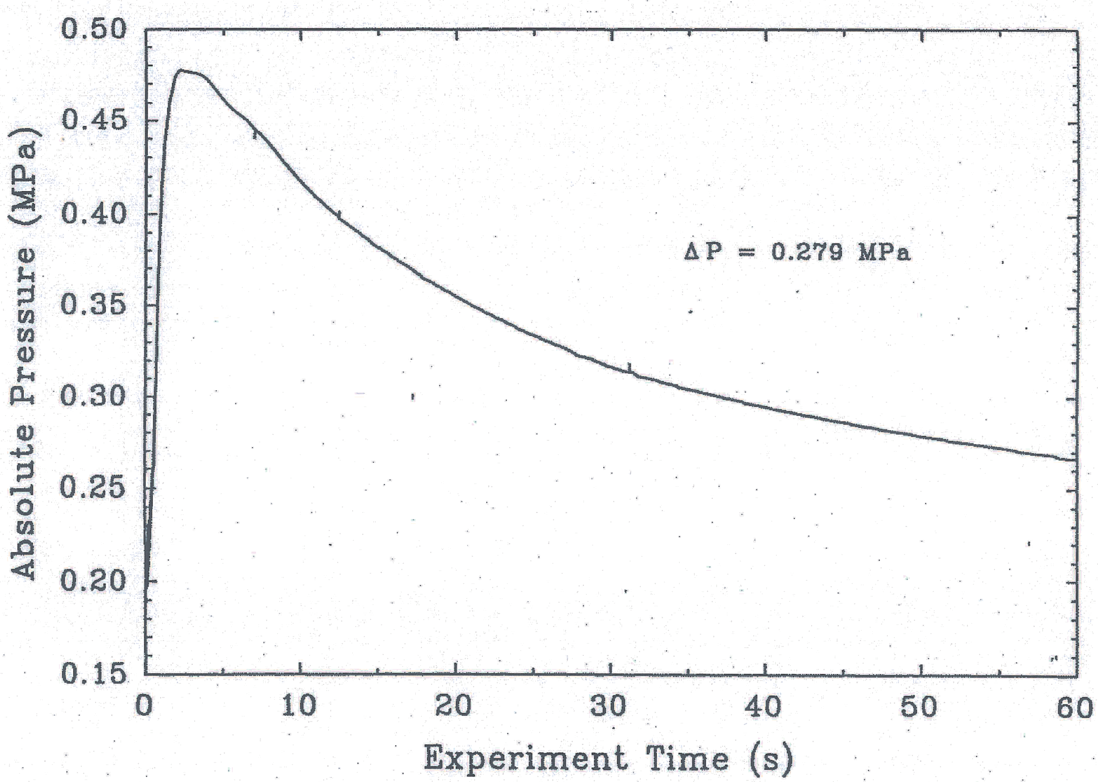

Figure 2-15 Surtsey vessel pressure versus time in the IET-6 experiment

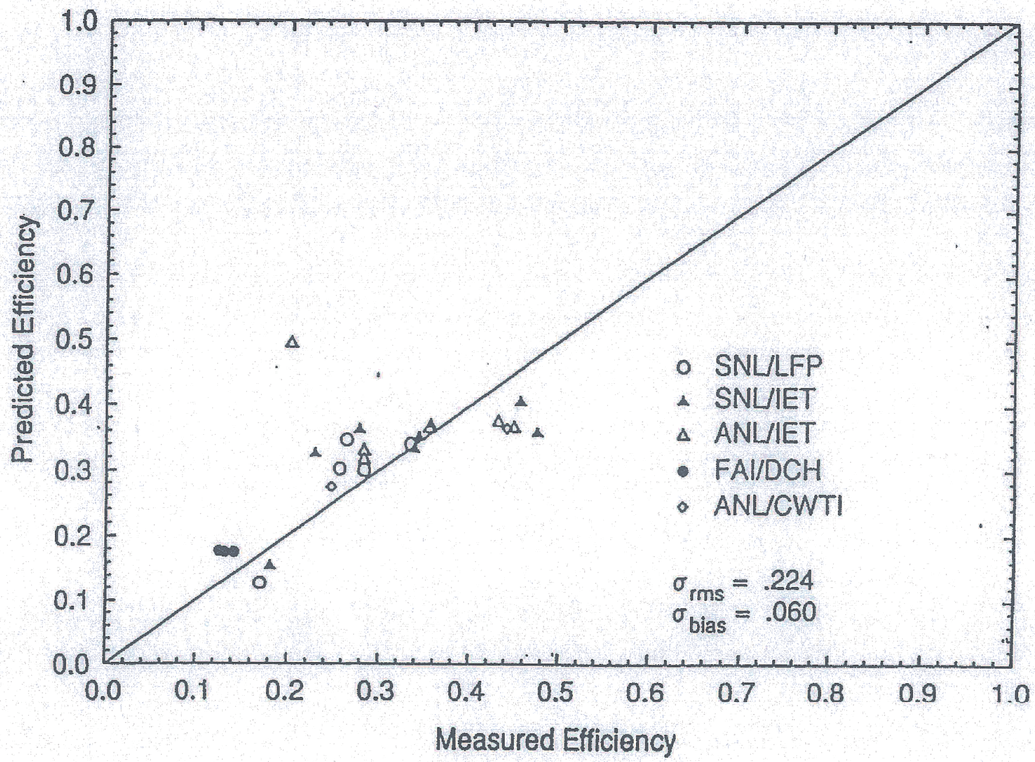

Figure 2-16 Validation of the TCE model against all experiments with compartmentalized geometry.

2.8 Purdue Air-Water DCH Simulation Experiments

Debris entrainment in the reactor cavity, movement of the debris out of the reactor cavity, impingement of the debris on containment structures immediately downstream of the reactor cavity, re-entrainment of the debris and dispersal of the debris to other containment compartments are the most important individual physical processes affecting direct containment heating. To address these processes, simulant fluid experiments were performed at Purdue University using water-air and Wood's metal-air systems to investigate these separate effects behaviors (Reference 28 and 29). These tests were specifically directed at understanding the dispersion mechanisms and the trapping behavior that would occur in subcompartments immediately downstream from the reactor cavity/instrument tunnel.

The experiments were performed for a Zion-like configuration. The reactor cavity and instrument tunnel were represented in the scaled configuration with the liquid being discharged from a separate vessel, followed by the gas blowdown from gas tanks through a separate discharge nozzle into the reactor cavity. The substantial containment structures that could intercept entrained and non-entrained debris as it exits the instrument tunnel were included in the simulant tests, as they were also included in the integral effects experiments performed with the thermite melts.

Numerous parametric studies were performed with this scaled separate effects facility. These tests indicated very interesting results with respect to the liquid film behavior in the reactor cavity, the extent of entrainment and the extent of carryover out of the lower compartment structures. As a result of the incoming momentum from the discharging liquid (water in this case) it was found that a liquid film spreads along the reactor cavity floor and up the walls of the reactor cavity and eventually the instrument tunnel. It was found that approximately one liter of water could flow out of the reactor cavity without entrainment. This corresponds to about 15% of the liquid mass inventory and this is removed from the reactor cavity before the entrainment process begins. For higher liquid inventories, approximately 30% of the liquid inventory was carried out of the cavity before the gas blowdown was initiated. Furthermore, it was found that during the entrainment process a significant fraction of the remaining mass (about 42%) was entrained droplets with the rest being transported out of the reactor cavity as a liquid film; however, the entrained droplet size is relatively large. This is important since this has a significant influence on the rate at which droplets can be deposited when flow direction changes are encountered as the two-phase mixture exits the instrument tunnel.

The entrapment of the two-phase mixture is clearly observed in this transparent apparatus. The first major entrapment occurs at the seal table and this is principally due to the droplet momentum and trajectory. The observation is this entrapment is mainly through the view factor and the ratio of the area opening in the cavity cross-sectional area. It is also observed that the larger droplets impact on structural surfaces and de-entrain to form liquid films. Only the very small droplets continue to remain entrained in the gas stream and they have a significant potential for being carried out of the subcompartment configuration and into the upper regions of the containment. However, the magnitude of the liquid mass observed to be transported out of the subcompartment region was quite small. Typically, only a few percent of the total liquid mass was carried to the upper compartment.

The observed substantial removal of debris from the airborne fluid stream as a result of interactions

with structure in the containment subcompartments and the small fraction of liquid mass entrained into the upper compartment region are clearly in agreement with the integral effects test reported elsewhere in this document.

2.9 Fauske & Associates 1/25th Scaled DCH Experiments for Vandellos and Asco Containments

As part of the plant specific IPE studies for Vandellos and Asco, the utilities operating these plants elected to perform scaled tests for HPME conditions to address the issue directly through experiments. Because of the specific reactor cavity and instrument tunnel designs for these two plants, and because of the proximity of the containment liner to the exit from the instrument tunnel in Vandellos, it was judged that plant specific scaled experiments were a more direct means of addressing the IPE questions than attempting to use experiments directed at other plant configurations. These experiments were performed in the Fauske & Associates, Inc. experimental facility using a 4% linear scale model of the reactor cavity, instrument tunnel, steam generator compartment and upper containment compartment (Reference 30).

Figure 2-17 shows the test facility configuration used for the two tests representing the different plant geometries. Plant drawings were used to determine the dimensions for the 1/25th scale representation of the reactor cavity, instrument tunnel, seal table room, adjacent containment liner, lower compartment/annular compartment and upper containment regions. The test facility consisted of (1) a melt delivery assembly, (2) the test assembly, (3) the lower containment volume, (4) the upper containment volume, and (5) the steam generator. Iron thermite was used to represent the high temperature melt with the specific initial conditions used for the two different experiments listed in Table 2-9. Based on the linear scaling, an iron thermite mass of 4.3 kilograms would be required to simulate the core inventory of uranium dioxide and zircaloy. However, with the greater propensity of freezing on cold walls in small scaled experiments, the scaled mass was increased to 10 kg. With this larger mass, that which could be released to the lower compartment was equal to or greater than that required to satisfy the volumetrically scaled behavior. With the higher energy content of the aluminum oxide in the thermite mass compared to the uranium dioxide in the reactor system, this results in a substantial conservatism in the scaled experiments.

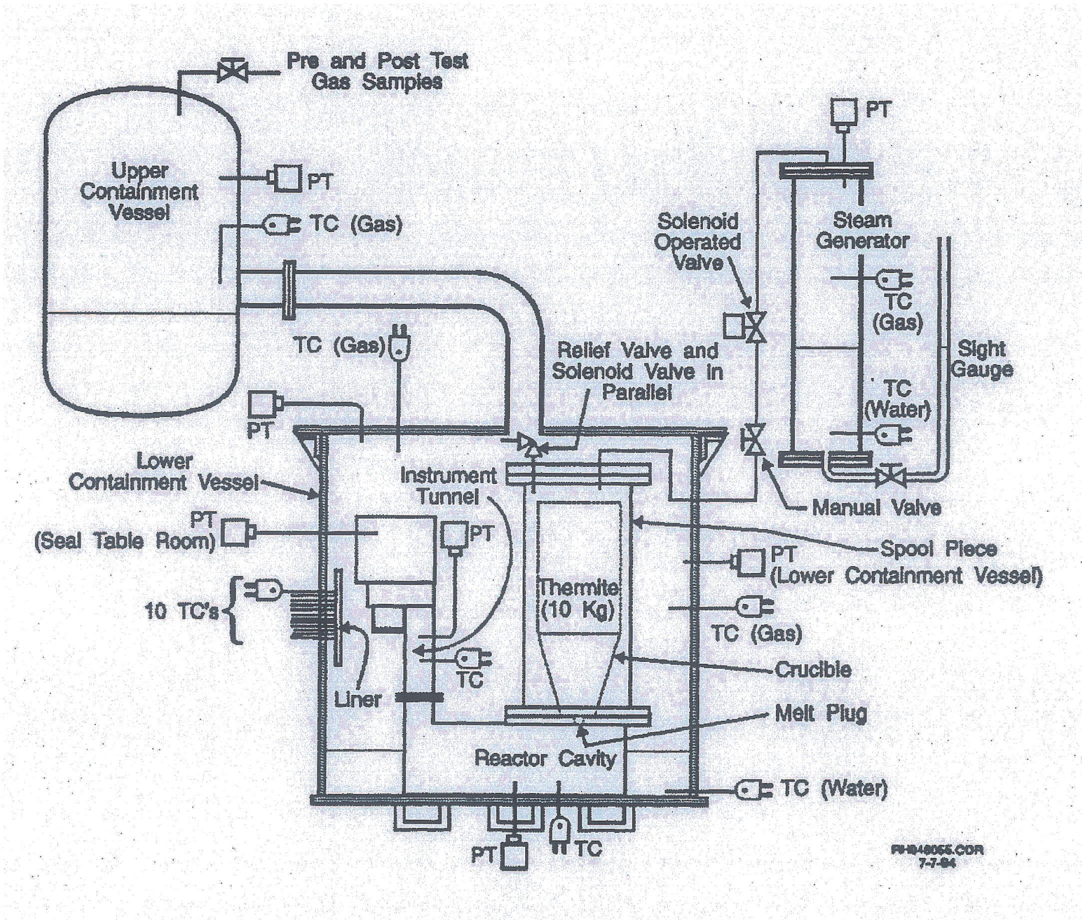

Figure 2-17 DCH test facility configuration

Table 2-9 Initial Conditions

Test	Mass of Thermite (kg)	Cont. Gauge Pressure (MPa)	Crucible Gauge* Pressure (MPa)	Containment Temperatures	
				Gas Space (°K)	Water (°K)
Vandellos	10	-0.025	1.90	296	296
Asco	10	0.018	2.94	298	298

* Steam pressure in crucible at time of vessel (melt plug) failure.

The pressure and temperature information used in these experiments is summarized in Figure 2-17. The carbon steel containment liner was represented in each test with the carbon steel plate located opposite the ventilation openings in the vertical instrument tunnel for the Vandellos test and opposite the seal table room for the Asco experiment. Figure 2-18 shows the scaled reactor cavity and instrument tunnel configuration for the Vandellos experiment and Figure 2-19 shows the configuration for the Asco test. In the experiments, water was added to the floor of the annular compartment (approximately 54 kg) as indicated in Figure 2-17. For the Asco experiment 4.7 kg of water were added to the reactor cavity, corresponding to a water depth of approximately one half the height of the horizontal portion of the instrument tunnel. There was no water in the reactor cavity for the Vandellos test.

Table 2-10 shows the peak pressures measured in the various containment compartments for the two different experiments. Of particular note for both experiments is that the net containment pressurization was limited being 5 psig in the upper compartment for the Vandellos test and 5.4 psig for the Asco experiment.

For both experiments, the debris was collected and weighed. Table 2-11 summarizes the debris masses found in the several regions. As is noted a significant fraction (50-60%) of the debris was discharged from the instrument tunnel and seal table for the Vandellos experiment. About one third of this mass was found to be a frozen film on the vessel wall during the post-test examination, with the balance collected on the floor of the lower compartment and therefore submerged in water. A very small amount of debris particulation was found and no debris was detected in the upper containment compartment or the pipe connecting the upper and lower compartments. Pre-test and post-test gas samples taken from the upper containment compartment were examined for hydrogen. There was no detected amount of hydrogen observed for the dry reactor cavity test used for the Vandellos configuration.

As mentioned previously, the Asco experiment used a configuration in which the reactor cavity was half full of water. A dynamic debris-water interaction was observed in the reactor cavity, causing substantial pressurization of this region as indicated in Table 2-10. For this configuration, a single vent path connected the instrument tunnel to the seal table room, with the area of this vent being only about 1.5 times the failure area in the bottom of the melt crucible. The temperature within the

reactor cavity and horizontal segment of the instrument tunnel reached a maximum value near 240°C, corresponding to the saturation temperature of the measured peak pressure.

As illustrated in Table 2-11, virtually all of the debris remained within the reactor cavity for the Asco configuration. No debris was observed in the upper compartment or the pipe connecting the upper and lower compartment. Also, the liner plate was found to have a layer of frozen debris covering the impingement surface. Pre-test and post-test gas samples were taken from the upper containment volume to examine the potential for hydrogen generation. A limited amount was detected (0.1 to 0.4 volume percent) which was the result of oxidation of the high temperature molten iron by the steam and water in the wet reactor cavity.

The observed pressure responses in both experiments for the upper and lower containment regions for both experiments were far less than the design basis pressure for these containments. Hence, these linear scaled experiments demonstrated no significant challenge to containment integrity as the result of a high pressure melt ejection.