COMPARISON OF CONDENSATION OSCILLATION AND CHUGGING LOADS FOR ASSESSMENT OF WPPSS NUCLEAR PROJECT NO. 2

SUMMARY REPORT

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for application to

WASHINGTON PUBLIC POWER SUPPLY SYSTEM

NUCLEAR PROJECT NO. 2

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1.0 INTRODUCTION AND SUMMARY

In Supply System's Reference (1) letter it was noted that submittal for NRC's review of plant-unique load definitions and application methodologies for WNP-2 was practically completed with transmittal of chugging and SRV discharge reports with References (2) and (3), respectively. In the same Reference (1) letter the Supply System indicated that it did not anticipate the need to assess the WNP-2 plant for the effects of condensation oscillations since results from LOCA steam condensation tests both in the full-scale single-vent 4TCO facility and in the full-scale multi-vent JAERI facility (representative of Mark II containment geometry) have indicated that the condensation oscillation (C.O.) load is smaller than the chugging load.

This report summarizes results of evaluation studies performed by Burns and Roe, Inc. to compare the C.O. and chugging loads. The main findings of these studies are:

- The C.O. load recorded at individual vent exits is characterized by randomly varying amplitude and frequency content (see Sections 3.1 and 4.1), similar to the chugging load (Reference (7));
- in a multi-vent configuration (JAERI facility) the C.O. loads recorded at different vent exits are desynchronized in a random manner (see Section 4.1), similar to the chugging load (Reference (7)); and,

- in a single-vent configuration (4TCO facility) the bounding boundary pressure traces recorded during C.O. are enveloped by the bounding boundary pressure traces corresponding to the design chugging load for WNP-2 with the exception of two C.O. traces characterized by low frequency content (<7.0 Hz) and which do not control the WNP-2 design.

As a result, it is expected that in the multi-vent Mark II containment configuration the boundary pressures during C.O. will be smaller than those due to chugging. Available data from full-scale multi-vent tests is supportive of this statement (Reference (6)). It is therefore concluded that the C.O. load does not represent a governing load and, consequently, need not be considered when assessing design adequacy of WNP-2 safety features: structures, piping and equipment.

2.0 GENERIC CONDENSATION OSCILLATION (C.O.) LOAD DEFINITION

2.1 SUMMARY REVIEW

The generic C.O. load definition described in Reference (4) report, is based on direct application to Mark II containment structures of pressure measurements from the full-scale single-vent 4TCO tests. For the wetted wetwell perimeter bounding pressure time windows recorded at the bottom center of the 4TCO tank were selected on the basis of power by frequency (PSD) analysis. These bounding pressure time windows are applied as "rigid wall" loads to the containment structure in an axisymmetric manner as shown in Figure 1. Concurrent drywell pressure time histories are identified and applied in a similar manner. Since drywell pressures are of small amplitude and slowly varying with time their effect is unimportant.

Two load cases are defined in Reference (4) report:

- the basic C.O. load, bounding for any C.O. condition expected during a hypothetical LOCA in a Mark II plant; and,

- the (much smaller) C.O. load for combination with ADS, bounding for any C.O. condition expected during a hypothetical LOCA in a Mark II plant when ADS actuation may be experienced.

The definitions of both C.O. load cases are based on the same "bounding" approach and utilize the single-vent 4TCO test data conservatively representative of Mark II plant conditions during LOCA.

2.2 AREAS OF CONSERVATISM

In the Reference (4) report it is noted that the generic C.O. load definition is inherently conservative since it does not account for the multivent Mark II geometry in connection with the random character of the load; also the 4TCO data used have not been adjusted to take credit for. fluid-structure interaction effects in the 4TCO test facility.

2.3 REPRESENTATIVE TEST DATA

2.3.1 4TCO TESTS

As noted in Section 2.1 the generic C.O. load definition was derived from the full-scale single-vent 4TCO condensation oscillation test results. Although, as discussed in Section 3.0 of this report, analysis of the data indicates that the C.O. load seen at the vent exit is random in nature, both in terms of its amplitude as well as its frequency content, the generic C.O. load definition conservatively envelopes the entire data base. Thus an important characteristic of the C.O. load, its randomness, is excluded from the load definition.

2.3.2 JAERI TESTS

Test data most representative for Mark II containments, and consequently most useful for the present discussion, was developed in JAERI's full-scale (multivent) Mark II CRT test program. The test matrix implemented as of March 1981 is shown in Table 1. To date, although data

reduction was completed for all tests indicated in Table 1 (as well as 3 additional tests, see Reference (6)) data evaluation results were provided with the Reference (5) report* only for eight early tests identified in Table 1 as tests No. 0002, 0003, 0004, 1101, 2101, 3101, 3102 and 1201. The remainder of the data will be covered in reports expected to be published in early 1982.

Analysis of JAERI data (see Section 4.0 of this report) confirmed the random nature of the C.O. load seen by individual vent outlets and, furthermore, established that pressure oscillations recorded at different vent exits during the same tests were desynchonized in a random manner. Random desynchronization is another important characteristic of the C.O. load not accounted for in the generic load definition.

*This report is expected to become available in early (February?) 1982. An advanced copy of the report was made available to Burns & Roe, Inc. by Dr. Shiba/JAERI.

3.0 EVALUATION OF 4TCO C.O. DATA

3.1 C.O. PRESSURE TRACES

The pressure traces recorded at different locations on the 4TCO tank wall (see Figure 2) during the C.O. time windows were studied. Several characteristics of these pressure traces were noted and are summarized below.

i. Temporal Behavior

Examination of the recorded pressure time histories are indicative of the impulsive and transient nature of the phenomenon. Figure 3a, as a typical example, indicates a quickly decaying pressure wave generated by an impulsive load repeated twice. For some recorded pressure traces this impulsive and transient characteristic wave form is superimposed on a more "steady state" like wave form described by lower frequency content, as illustrated in Figures 4A and 5A. These pressure time histories are characteristic for most C.O. time windows.

ii. Frequency Content

Examination of the amplitude of frequency spectra (see Figures 3B, 4B, and 5B) of the recorded pressure traces discussed in (i) above show wide band high frequency content, (as high as 50.0 Hz.). This indicates that the controlling forcing function at the vent exit during these events is of short duration, i.e., impulsive.

iii. Spatial Distribution of Amplitudes

The spatial distribution of the amplitude of the frequency spectra was found to be highly frequency dependent, as shown in Figure 6. This indicates that during C.O. different hydrodynamic modes are excited in the 4TCO system. The same was found to be true during chugging (Reference (7)).

iv. Randomness of the C.O. Data

The frequency content, as well as the pressure amplitudes, were found to vary randomly between different C.O. time windows. This indicates the random nature of the C.O. load.

These characteristics of the C.O. pressure traces are found to be similar to those observed in the chugging traces (Reference (7)).

3.2 COMPARISON BETWEEN MEASURED C.O. AND CHUGGING IN THE 4TCO SYSTEM

Similarities in the 4TCO system behavior during both C.O. and Chugging events were noted and described in Section 3.1. It is of interest to compare the pressures recorded on the 4TCO boundary during both these events: C.O. and chugging. The envelope of frequency spectra amplitudes of pressures recorded at the 4TCO bottom center during C.O. is shown in Figure 7. In the same figure it is also shown the envelope of frequency spectra amplitudes at the same location when chugging design sources (Reference (7)) are applied at the vent exit of the finite element model of the 4TCO tank. The

chugging design sources envelope the C.O. test data everywhere and by a significant margin, except at two frequency zones in the lower frequency range (<7.0 Hz.). These two frequency zones were identified to correspond to the following C.O. time windows:

i. Test #9, start time 19.5 sec., end time 21.5 sec.

ii. Test #22, start time 12.5 sec., end time 14.5 sec.

The pressure time histories and associated frequency spectra for these two time windows are shown in Figures 8 and 9, respectively. In order to assess the effects these two pressure traces will have on WNP-2 design, the reactor building model response to these two pressure traces was calculated. The load (pressure traces) were applied as described in Figure 1. The calculated building responses due to either of the two wave forms were found to be less than the calculated building responses due to design chugging sources, as illustrated, at a critical location, in Figure 10.

3.3 CONCLUDING REMARKS

Similarities in the behavior of the 4TCO System during both C.O. and chugging events were established. The design chugging loads were found to envelope the measured C.O. load by a wide margin except at two frequency zones. However, the WNP-2 responses to the C.O. load corresponding to these two frequency zones were found to be smaller than the responses to the chugging design load.

4.0 EVALUATION OF JAERI C.O. DATA

4.1 RANDOM CHARACTER OF C.O. LOAD/MULTIVENT GEOMETRY EFFECTS

Although not quantified, the random nature of the C.O. load and desynchronization of pressure oscillation in the vents during C.O. was well established. Desynchronization is evident from comparative examination of pressure oscillations recorded at different vent outlets during test 3102*, shown in Figure 11.

Examination of PSD functions for pressures at different vent outlets plotted in Figures 12, 13, 14 and 15 (available from Reference (8)) indicates the random nature of the single vent C.O. load, in terms of amplitude and frequency content. Coherence functions for pressures at different vent outlet pairs plotted in Figures 12 to 15 indicate that there is no correlation between vents. Furthermore, examination of phase angle plots from same figures indicate that the phase angle between different vent outlet pairs varies randomly.

In summary, the above findings indicate the following:

- The C.O. load at individual vent exits is characterized by randomly varying amplitude and frequency content; and,

- in a multivent configuration, the C.O. loads recorded at different vent exits are desynchronized in a random manner and no correlation exists between the individual vent loads.

*Test 3102 is used as an example since it was reported (Reference (6)) to have produced the largest C.O. loads [illegible]

In view of these findings, one concludes that the C.O. load actually seen by a Mark II containment structure will be smaller than the envelope of boundary pressures recorded in the single vent 4TCO test facility, presently recommended to be used as a design load (see Reference (4)). This is verified by the rather small C.O. loads recorded in the JAERI multi-vent test facility relative to those recorded in the 4TCO single-vent test facility at comparable test conditions, as illustrated by comparative examination of Figures 16 and 17, or Figures 18 and 19, respectively (see Reference (4)).

5.0 CONCLUSIONS

Evaluation of 4TCO's full-scale single vent and JAERI's full-scale multivent (representative of Mark II containment configuration) LOCA steam condensation test data resulted in the following conclusions:

- The C.O. load recorded at individual vent exits is random in nature, from the viewpoint of both amplitude and frequency content, and thus similar to the chugging load, (Reference (7));

- The C.O. loads recorded at different vent exits in a multivent configuration occur in a desynchronized and random manner, similar to chugging loads (Reference (7));

- In a single-vent configuration (4TCO facility) the bounding boundary pressure traces recorded during C.O. are enveloped by the bounding boundary pressure traces corresponding to the design chugging load for WNP-2 with the exception of two C.O. traces characterized by low frequency content (<7.0 Hz); it has been determined that these two traces are not governing in the WNP-2 design.

As a result, in a Mark II (multivent) containment configuration the boundary pressures induced during the C.O. phase of steam condensations are expected to be smaller than those induced by chugging. Available test data is supportive of this statement (Reference (8)).

It is concluded that the C.O. load does not represent a governing load and need not be considered for assessing the design adequacy of WNP-2 structures, piping and equipment.

6.0 References:

1. Letter, G02-81-239, G.D. Bouchey, Supply System, to R. L. Tedesco, NRC, dated August 13, 1981.

2. Letter, G02-81-189, G. D. Bouchey, Supply System, to R. L. Tedesco, NRC, dated July 22, 1981.

3. Letter, G02-80-172, D. L. Renberger, Supply System, to B. J. Youngblood, NRC, dated August 8, 1981.

4. "Generic Condensation Oscillation Load Definition Report", General Electric Co. Report NEDE-24288-P (Proprietary), dated November 1980.

5. "Statistical Evaluation of Steam Condensation Loads in Pressure Suppression Pool - Full Scale Mark II CRT Program Test Evaluation Report No. 2," JAERI Report M 9665, dated October 27, 1981.*

6. "Status of JAERI Full-Scale Mark II CRT Data Evaluation", Private Communication, H. Aoki, Toshiba Corporation, to B. Bedrosian, Burns and Roe, Inc., October 1981. (Proprietary)

7. "Chugging Loads - Revised Definition and Application Methodology for Mark II Containments (based on 4TCO test results)", Technical Report (Proprietary), prepared by Burns and Roe, Inc. for application to Washington Public Power Supply System, Nuclear Project No. 2, dated 7/21/81.

8. Forwarding of JAERI proprietary reports and information. Note from F. Eltawila/NRC to Dr. D. Roth/Mark II Owners Group, et al., Oct. 27, 1980.

*This report is expected to become available in early (February?) 1982. An advanced copy of the report was made available to Burns and Roe, Inc. by Dr. Shiba/JAERI.

TABLES AND FIGURES

The tables and figures are proprietary to the General Electric Company and Burns and Roe, Inc. and are included in a proprietary version of this report.