UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION ON THE ACCEPTABILITY OF THE ANALYTICAL MODEL FOR PREDICTING VALVE DYNAMICS

I. Introduction

Mark I containments are equipped with simple check valves to serve as vacuum breakers to equalize any overpressure of the wetwell air space region relative to the drywell so that the reverse direction differential pressure will not exceed the design value. In general, the vacuum breakers will swing open when the wetwell air space pressure is 0.5 psi (or more) greater than the vent header pressure. Typical vacuum breaker arrangements for the Mark I plants are shown in Figure 1. As shown, internal vacuum breakers are located on the vent pipes, and external vacuum breakers are located in a supplementary piping system. Following the onset of a loss-of-coolant accident (LOCA) and during the chugging phase, caused by the rapid condensation of the steam at the vent exit, the vacuum breaker may be called upon to function in a cyclic manner. This is due to the fact that the chugging phenomenon is repeated on the average every two seconds causing strong dynamic underpressure conditions in the vent pipe, which depending on the chug strength may open the vacuum breaker with high velocity. The underpressure condition which normally lasts for about 5 msec is followed by a dynamic overpressure condition, which again depending on the strength of the chug, may close the vacuum breaker with high velocity. Failure of a vacuum breaker to reclose could result in a pathway for steam bypass of the pool, thus jeopardizing the integrity of the containment.

~~8502130414~~

II. Background

During the Mark I Full Scale Test Facility (FSTF) containment loads program, a GPE wetwell to drywell vacuum breaker was observed to cycle. Inspection of the valve after Test MI, which had the highest opening velocity, revealed that the pallet hinge was bent, the latching magnet was broken and indentation was observed in the valve casing which suggested that the pallet opened fully during the test. In other tests, there also was observed damage but it was limited to the pallet sealing gasket. MI was the only test in the FSTF test series which had fully opened the vacuum breaker. Having presented the test results it should be noted that the actuation velocities sustained in the FSTF test program are not considered to be prototypical. The results are considered very conservative because the drywell volume in the FSTF is much smaller than any domestic Mark I plant. For this reason, it was concluded in CDI report #84-3, that opening impacts and hence the vacuum breaker damage observed in test MI, are not anticipated in domestic Mark I plants.

III. Summary of the Topical Reports

Report CDI #82-31 describes the methodology used to predict the drywell to wetwell vacuum breaker cycling velocities, particularly when and if the valve disk strikes the full open stop or seat. Since the location of vacuum breakers vary from plant to plant, a need exists to quantify the ring header/wetwell pressure fluctuations for plant unique application. CDI report #84-3 describes an analytical model to extract condensation source time

histories from the FSTF test facility. After transferring these condensation sources to a model of an actual Mark I plant, the analytical model would compute the pressure time history across the disk of the vacuum breaker. Figure 2, extracted from CDI report 84-3, provides the steps followed to determine the plant unique vacuum breaker forcing functions.

III.1 Valve Dynamic Model Verification

The dynamics of the vacuum breaker, described in CDI report 82-31, is simulated in terms of the hydrodynamic torque about the valve shaft. This torque is as a consequence of a differential pressure across the valve disk. During run #S-DA of the FSTF tests, the vacuum breaker was instrumented such that the valve displacement and pressure differential across the valve disk were recorded. This information was used to verify the valve dynamic model as follows. By driving the valve dynamic model with the measured differential pressure across the valve from test #S-DA, predictions of valve displacement versus time were made and compared against the measured data from the same FSTF run #S-DA.

The results of this comparison indicated that the predicted impact velocities were greater than the experimental values by an average factor of more than 2½. This extreme conservatism was attributed to the fact that the valve dynamic model did not account for the reduction in the hydrodynamic torque as a result of the reduced static pressure across the valve disk due to flow computations. A parametric study was performed to reduce this

conservatism. The result was the development of a conservative yet realistic valve dynamic model described in CDI report #82-31. Comparison of the predicted valve impact velocities based on the improved model still bounded all test impact velocities with approximately a 12% margin.

It was, therefore, concluded in the CDI report #82-31 that the valve dynamic model is appropriate for the analysis and/or qualification of Mark I wetwell to drywell vacuum breaker.

III.2 Vent Dynamic Model Verification

The model described in CDI report #84-3 was developed to allow the development of unsteady condensation rate at the vent exit from the measured FSTF drywell pressure. A transfer function was developed which translates the condensation source at the vent exit to a pressure at any location in the vent system.

The pressure time history measured in the drywell was used with the transfer function to deduce the condensation rate at the vent exit. This source was then used with the transfer function to predict the unsteady pressure at a location in the vent header where measurements were taken. The comparisons between the measured and predicted pressures were favorable and, therefore, it was concluded that the transfer function model contains the essential elements required to predict pressure oscillations in Mark I steam vent systems. Since the condensation rate is fixed by local conditions at the vent exit, i.e.,

steam mass flow rate, noncondensibles and thermodynamic conditions, these conditions would only vary slightly between plants and, therefore, the condensation rate/source thus developed can be used in any Mark I facility to predict the unsteady pressure at the prescribed location of the vacuum breaker.

III.3 Selection of the Condensation Source

The FSTF test data were screened to determine the chugging events that produced the most severe actuation of the vacuum breaker, i.e., large impact velocities. Over 1000 seconds of chugging data were recorded in which 400 distinct chug events actuated the vacuum breaker 179 times. Three runs were noted to have significant chugging: runs M1, M4 and M9. Data from these runs were used to drive the vacuum breaker valve described in Section III.1 to determine the maximum impacts of the valve disk on the body and the seat of the valve. It was determined by CDI that the time interval 65.9-105.9 seconds of run M1 would bound all FSTF data including those that caused the valve damage in test M1; therefore, the 65.9 to 105.9 seconds time interval was chosen to determine the condensation rate as described in Section III.2

IV. Plant Unique Application

The transfer function discussed in Section III.2 is modified for plant unique application by inputting the 1) drywell volume/total vent area, 2) pool submergence and 3) damping due to external piping length (for the six Mark I plants that have external vacuum breakers). The condensation rate discussed

in Section III.3 is used with the plant unique modified transfer function to compute the pressure on the vent side of the vacuum breaker disk and the wetwell air space pressure. A sensitivity study of the vent dynamic model demonstrated that the wetwell air space pressure is insensitive to the wetwell air space volume. (Pool pressure coefficient in response to question 4 represents the wetwell air space volume in the sensitivity study). Therefore, this volume is not considered as a plant unique input in the model. These two pressures are then subtracted, multiplied by a load factor of 1.07 (to account for uncertainty in calculating the underpressure) and applied across the vacuum breaker valve dynamic model discussed in Section III.1 to obtain disk actuation velocities.

V. Staff's Evaluation and Recommendation

During the review of the information presented in the CDI reports, the staff expressed concern on weather the damage sustained to the valve installed on the FSTF could occur in domestic Mark I plants. The staff also expressed concern that using the methodology, no opening impacts were anticipated in Mark I plants even though the valve that was installed on the FSTF had an opening impact during test M1.

In response to these concerns, CDI stated that the vacuum breaker response in the FSTF was not prototypical and is very conservative. This is due to the fact that the drywell volume/total vent area ratio in the FSTF is much smaller than any domestic Mark I plant. CDI contends that this ratio has a significant

influence on the pressure oscillation in the ring header and in turn, an influence on the load across the vacuum breaker. To illustrate this point, CDI provided the results of analyses which showed that the vent pressure monotonically decreases with increasing drywell volume/vent area ratio. The calculated load across the vacuum breaker would also decrease as this ratio increased. Based on the above, CDI concluded that the large opening impact velocities and valve damage experienced during the FSTF test M1 are unlikely to occur in any domestic Mark I plant.

Based on our review of the methods and assumptions described in the CDI reports, and the response to the request for additional information (RAI), we conclude that the valve dynamic model conservatively predicts valve opening and closing velocities and, therefore, is acceptable for use in the analysis and/or qualification of Mark I wetwell to drywell vacuum breakers subject to the following restrictions:

1. The plant unique loads are to be computed using one of two drywell models which result in the most conservative prediction. One model examined by CDI represents the drywell by a capacitance in the vent dynamic model as discussed in Section III.2. The other model divides the drywell into two cylinders; treating each volume as an acoustic circuit in the vent dynamic model;

2. The value of all plant unique parameters inputted to the models to obtain plant-unique wetwell to drywell vacuum breaker load definitions should be provided with the results; and

3. Any plant-unique deviations of the methodology and/or assumptions that were found acceptable in this report should be identified. Additionally, the rationale and justification for the proposed alternative method and/or assumptions should be provided. Justification should include the identification of the conservatism associated with the deviation.

Principal Contributor: F. Eltawila

Dated: December 24, 1984

REFERENCES

1. CDI TECH NOTE 82-31, "Mark I Vacuum Breaker Improved Dynamic Model - Model Development and Validation."

2. CDI Report No. 84-3, "Mark I Wetwell to Drywell Vacuum Breaker Load Methodology."

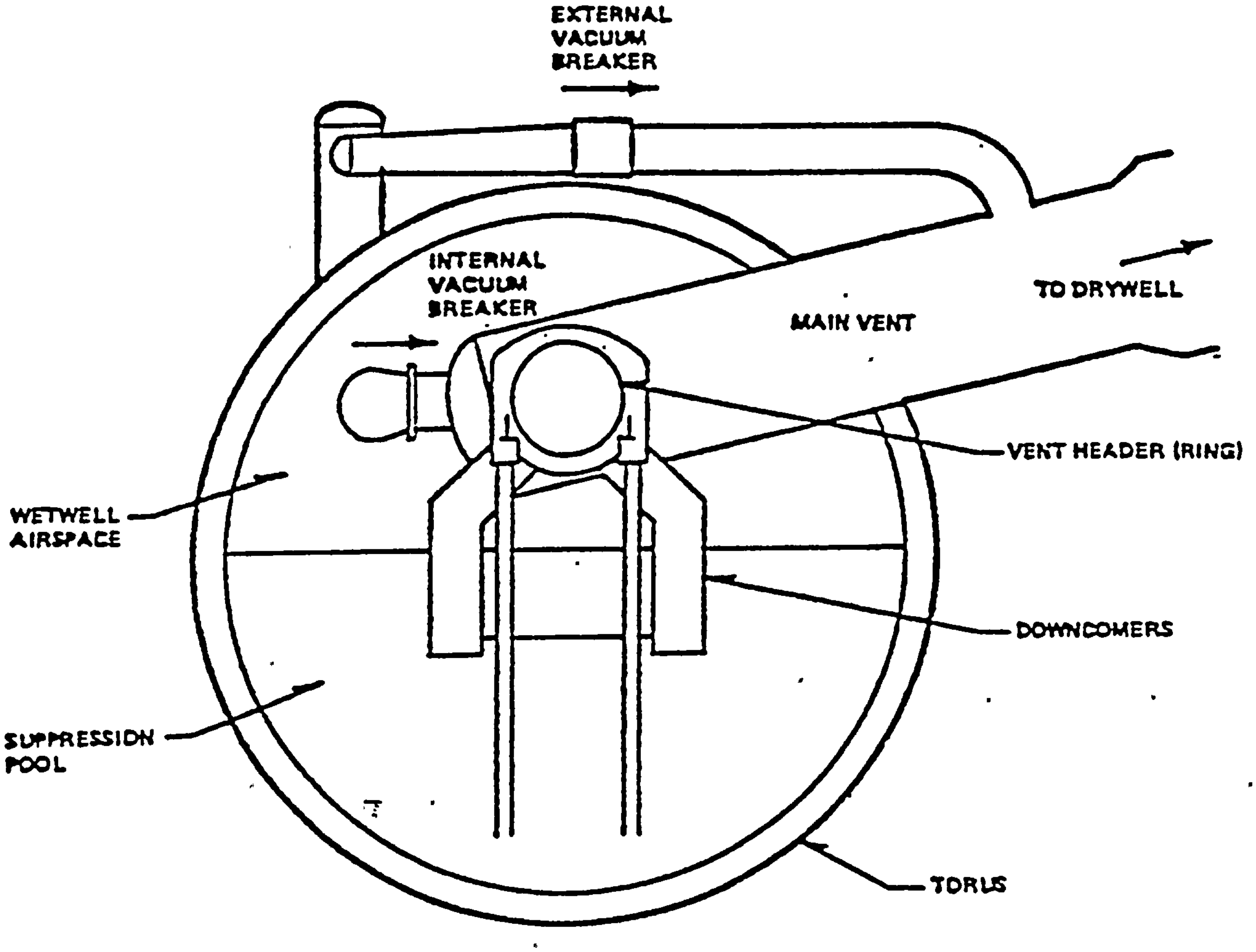

Figure 1 Mark I Vacuum Breaker Location

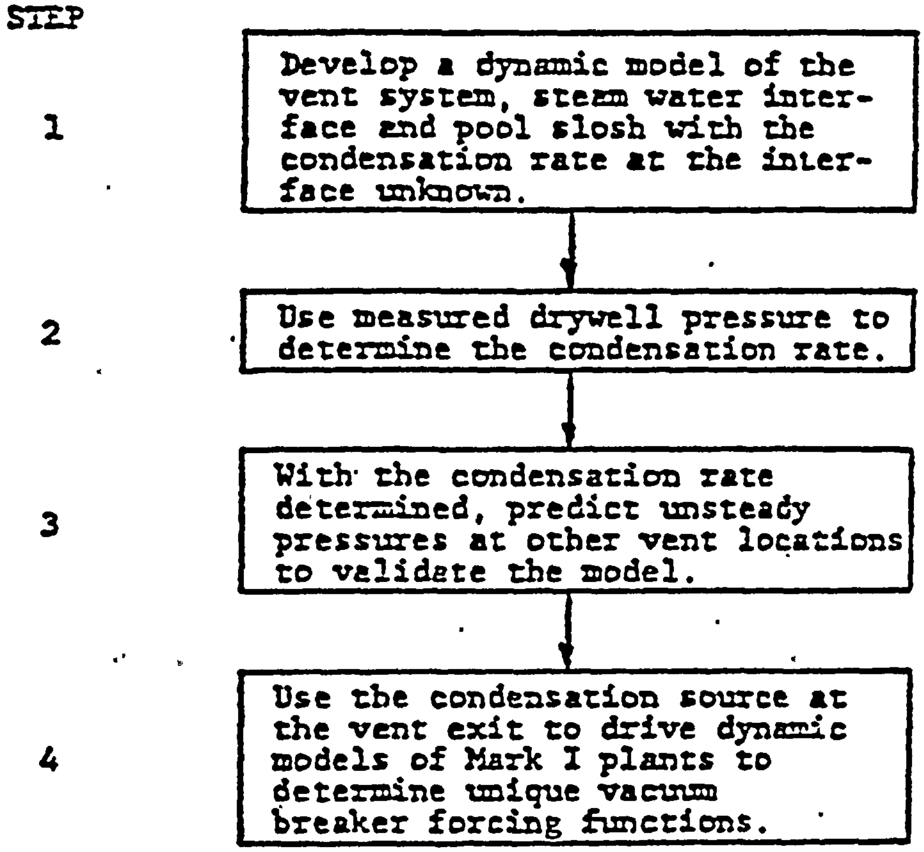

Figure 2 Steps in determining plant unique vacuum breaker forcing functions