50 - 254

DOCKET NO. ~~50 - 265~~

Regulatory Suppl File Cy.

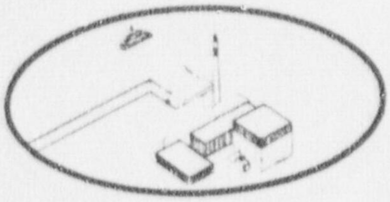
Received w/Ltr Dated [illegible]

QUAD-CITIES STATION

UNITS 1 AND 2

AMENDMENT 5

DOCKETED
USAEC
NOV 14 1967
REGULATORY
MAIL SECTION
DOCKET CLERK



Commonwealth Edison Company

REGULATORY DOCKET FILE COPY

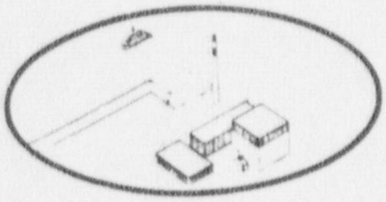
DOCKET NO.

3760

QUAD-CITIES STATION

UNITS 1 AND 2

AMENDMENT 5



Commonwealth Edison Company

TABLE OF CONTENTS

I. INTRODUCTION AND SUMMARY

This report and attached appendix presents an analysis upon which the deletion of the suppression chamber baffles in Quad-Cities Units 1 and 2 is based. In the case of Quad-Cities Unit 1, construction of the suppression chamber has reached a point where the baffles have been installed: however, it is planned that they be removed at some future date. For Quad-Cities Unit 2, construction of the suppression chamber is in an early stage, and omission of the baffles is feasible and desirable.

II BASES FOR BAFFLE REMOVAL

The suppression chamber baffles were originally included in the design to prevent a short term overpressure of some 6 psig as observed in a series of 1/4 scale tests performed at Moss Landing. The basis for their removal is three fold:

1. The suppression chamber design pressure is 62 psig rather than 35 psig, as first proposed for Dresden Unit 2. Therefore, even if the observed overpressure were to occur, the design pressure of the suppression chamber would not be exceeded.
2. Convincing evidence exists that the overpressure would not occur in a full scale geometry.
3. The installation of baffles is not required to prevent azimuthal sloshing, uniform distribution, or other fluid perturbations.

III. MARGIN IN DESIGN PRESSURE TO ACCOMMODATE SHORT-TERM OVERPRESSURE

The design pressure for the drywell and suppression chamber for Dresden Units 2 and 3 (AEC Docket 50-237 and 50-249) and Quad-Cities Units 1 and 2 (AEC Docket 50-254 and 50-265) were established on the basis of the Bodega Bay pressure suppression tests.(1) The applications of these tests in the design of Dresden Unit 2 containment resulted in a drywell pressure of 62 psig and a suppression chamber pressure of 35 psig. However, to simplify future pneumatic tests of the primary containment, the suppression chamber design pressure was increased from 35 psig to 62 psig. The primary containment design pressures of Dresden Unit 3 and Quad-Cities Units 1 and 2 are the same as that for the revised Dresden Unit 2.

Item II. 1 above, is the keypoint in justifying the deletion of the baffles, i. e., the design pressure is much higher than the maximum pressure observed in any of the tests.

IV. OVERPRESSURE WOULD NOT OCCUR IN A FULL SCALE GEOMETRY

A. Description of Quarter Scale Bodega Bay Tests

The support of Item II. 2 is based on a detailed study of the test data available. In Figure 1 the measured pressure response of the suppression chamber is illustrated for the 1/4 scale tests with and without baffles and for the full scale tests which were, in essence, fully baffled. Note that with no baffles the suppression chamber pressure at about 0.7 seconds is greater than the end of transient pressure. This early overpressure was the original basis

---

(1) Bodega Bay Preliminary Hazards Summary Report, Appendix I, Docket 50-205, December 28, 1962.

for the baffles. Note also that at approximately the same time as the overpressure in the 1/4 scale tests, a pressure peak occurred in the full scale tests. However, in the full scale test the mean pressure was still low enough that the pressure peak did not exceed the end of transient pressure. This difference in mean pressure at the time of the peak was caused by a difference in the pressure rate in the suppression chamber. In the 1/4 scale tests, the drywell and suppression chamber volumes were reduced by 1/4. The downcomer diameter was also reduced by 1/4, which reduced the flow area per downcomer to approximately 1/16 of full scale. With fourteen downcomers the total vent flow area was approximately the same as full scale. Since the vent exit velocity was also the same for both tests, the total mass flow rate into the suppression chamber was the same. Therefore, the 1/4 smaller suppression chamber air volume was pressuriezed four times as fast. This results in accentuating the pressure peak for the 1/4 scale tests, since the average pressure at the time it occurred was much higher than for the full scale tests.

B. Analytical Explanation for the Pressure Peak

It is possible to calculate the suppression chamber mean pressure rise assuming complete condensation in the pool. The overpressure peak can be simulated by superimposing a mass flow into the suppression chamber air volume which is condensed after a short delay. It has been determined that a sinusoidal input can reasonably reproduce the quarter scale test pressure response with and without baffles (see Appendix 1). Applying the same input to the full scale tests confirms that the pressure peak would not exceed the end of transient pressure.

It might be postulated that the time constant of the sinusoidal input should be greater for the full scale geometry. If a time constant four times greater than the quarter scale tests is assumed in calculating the full scale pressure response a pressure in excess of the end of transient pressure is obtained. However, the overpressure is only a few psi and would be of no concern with the higher design pressure. Further, the superimposed steam flow rate exceeds the total steam flow rate making delayed condensation to this extent impossible. The test data also indicates that the time constant should not be four times greater than for the quarter scale tests. First, there was the pressure peak in the full scale test at about 0.7 second. Second, movies taken of the Humboldt tests showed violent splashing of the water initially, but after about one second the water in the pool settled down to a relatively calm bubbling type phenomena. The delayed condensation is postulated to occur during the initial violent pool action when the water has been thrown away from the downcomer exit by the incoming steam-air mixture. The time required for the water to rise and fall back to the pool should be approximately the same for both full scale and quarter scale geometry. Hence, the pressure peak should occur at about the same time in both geometries. The test data confirm this hypothesis. Therefore: it is concluded that the overpressure observed in the 1/4 scale tests would be manifested as a pressure peak less than the end of transient pressure in a full scale geometry.

V. AZIMUTHAL SLOSHING

The basis for using baffles to control or limit azimuthal sloshing of water in suppression chamber is based upon two postulated effects, i.e.:

1. Sloshing could result in large waves which might uncover the downcomer; and
2. Sloshing could result in danger to the vent header due to an uplifting force caused by large waves.

Neither of these postulated effects is of concern. Tests from both the Humboldt and Bodega series of pressure suppression tests proved that condensation would be complete even if the downcomers were uncovered during the blowdown; therefore, postulated uncovering of the downcomers is not cause for concern. With respect to the second postulated effect, the loading imposed by wave action is less than 30% of the loading imposed by jet action on the downcomers during venting. Since the jet action and the wave action will never be superimposed one upon the other, the design of the vent header to withstand the larger force from the jet action aborts any concern with respect to wave action. Further, it is highly improbable that a large wave would be established in the first place. The natural frequency of the pool is quite low (on the order of 0.1 cps for large waves) and there is no apparent exciting force of a sufficiently low frequency to establish a large wave. The venting action would be a uniform (circumferentially) high frequency loading which, at most, would exit many small waves, but not a large wave. The small waves would not have a large enough amplitude to be of any concern and would die out quite rapidly, therefore, large waves are not likely to be established.

Finally, the vents will blowdown nearly uniformly since the resistance of the vents is much higher than the resistance encountered by the flow traversing the drywell to any of the vents. This should preclude any inherent tendency to initiate sloshing in the first phase.

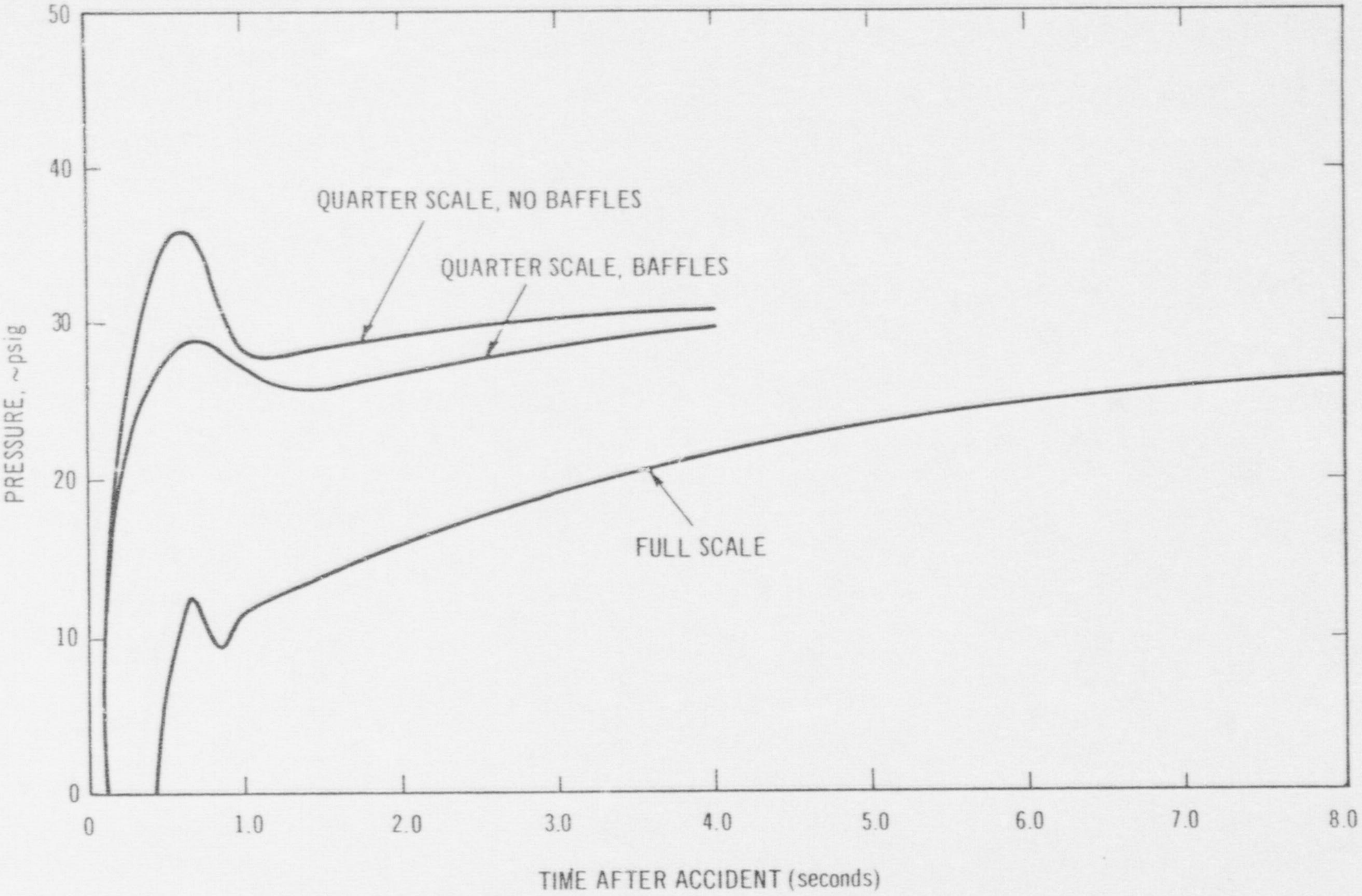


FIGURE 1. SUPPRESSION CHAMBER PRESSURE RESPONSE FROM FULL SCALE AND QUARTER SCALE TESTS

APPENDIX 1

In order to obtain a quantitative feel for the degree of delayed condensation required to cause the overpressure observed in the 1/4 scale tests, a simplified model was analyzed. The model analyzed can be outlined as follows:

1. Constant total mass flow rate from the drywell is assumed and the fraction of steam and air is determined assuming ideal mixing and constant pressure in the drywell.
2. Assuming complete condensation of the steam, the pressure response of the suppression chamber is calculated. The suppression chamber air space is assumed to be isothermal and constant volume.
3. To simulate steam added to the suppression chamber, but not condensed, an additional mass addition is made to the air volume. An equal negative mass addition later simulates the delayed condensation of this steam. One complete sine wave is used to accomplish the mass addition and removal.
4. The total pressure response is calculated for the quarter scale tests with and without baffles. The magnitude of the sinusoidal mass flow of part 3 is selected to agree with the experimental data.
5. Using the same constants derived in 4 the pressure response for the full scale test is calculated and compared with the data.
6. The effects of changes in some of the key constants are discussed.

Analysis

By assuming ideal mixing in the drywell the ratio of steam flow to total flow can be approximated by:

$$\frac{\dot{m}_e}{\dot{m}_t} = 1 - e^{-\lambda t} \tag{1}$$

The constant λ is a function of the total mass flow rate and the air volume of the drywell and suppression chamber. For the 1/4 scale tests $\lambda = 4.61$ while for the full scale tests $\lambda = 0.77$.

Assuming an ideal gas in the suppression chamber

$$P = \frac{M_{as} RT}{V_{as}}$$

For variable mass

$$P(t) = \frac{RT}{V_{as}} M(t) \tag{2}$$

Where:

$$M(t) = M_o + \int_o^t \dot{m}_{nc}\,dt \qquad (3)$$

Assuming complete condensation of the steam, the flow into the suppression chamber free volume is:

$$\dot{m}_{nc} = \dot{m}_T - \dot{m}_g = \dot{m}_T \left(1 - \frac{\dot{m}_g}{\dot{m}_T}\right).$$

Substituting from (1)

$$\dot{m}_{nc} = \dot{m}_T\, e^{-\lambda t} \qquad (4)$$

$$\therefore P(t) = P_o + \frac{R\,T\,\dot{m}_T}{\lambda} \left(1 - e^{-\lambda t}\right) \qquad (5)$$

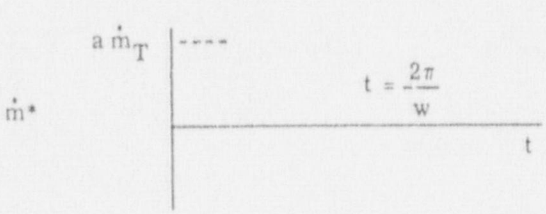
Equation (5) is compared with the test data in Figure 1-1 for both the full scale and quarter scale tests. For easy comparison, equation (5) has been nondimensionalized, and the test data normalized to agree with (5) at the end of transient.

In order to simulate the effects of delayed condensation, an additional mass flow into the suppression chamber was superimposed on the above flow. A sinusoidal input was arbitrarily assumed, i.e.

$$\dot{m}^* = a\,\dot{m}_T \,\mathrm{Sin}\,wt \qquad 0 \leq \frac{2\pi}{w}$$

$$\dot{m}^* = 0 \qquad t > \frac{2\pi}{w}$$

Where: a is a constant representing the maximum fraction of the total flow rate which is not condensed in addition to the flow given by equation (4).



The constant w was selected to give the peak overpressure at the time observed in the tests. Specifically w = 2 so that the steam is completely condensed at t = 1 second.

In Figure 1-2, the calculated responses for

$a = 0.136$

$a = 0.264$

are illustrated along with test data with and without baffles. Also shown in Figure 1-2 is the suppression chamber pressure response under the assumption of no condensation. As can be seen, the above analysis can reasonably reproduce the data if the correct constants are used.

Unfortunately, there is no way to á priori calculate the constants "a" and "w" for use in calculating the full scale response. As far as "w" is concerned, it seems reasonable to assume the same value as for the quarter scale tests, as discussed in the text of the cover letter. In Figure 1-3, the pressure response for the fully baffled full scale test is illustrated. The calculated responses assume $a = 0.3$ and $a = 0.9$. Two points should be noted:

1. The test pressure rate is faster than the calculated pressure rate for no condensation.

2. Assuming $a > 0.3$ results in $\dot{m}_{nc} + \dot{m}^* > \dot{m}_T$, i.e., air flow plus uncondensed steam flow is greater than the total flow rate, which is not physically possible.

Item (1) is due to a combination of effects. The most important are:

(a) A piston like action of the pool water which compresses the air in the free suppression chamber. This piston action apparently did not occur in the 1/4 scale tests, probably because the smaller water volume covering the downcomer exit broke up when hurled upward by the initial air blast.

(b) Initial flow rates in excess of the average value used in analysis.

In spite of the disparities between the calculated response and the measured response, one conclusion can still be reached. With $w > 2\pi$ overpressures in excess of the design pressure are not possible without some kind of piston action by the pool water. Such a piston action is more likely to be promoted by baffling rather than prevented.

In Figures 1-4 and 1-5, the calculated pressure responses for $w = \pi$ and $\pi/2$ are shown even though these values of w are not considered reasonable. For $w = \pi$, a pressure peak in excess of the end of transient pressure is obtained only for $a \geq 0.9$, which requires uncondensed flow greater than the total flow. Only when $w = \pi/2$ is an overpressure obtained for a reasonable value of "a". Even then, with $a = 0.3$, the overpressure only exceeds the end of transient pressure by about 3 psi. Recall that for the quarter scale tests, $a = 0.264$ correlated the overpressure reasonably well for the unbaffled case. Note, however, that for $w = \pi/2$, the full scale data cannot be approximated for any value of a. This fact further confirms the argument that w must equal approximately 2π.

In conclusion, if condensation of the steam flowing into the suppression chamber is complete after about one second pressure peak in excess of the end of transient, pressure cannot occur. Comparison of test data and analysis indicate that any delay in condensation will occur during the first one second of the transient. Therefore, baffles are not required in any design having suppression chamber pressure rates comparable to or less than the full scale Bodega Bay tests.

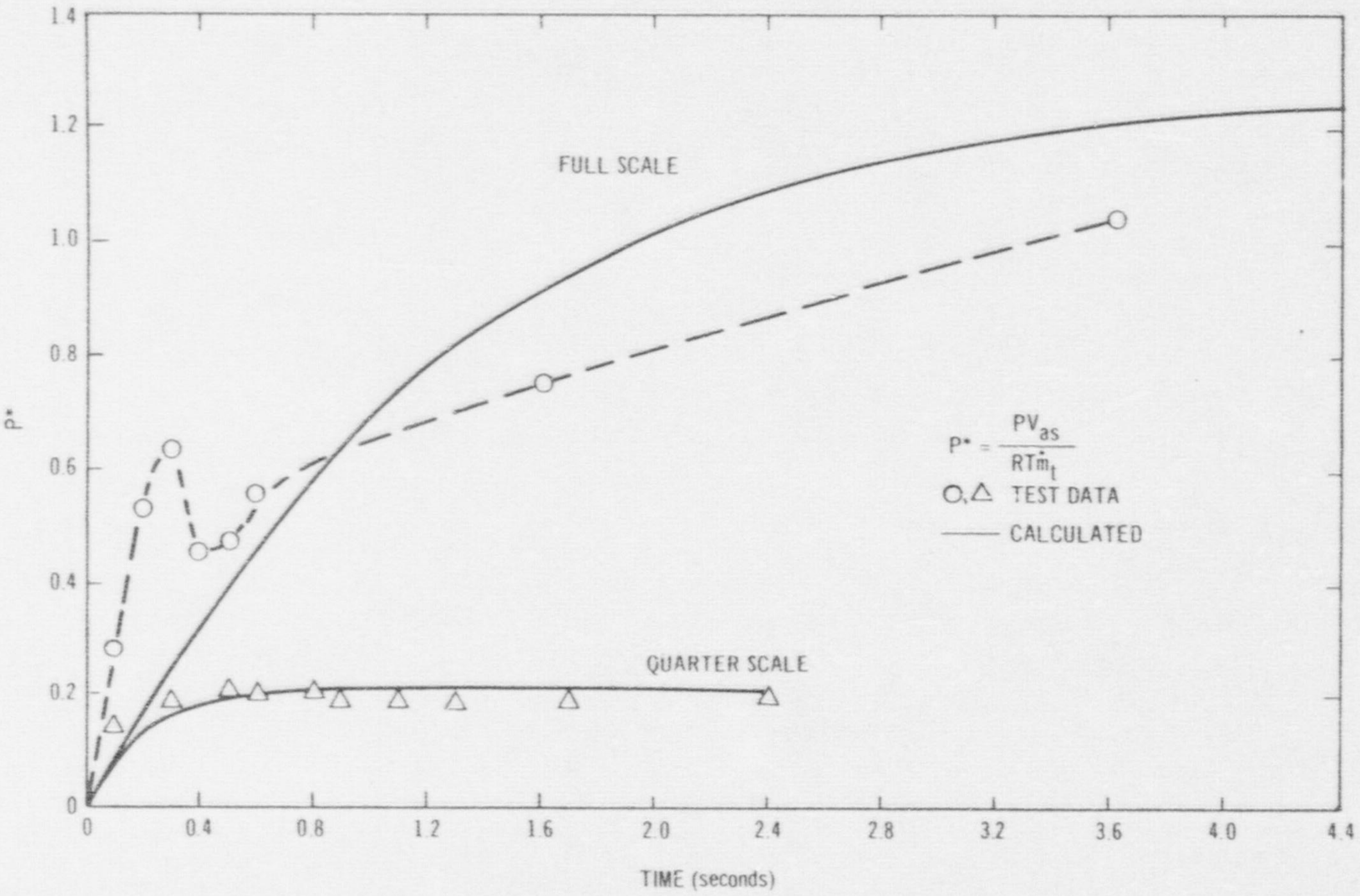


FIGURE 1-1. COMPARISON OF COMPLETE CONDENSATION MODEL AND TEST DATA

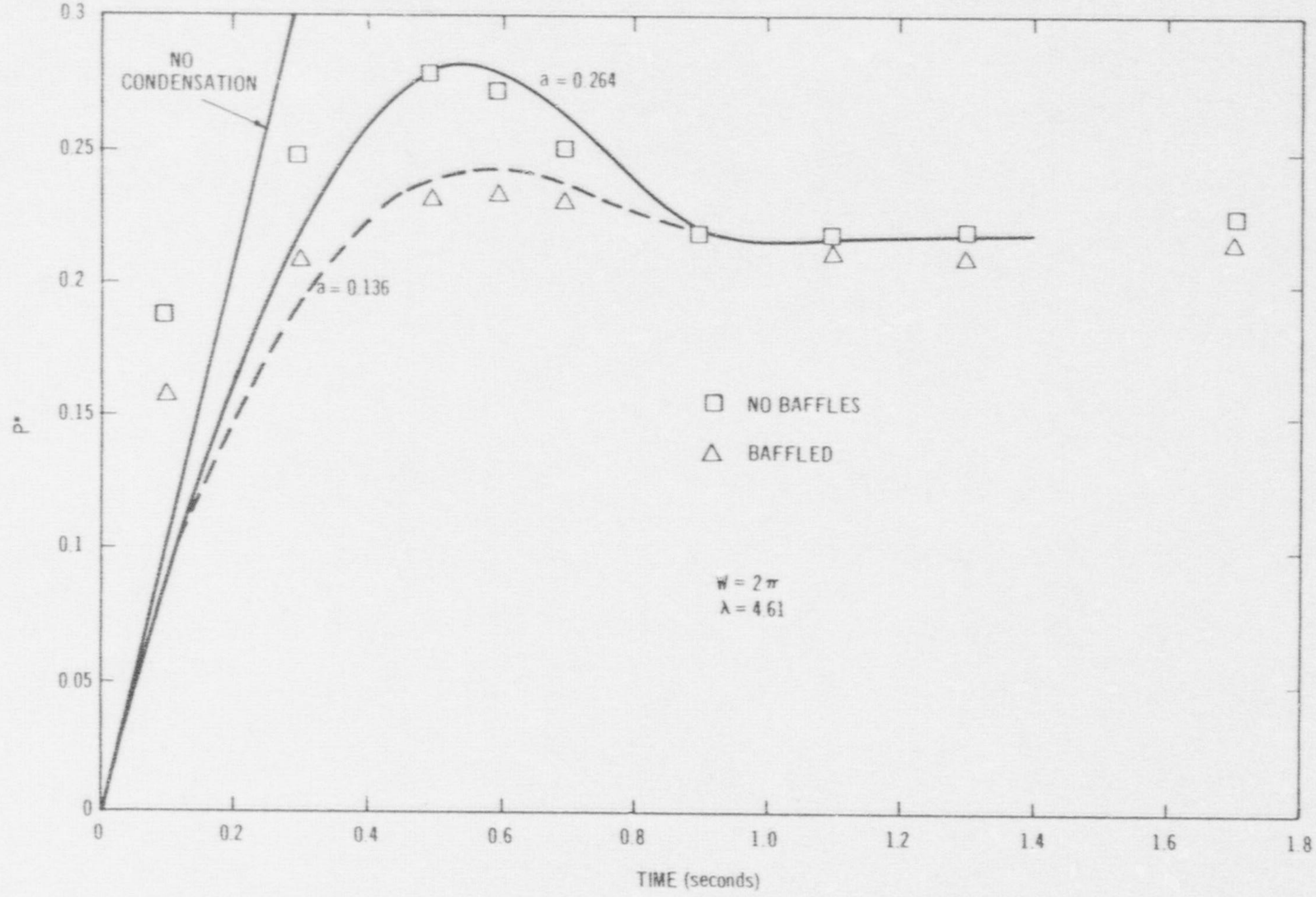


FIGURE 1-2. QUARTER SCALE TESTING

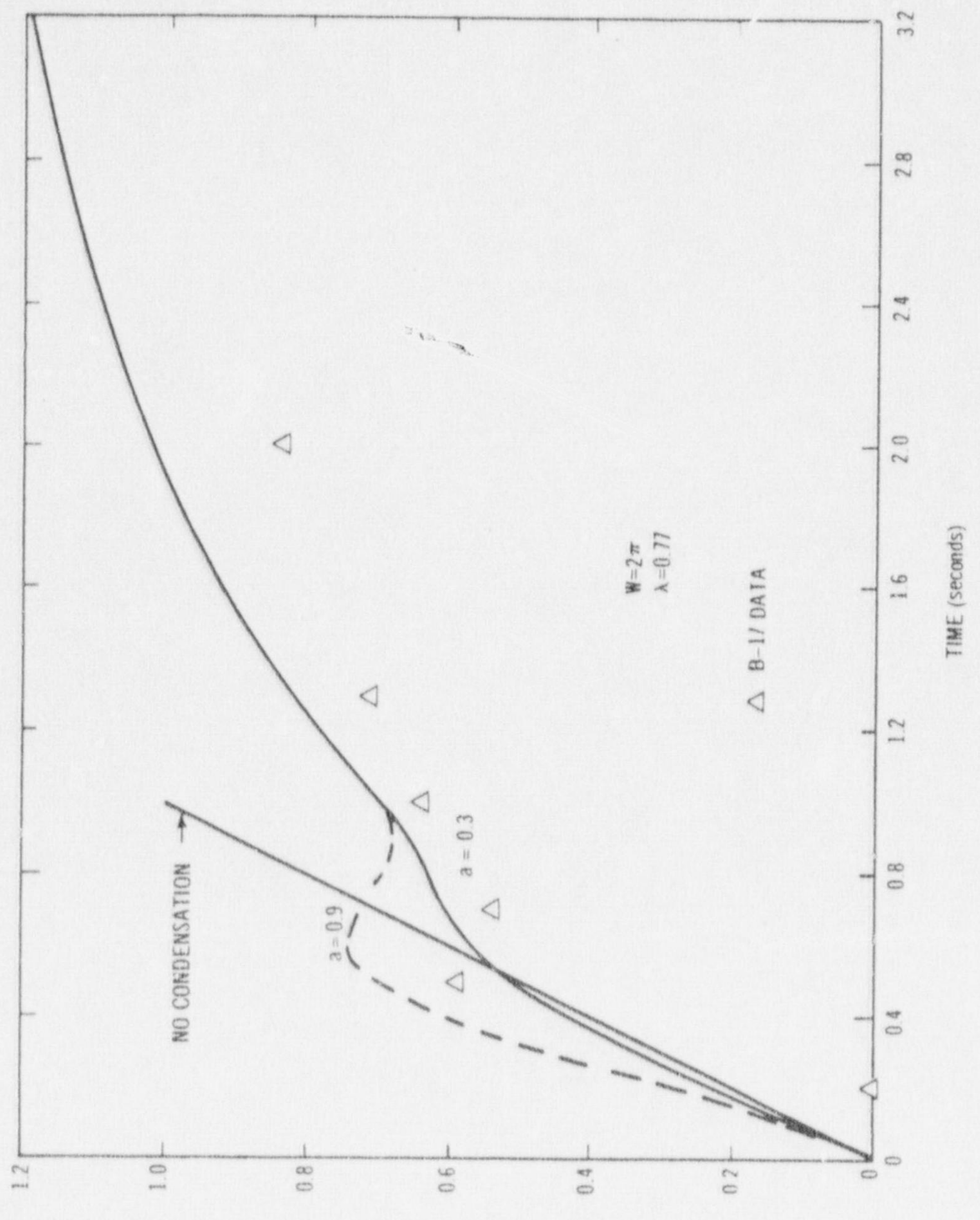


FIGURE 1-3. FULL SCALE TESTING

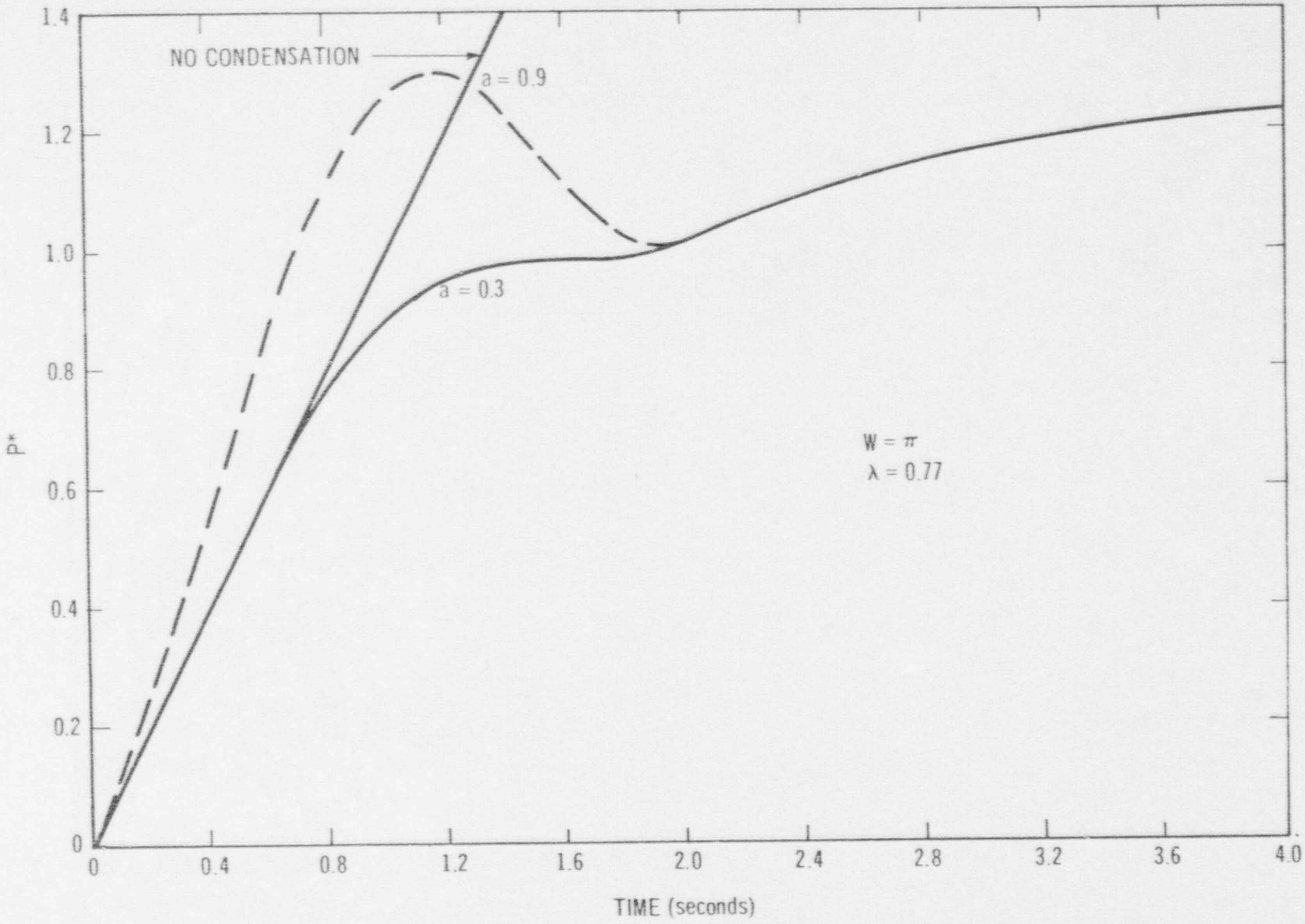


FIGURE 1-4. FULL SCALE TESTING

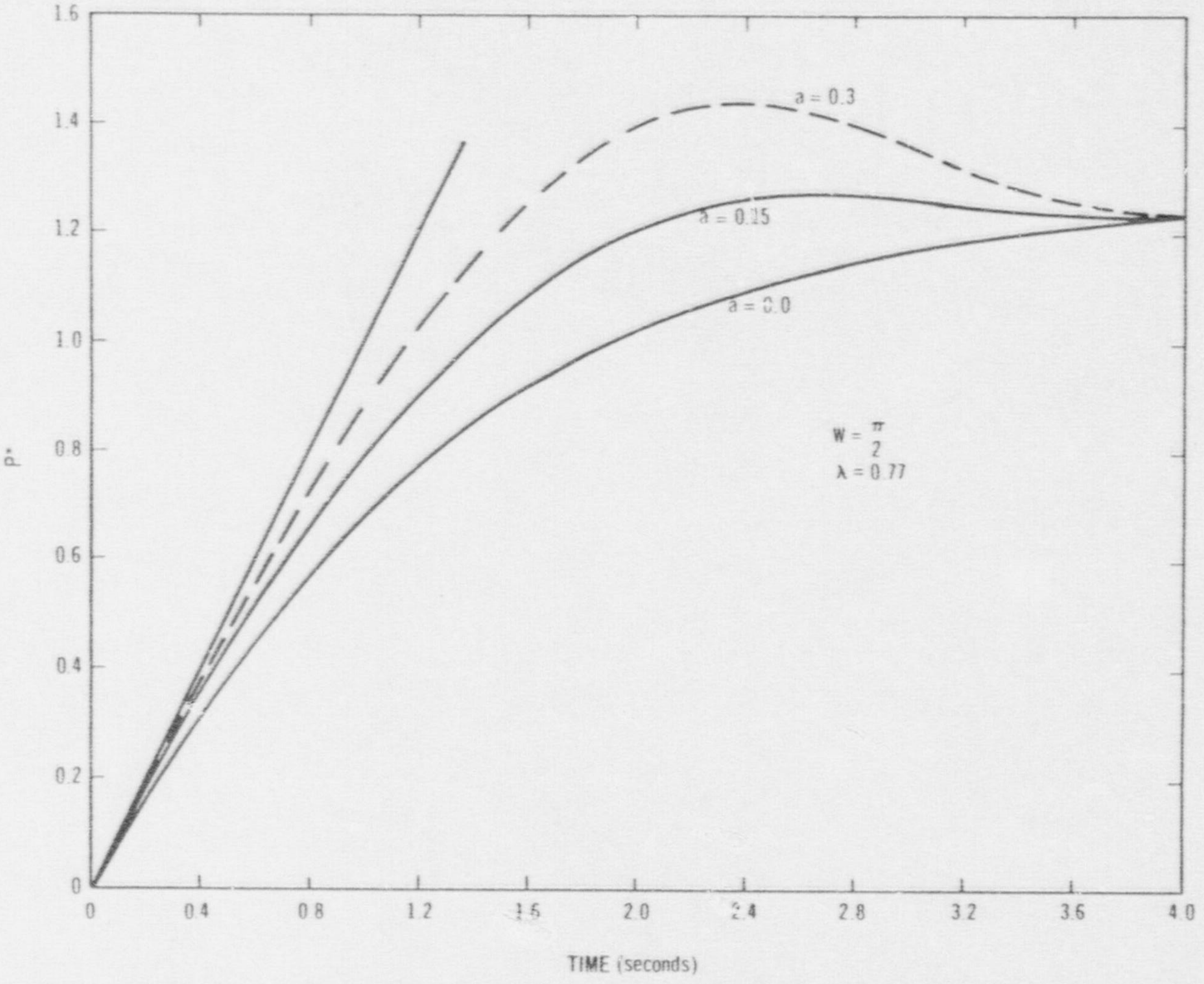


FIGURE 1-5. FULL SCALE TESTING

✓

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Distribution:
Suppl. (2)
RPB-3 Reading
Orig: FWKaras
R. S. Boyd
T. F. Engelhardt, OGC
C. G. Long

November 16, 1967

Docket Nos. 50-254
and 50-265

Mr. Nunzio Palladino
Chairman, Advisory Committee
on Reactor Safeguards
U. S. Atomic Energy Commission
Washington, D. C.

Dear Mr. Palladino:

Transmitted for the information of the Committee are three copies of the following:

COMMONWEALTH EDISON COMPANY
(Quad-Cities Station, Units 1 and 2)

Commonwealth Edison Company letter dated November 10, 1967, transmitting Amendment No. 5 to Application for Licenses for its proposed Quad-Cities Station Units 1 and 2.

Sincerely yours,

Peter A. Morris

Peter A. Morris, Director
Division of Reactor Licensing

Enclosures:
As stated above

OFFICE ▶	RPB-3/DRL					
SURNAME ▶	FWKaras/ltj					
DATE ▶	11/16/67					

8707070378 1p.