UNIVERSITY OF MINNESOTA
INSTITUTE OF TECHNOLOGY
MINNEAPOLIS 14

DEPARTMENT OF CHEMICAL ENGINEERING

February 27, 1960

Dr. Clifford K. Beck, Chief
Hazards Evaluation Branch
U.S. Atomic Energy Commission
Washington 25, D.C.

Dear Dr. Beck:

I have prepared a very short summary of my opinions on the PG&E Pressure Suppression Containment, and in order to expedite the transmission to you, the material is hand written.

You will need to advise me whether my services have been sufficient or might be needed for a final and more formal report.

Incidentally, the problems and phenomena associated with the air entrainment and jet behavior are so interesting that we will do some investigations are our own at the University.

Sincerely,
Herbert S. Isbin
Professor

Summary Report by Herbert S. Isbin

February 26, 1960

On the basis of my review of the Pacific Gas and Electric Company's Preliminary Hazards Summary Report, Amendment No's. 3, 4, 5 and 6, discussions with M. Booth and C. Robbins, and participation at the February 25, 1960 Oak Ridge meeting, I have prepared a short summary of my opinions regarding the design pressures for the dry well and suppression chamber.

Design Pressure of the Dry Well

Steady-State Analyses

The model used for the steady-state analyses for a given sized break is conservative in two major aspects, but is not sufficiently bounded in several respects.

The critical flow discharge pressure calculation is conservative because the homogeneous model has been used and the entire two-phase flow has been used with no water drop out. The steady-state flow from the break is conservative for no allowances are made for flashing at the break and decline in reactor pressure.

The calculations have not been sufficiently bounded in the treatment for the frictional and momentum two-phase pressure drops, and the inclusion of the effects of an added air entrainment. Although it is not expected that the additional calculations will produce a major change in the present calculated value of the maximum dry well pressure, such calculations are deemed necessary for a more complete evaluation of the two-phase flow.

My approach would have been to use as realistic a model as is possible, starting with observed measurements and correlations on critical two-phase flow. The frictional and momentum two-phase pressure drops would be estimated using both the homogeneous and Martinelli-type models. The flow through the break and some water drop out should also be made realistic. Such a model would define a "maximum steady-state flow" pressure, to which could be added pressure increments due to uncertainties in specified factors and conditions in the design calculations.

Transient Analyses

The transient analyses appears to be well done in spite of suggestions for some of the mass acceleration terms and on the method for scaling. The answers provided by C. Robbins are sufficient and adequate.

The Humboldt design with the restricted vent area presumably requires a "steady-state" design pressure in excess of the maximum transient pressure.

Design Pressure of the Suppression Chamber

Condensation Tests

The condensation tests have demonstrated the ease in which the steam jets condense in the water pools. With the exception of effects of air entrainment, the experience obtained by the condensation tests should be sufficient for the Humboldt design.

Effect of Air Entrainment in the Condensation

The carry over of steam into the suppression chamber by air entrainment in the two-phase jet was seriously questioned by one member at the Oak Ridge meeting, and it was deemed desirable that C. Robbins further amplify and support his contention on the extent of possible steam carry over. After I left the meeting, I thought of the following examples:

Consider a 0.54-inch diameter bubble of air and steam in a pool of subcooled water. The diffusivity of steam in air is about 0.25 cm^2/sec at room temperature and increases almost by the temperature ratio raised to the 3/2 power. As an order-of-magnitude estimation, consider the diffusion of steam in the 0.54-inch dia. sphere and estimate the time required to reduce the steam content to 50%, 1% and 0.1% of the initial steam content. Assuming that the diffusion rate is controlling, the surface concentration of the steam in the air bubble may be taken as zero. Unsteady-state diffusion in a sphere leads to the following results: $a = \frac{(0.54)(2.54)}{2} = 0.69$ cm

For $E = 0.5$, $\frac{D\theta}{a^2} = 0.03$, $\theta = \frac{0.03}{0.25}(0.69)^2 = 0.057$ seconds

$E = 0.01$, $\frac{D\theta}{a^2} = 0.41$, $\theta = \frac{0.41}{0.25}(0.69)^2 = 0.78$ seconds

$E = 0.001$, $\frac{D\theta}{a^2} = 0.65$, $\theta = \frac{0.65}{0.25}(0.69)^2 = 1.2$ seconds

Smaller bubbles and higher values for the diffusivity would yield shorter times for the fractional reductions.

These calculations are not sufficient to predict the steam carryover, but they do illustrate maximum rates for diffusion, and could be used by C. Robbins to further support his stand.

Herbert S. Isbin