Docket File

52-003

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 21, 1996

APPLICANT: Westinghouse Electric Corporation

PROJECT: AP600

SUBJECT: SUMMARY OF MEETING TO DISCUSS AP600 REACTOR SYSTEM TESTING ISSUES

The Nuclear Regulatory Commission (NRC) staff and representatives of Westinghouse Electric Corporation held a meeting in on January 23 and 24, 1996, in Rockville, Maryland, to discuss AP600 testing issues. The issues included problems with the passive residual heat removal system (PRHR) testing program; questions raised during the review of ADS Phase B1 and Oregon State University Final Data Reports and Test Analysis reports; and general testing scaling concerns. Attachment 1 is a list of meeting attendees. Attachment 2 contains the agenda, and outline of the proposed Westinghouse scaling and PIRT closure report along with other handout materials provided during the meetings. Attachment 3 is a summary of specific discussions questions together with the Westinghouse responses.

Highlights of the discussion are summarized as follows:

PRHR

In view of the staff questions concerning the adequacy of the PRHR test program report, Westinghouse has committed to issue a revision to the PRHR final data report. The report will conform to the format of other AP600 test reports and provide relevant test data and associated analysis on a test-by-test basis.

Westinghouse discussed and clarified the flow rate data reduction methodology. Reduction equations were tailored to vendor orifice calibration information based at 14.7 psia and 68°F. Westinghouse noted that there is an error in the code during the conversion to mass flow rate due to use of the wrong density value (approximately 5 percent to 8 percent error). Westinghouse plans to rework the reduction code to provide a more straightforward analysis of the data. Westinghouse noted that this will also tend to drive the heat transfer correlations towards the expected Dittus-Boelter results.

Westinghouse also addressed secondary side heat transfer deviations. Westinghouse contends that pool boiling is not the dominant mode of heat transfer. Results appear to indicate that flow induced in the heat exchanger tube bundle is sufficient to make the heat transfer resemble convective boiling. However, wall temperature anomalies were not easily explained. Westinghouse does not consider them safety significant. They will attempt to address the anomalies in more detail in their revised PRHR report. Westinghouse also agreed to address dryout, scalibility, and single tube versus bundle concerns in their revised PRHR report.

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Discussions on the applicability of the PRHR testing to the AP600 and the possible need for additional testing were brought up. The staff favors some additional testing - possibly via ITAAC or during the initial test program. Westinghouse would prefer bounding analysis approach. Resolution of this issue will likely be subsequent to the supplemental DSER.

SCALING

Westinghouse and the staff reviewed the proposed outline for the scaling and PIRT closure report. Suggestions from the staff were incorporated into the final outline provided in Attachment 2. The staff had some differences with Westinghouse on how the scaling report will support the conclusions. Westinghouse intends to emphasize qualitative arguments. The staff would prefer a more quantitative approach. Westinghouse stated that they are looking to complete the report in May of 1996 and that it was considered to be a post supplemental DSER item. The staff stated that this would have to be resolved by NRC management during the current efforts to specifically identify the material to be included into the supplemental DSER.

TEST REPORT QUESTIONS

The specific test report questions and Westinghouse responses are provided in Attachment 3 to this letter. Those question responses in which the staff were not fully satisfied will be followed up with a formal RAI request.

original signed by:
William C. Huffman, Project Manager
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Office Of Nuclear Reactor Regulation

Docket No. 52-003

Attachments: As stated

cc w/attachments: See next page

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WESTINGHOUSE/NRC AP600
MEETING ATTENDEES
JANUARY 23 AND 24, 1995

NAME	ORGANIZATION
JOHN BUTLER	WESTINGHOUSE
LARRY HOCHREITER	WESTINGHOUSE
GENE PIPLICA	WESTINGHOUSE
PAUL BOEHNERT	ACRS (1/23/96 ONLY)
TIM LEE	RES (1/23/96 ONLY)
RALPH LANDRY	NRC (1/23/96 ONLY)
BILL HUFFMAN	NRC
ALAN LEVIN	NRC
MARCOS ORTIZ	INEL
ABDER OUGOUAG	INEL
SANDRA SLOAN	INEL
DOUG HALL	INEL (1/23/96 ONLY)

Attachment 1

HANDOUTS

PRESENTED AT THE JANUARY 23 AND 24, 1996

WESTINGHOUSE/NRC AP600 MEETING

Attachment 2

Proposed Agenda Items for Westinghouse Meeting

1. Passive Residual Heat Removal Heat Exchanger Test Program

   a. Data Reliability

      i. Conversion of millivolts data to engineering units

      ii. Anomalies in wall temperature data

   b. Use of data for model development (design and analysis)

      i. Deviation of data from conventional heat transfer correlations

      ii. Possibility of dryout in bundles

      iii. Prediction of local conditions

      iv. Prediction of overall HX operating performance

   c. Path to resolution of PRHR design certification testing issues

2. Scaling Closure

   a. Discussion of Westinghouse outline on closure report (assuming outline is provided by Westinghouse prior to meeting)

[Note: the RAIs recently provided (I hope--by the time we meet) to Westinghouse contain the "scaling closure" question. In addition, questions have been raised in other reviews along the lines of "how is Westinghouse planning to use these data?" While the use of the integral systems data is fairly clear (i.e., validation of the licensing basis analysis codes), the way in which insights/data/models derived from the separate effects tests are factored into the process is not at all clear. Westinghouse needs to make this issue a prominent feature of its discussion of scaling closure, and may want to address the issue at the meeting.]

3. Discussion and Clarification of Previous RAIs on Testing Program

4. Discussion of Progress of Continuing INEL Review of OSU TAR

   a. Clarification of "generic" questions from initial part of review (i.e., questions raised in initial RAIs that might be applicable to tests other than SB01 and SB18)

   b. Insights from questions raised in FDR RAIs that could assist INEL/staff in review of information in TAR

   c. Other sources of relevant information on test data analysis (e.g., code validation reports).

[Note: With respect to 4c, the staff realizes that the scope of the TAR is fairly limited. The main objectives, consistent with other TARs in the Westinghouse test program, is to provide a reasonably comprehensive qualitative discussion of the test facility response in the various experiments, backed by mass and energy balances that are intended to help bound the uncertainties in the test data. To the extent that additional relevant information is contained in the code V&V reports, which may help to provide insight into the thermal-hydraulic phenomena observed in the tests and in Westinghouse's ability to model them, these reports may need to be reviewed as part of the test program review, as well.]

1/23/96

AP600 SCALING AND PIRT CLOSURE REPORT
[Revision 1, January 24, 1996]

EXECUTIVE SUMMARY

- Brief overview of the key AP600 systems (what's new), the important phenomena, importance of the PIRT and how used, scaling basis, and how scaling distortions were handled.

- The integration of the separate effects tests and the integral tests for computer code validation.

1. INTRODUCTION

- Purpose of document.

- AP600 design and functions of the passive safety systems (exists in papers).

- Test/analysis program goals (test/analysis plan).

2. TRANSIENT PERIODS FOR DIFFERENT SCENARIOS AND PHENOMENA IDENTIFICATION AND RANKING TABLES (PIRT)

2-1 Introduction, mention what will be presented in this section.

2-2 Large-Break LOCA

Discussion of the AP600 LBLOCA, show the passive systems are not important, same as an operating plant, identify differences and relate to PIRT.

LBLOCA PIRT, discuss for the different periods and discuss that it is covered by WC/T, and that the AP600 LBLOCA is independent of the test program.

2-3 SBLOCA

Discuss the small break LOCA scenario for the AP600, break into time periods that will correspond to the PIRT, discuss which passive systems are most important and their role in the SBLOCA, identify critical functions/behavior, show the SSAR results including the key periods that will be used for the PIRT.

Show the SBLOCA PIRT and discuss.

2-4 NON-LOCA TRANSIENTS

An introduction which separates the transient analysis into those transients which are important for the AP600 and rely on the passive systems and those transients which are the same as operating plants. The AP600 features are the PRHR and the CMT.

Show the transient analysis and SGTR PIRT and explain.

2-5 LONG TERM COOLING

Describe this portion of the transient using the large-break and the small-break as the starting points, identify which systems are important and why, address the primary system and containment system interaction.

Show the LTC PIRT and explain.

2-6 SUMMARY

Identify the high ranking items from the PIRTs for the AP600 passive safety systems.

3. CORE MAKEUP TANK SEPARATE EFFECTS TESTS AND ANALYSIS

3-1 Introduction, modes of operation for the CMT and how this is related to the highly ranked PIRT items. Role the tests played for code validation, how as the data used.

3-2 Scaling basis for the CMT test and relationship to the AP600 Plant.
loop and CMT
diffuser

3-3 Scaling distortions in the test and which PIRT parameters were effected, how handled.

3-4 Unanticipated phenomena observed in the tests, relationship to the AP600 Plant.

3-5 Overlap between the separate effects CMT tests and the CMT behavior in the integral systems tests.

3-6 Conclusions, what was learned.

4. ADS SEPARATE EFFECTS TESTS AND ANALYSIS

4-1 Introduction, modes of operation of the ADS and how this is related to the highly ranked PIRT items. Role of the tests for code validation, how as the data used.

4-2 Scaling basis for the ADS and relationship to the AP600 Plant.
loop, pressurizer tank
valves, orifices, ADS package

4-3 Scaling distortions of ADS test, which PIRT items are effected, how handled.

4-4 Unanticipated phenomena observed in the tests, relationship to AP600.

4-5 Overlap between ADS separate effects tests and the integral systems tests.

4-6 Conclusions, what was learned.

5. PRHR SEPARATE EFFECTS TESTS

5-1 Introduction, test description/objectives role the tests played for code/model validation, and how data was used.

5-2 Scaling basis for tests.

5-3 Scaling distortions in the tests, and which PIRT parameters were effected, how handled. Relationship to C-tube design.

5-4 Unanticipated phenomena observed in the tests, and relationship to AP600 Plant.

5-5 Overlap between the separate effects tests and integral test behavior.

5-6 Conclusions, what was learned.

6. SPES FULL PRESSURE INTEGRAL SYSTEMS TESTS AND ANALYSIS

6-1 Introduction, types of tests simulated in SPES, description (brief) of the facility, the role this test program played in the analysis and code validation.

6-2 Scaling basis used in SPES and relationship to AP600, analysis.

6-3 Scaling distortions observed and know in SPES tests, which PIRT parameters were effected, how handled, impact on the data and conclusions.

6-4 Unanticipated phenomena observed in the tests, relationship to the AP600 Plant.

6-5 Conclusions, what was learned.

7. OSU SMALL BREAK AND LONG TERM COOLING TESTS AND ANALYSIS

7-1 Introduction, types of transients simulated in OSU, brief description of the test facility, the role this test program played in the analysis and code validation.

7-2 Scaling basis for OSU, relationship to AP600 Plant (show the pre-test calc's, and the scaling with the calc's), show the overlap between the SPES and OSU tests, data to data.

7-3 Scaling distortions in OSU, which PIRT items were effected, how handled, impact on data and conclusions.

7-4 Unanticipated phenomena which were observed in OSU and relationship to the AP600 Plant.

7-5 Conclusions, what was learned.

8. PIRT CLOSURE AND SCALING OVERLAP

8-1 Introduction discussion on closure process.

8-2 PIRT closure, basis for confirming PIRT, what changed, why, show that test program covered the broad range of conditions for code validation, show test covered AP600 Plant performance.

8-3 Scaling overlap between tests and relationship to AP600 Plant, examine the same phenomena at different scales.

8-4 Conclusions.

9. APPLICATION OF THE TEST RESULTS FOR AP600 COMPUTER CODE VALIDATION

9-1 Large-break LOCA, no impact.

9-2 Small-break LOCA, show the validation plan for NOTRUMP with separate effects tests and integral systems tests.

9-3 Transient analysis, show the validation plan for LOFTRAN with the separate effects and integral systems tests.

9-4 Long term cooling, show the validation plan for the CMT separate effects tests and the OSU "window mode" calculations for the LTC.

9-5 Conclusion, sufficient data exists to validate the Westinghouse codes over the expected range of conditions.

10. PROGRAM CONCLUSIONS

- Scaling is appropriate and does not lead to significant distortion of the key PIRT phenomena for a given transient.
- Distortions have been analyzed and would not violate the application of the data for computer code validation for the AP600 passive safety systems.
- Describe what was new or unexpected.
- An integrated plan exist for the safety analysis computer code validation using both the separate effects and integral systems tests..

11. REFERENCES (give sections where possible)

AP600 PRHR Test - Calculation of Mass Flow Rates

AP600

Definitions

Base Conditions	14.7 psia, 68°F
Flowing Conditions	PRHR conditions at exit of tubes where the meter is located.
Reference Conditions	As specified to vendor, 2414 psia, 650 °F

- FLOWING MEDIA - WATER
- MAX VOLUME RATE OF FLOW - GPM
- MAX ΔP - INCHES WATER COLUMN
- FLUID TEMPERATURE - F
- FLUID PRESSURE - PSIG
- LINE SIZE - INCH

SUPPLIERS SIZE ORIFICE BORE BASED ON DEFINED PARAMETERS

AP600

SUPPLIER PROVIDES FLOW CALCULATION BASED ON REFERENCE VOLUME RATE OF FLOW, Q0

$$Q0 = BV_B = 43.1702\ K\ F_a\ \beta_{68^\circ F}^{\ 2}\ D_{68^\circ F}^{\ 2}\ \sqrt{h_{w_0}\ \rho_{f_0}}$$

WHERE:

h_{w_0} = PRESSURE DROP (in.H_2O) AT REFERENCE CONDITIONS

ρ_{f_0} = DENSITY (lbm/ft^3) @ THE REFERENCE FLOW CONDITIONS

D = LINE SIZE (inch)
β = BETA RATIO
F_a = ORIFICE THERMAL EXPANSION CORRECTION FACTOR
K = ORIFICE "K" FACTOR

BV_B = VOLUME RATE OF FLOW (GPH) AT BASE CONDITIONS

AND THE CONSTANT, 43.1702, INCLUDES A SPECIFIC GRAVITY TERM, ρ_B

THEREFORE, Q0, THE REFERENCE FLOWRATE USED IN PRHR DATA REDUCTION CODE, IS REFERENCED TO BASE CONDITIONS

W-STC PROVIDES SUPPLIER ORIFICE CALCULATIONS TO W-EC
W-EC DEVELOPS PRHR DATA REDUCTION CODE

- SUPPLIER ORIFICE CALCULATIONS IMPLEMENTED IN CODE
- VOLUME RATE OF FLOW CALCULATED BASED ON REFERENCE FLOWRATE MULTIPLIED BY RATIO OF DENSITIES AND PRESSURE DROP - EQUATION DERIVED BASED ON SUPPLIERS CALCULATION

$$\frac{Q1}{Q0} = \frac{43.1702\ K\ F_a\ \beta^2\ D^2\ \sqrt{h_{w_1}\ \rho_1}}{43.1702\ K\ F_a\ \beta^2\ D^2\ \sqrt{h_{w_0}\ \rho_0}}$$

OR

$$Q1 = Q0\sqrt{\frac{\rho_1}{\rho_0}}\sqrt{\frac{h_{w_1}}{h_{w_0}}}$$

WHERE ρ_1 AND h_{w_1} ARE AT THE FLOWING CONDITIONS AT THE METER.

CALCULATED VOLUME RATE OF FLOW IS ASSUMED TO BE AT FLOWING CONDITIONS BUT, SINCE VENDOR INCORPORATED SPECIFIC GRAVITY TERM IN CONSTANT, FLOW IS REFERENCED TO BASE CONDITIONS

AP600

INEL IDENTIFIES POTENTIAL ERROR INDICATING THAT DENSITY RATIO IN CODE IS INVERTED

$$Q_0 = A\,V_0 = A\sqrt{\frac{2\,g_c\,\Delta P_0}{\rho_0}}\ \ (Reference Conditions)\ \ ;\ Q_1 = AV_1 = A\sqrt{\frac{2g_c\Delta P_1}{\rho_1}}\ \ (Flowing Conditions)$$

$$\frac{Q_1}{Q_0} = \frac{A\sqrt{\frac{2\,g_c\,\Delta P_1}{\rho_1}}}{A\sqrt{\frac{2\,g_c\,\Delta P_0}{\rho_0}}}$$

$$Q_1 = Q_0\sqrt{\frac{\Delta P_1}{\Delta P_0}}\sqrt{\frac{\rho_0}{\rho_1}} = Q_0\sqrt{\frac{h_{w_1}}{h_{w_0}}}\sqrt{\frac{\rho_0}{\rho_1}}$$

THE DENSITY TERM IN THIS RELATIONSHIP IS INVERTED WITH RESPECT TO THAT IN THE EQUATION CONTAINED IN THE PRHR DATA REDUCTION CODE.

HOWEVER, THE INEL DERIVATION IS BASED ON FLOW AT <u>FLOWING</u> CONDITIONS, NOT BASE CONDITIONS

THE VOLUME RATE OF FLOW AT FLOWING CONDITIONS CAN BE EQUATED TO THE VOLUME RATE OF FLOW AT BASE CONDITIONS (e.g. 68 °F AND 14.696 psia) BY THE RELATIONSHIP:

$$Q_1 = \frac{BV_1 \, \rho_B}{\rho_1} \; ; \; Q_0 = \frac{BV_0 \rho_B}{\rho_0}$$

WHERE:

BV REFERS TO VOLUME RATE OF FLOW AT BASE CONDITIONS

ρ_B IS THE FLUID DENSITY AT BASE CONDITIONS (68°F, 14.696 psia)

ρ_1 IS THE FLUID DENSITY AT FLOWING CONDITIONS

ρ_0 IS THE FLUID DENSITY AT STANDARD CONDITIONS

SUBSTITUTING THIS RELATIONSHIP INTO THE INEL EQUATION GIVES:

$$BV_1 \left(\frac{\rho_B}{\rho_1}\right) = BV_0 \left(\frac{\rho_B}{\rho_0}\right) \sqrt{\frac{h_{w_1}}{h_{w_0}}} \sqrt{\frac{\rho_0}{\rho_1}}$$

OR

$$BV_1 = BV_0 \sqrt{\frac{h_{w_1}}{h_{w_0}}} \sqrt{\frac{\rho_1}{\rho_0}}$$

THIS EQUATION IS IN AGREEMENT WITH THE EQUATION USED IN THE PRHR DATA REDUCTION CODE

RESULTS OF W-EC REVIEW OF PRHR DATA REDUCTION CODE:

- DENSITY RATIO IMPLEMENTED IN CODE IS CORRECT SINCE REFERENCE FLOW, Q0, IS REFERENCED TO BASE CONDITIONS

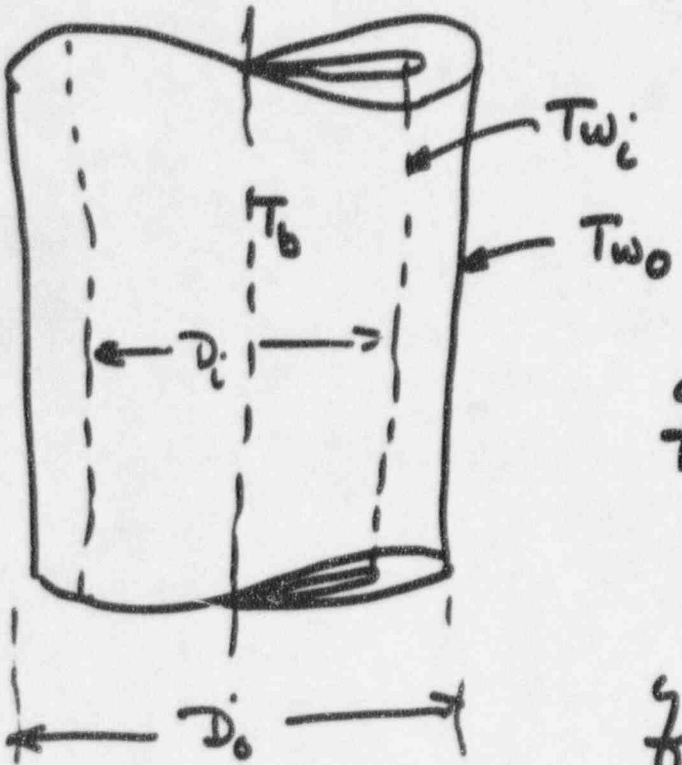
- THE DENSITY RELATIONSHIP IDENTIFIED BY INEL IS CORRECT IF REFERENCE FLOW, Q0, IS BASED ON FLOW AT FLOWING CONDITIONS

- SINCE VOLUME RATE OF FLOW CALCULATED BY PRHR CODE WAS ASSUMED TO BE AT FLOWING CONDITIONS BUT IS ACTUALLY AT BASE CONDITIONS, CALCULATED VOLUME RATE OF FLOW SHOULD BE MULTIPLIED BY DENSITY AT BASE CONDITIONS TO CONVERT TO MASS RATE OF FLOW

- RECOMMEND REVISION OF PRHR CODE TO IMPLEMENT STANDARD ASME ORIFICE FLOW EQUATION TO CALCULATE THE MASS RATE OF FLOW DIRECTLY FROM THE ACTUAL RECODED TEST CONDITIONS. IF DESIRED, THE VOLUME RATE OF FLOW AT FLOWING CONDITIONS MAY BE OBTAINED BY DIVIDING THE MASS RATE OF FLOW BY THE FLUID DENSITY AT FLOWING CONDITIONS.

(3)

HEAT TRANSFER COEFFICIENT CALCULATION FROM DATA



$$q = \frac{2\pi k l \left(T_{w_i} - T_{w_o}\right)}{\ln\left(D_o/D_i\right)} \left(\frac{Btu}{Hr}\right)$$

$$q = h \pi D_i l \left(\bar{T}_b - T_{w_i}\right) \left(\frac{Btu}{Hr}\right)$$

$\therefore$

$$\frac{q \ln\left(\frac{D_o}{D_i}\right)}{2\pi k l} = T_{w_i} - T_{w_o}$$

$$\frac{q}{h\pi D_i l} = \bar{T}_b - T_{w_i}$$

Add.

$$q\left[\frac{\ln\left(D_o/D_i\right)}{2\pi k l} + \frac{1}{h\pi D_i l}\right] = \bar{T}_b - T_{w_o}$$

$$\frac{q}{\theta} = q'' \pi D_i l$$

$$q'' \pi D_i l \left[\frac{\ln(D_o/D_i)}{2\pi k l} + \frac{1}{h \pi D_i l} \right] = \bar{\bar{T}}_b - T_{wo}$$

$$q'' \left[\frac{D_i \ln(D_o/D_i)}{2k} + \frac{1}{h} \right] = \bar{\bar{T}}_b - T_{wo}$$

501 DATA - 1st step

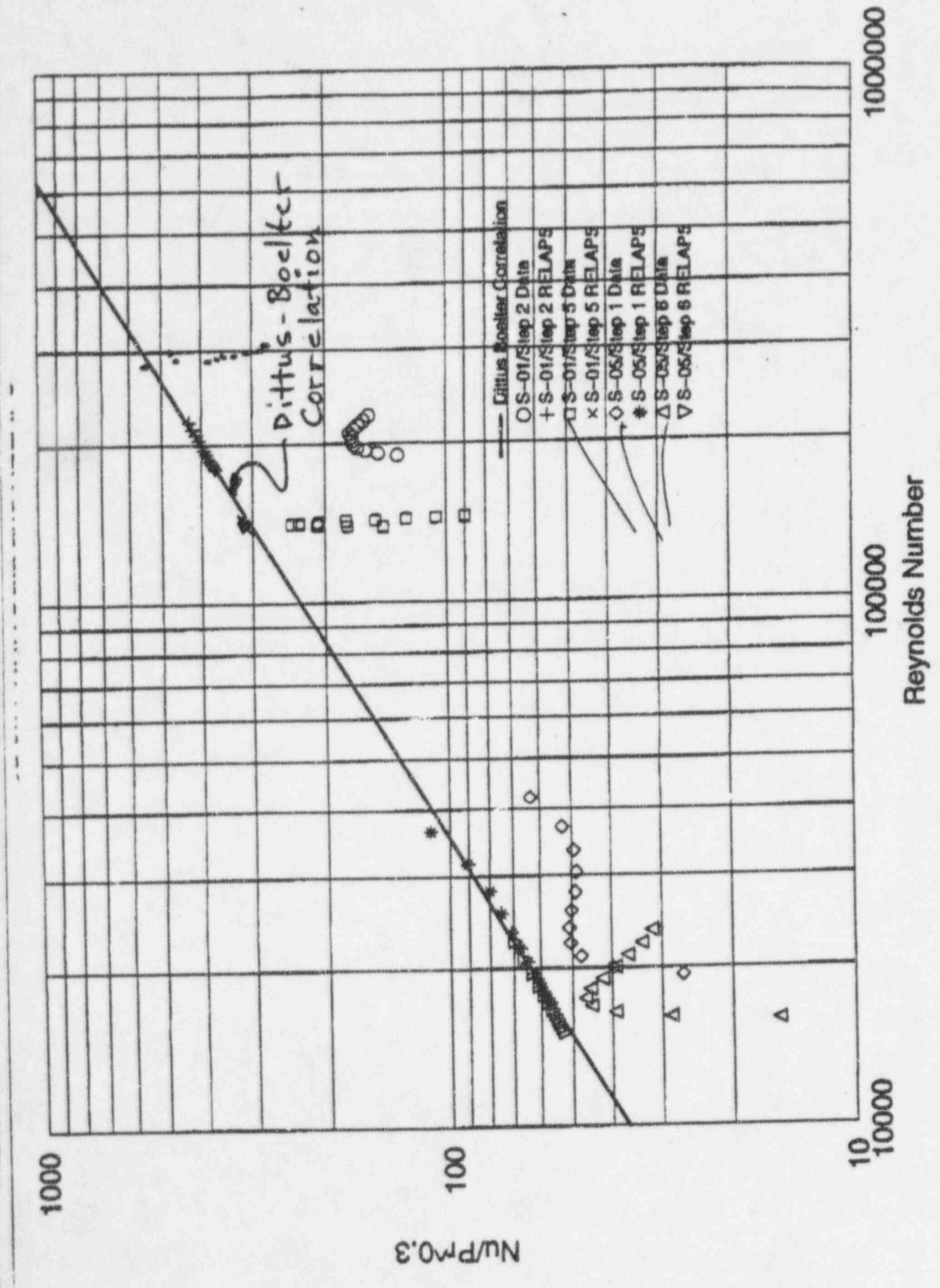
$$83331.8 \left[\frac{(.6152)(.1974)}{(24)(9.184)} + \frac{1}{h} \right] = 350.8 - 281.3$$

$$h = 3530 \frac{Btu}{hr\,ft^2\,°F}$$

$$Nu/Pr^{.33} = \left(\frac{hD}{k}\right) / Pr^{.33}$$

$$Nu/Pr^{.33} = \frac{(3530)(.6152)}{(12)(.396)(.98)^{.33}} = 460.2$$

$$= Re = 278418.2$$



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+ T_{wc}

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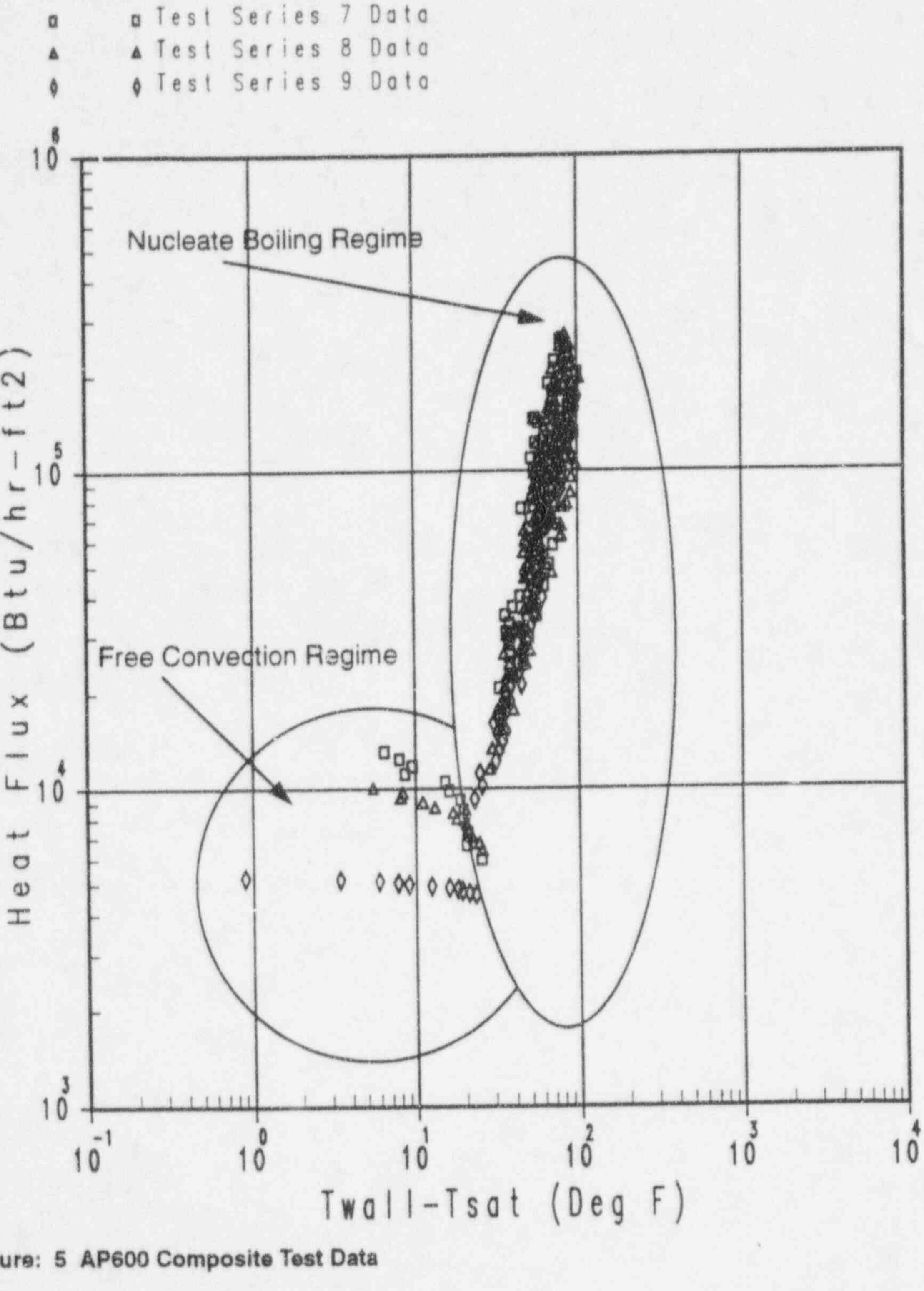

Figure: 5 AP600 Composite Test Data

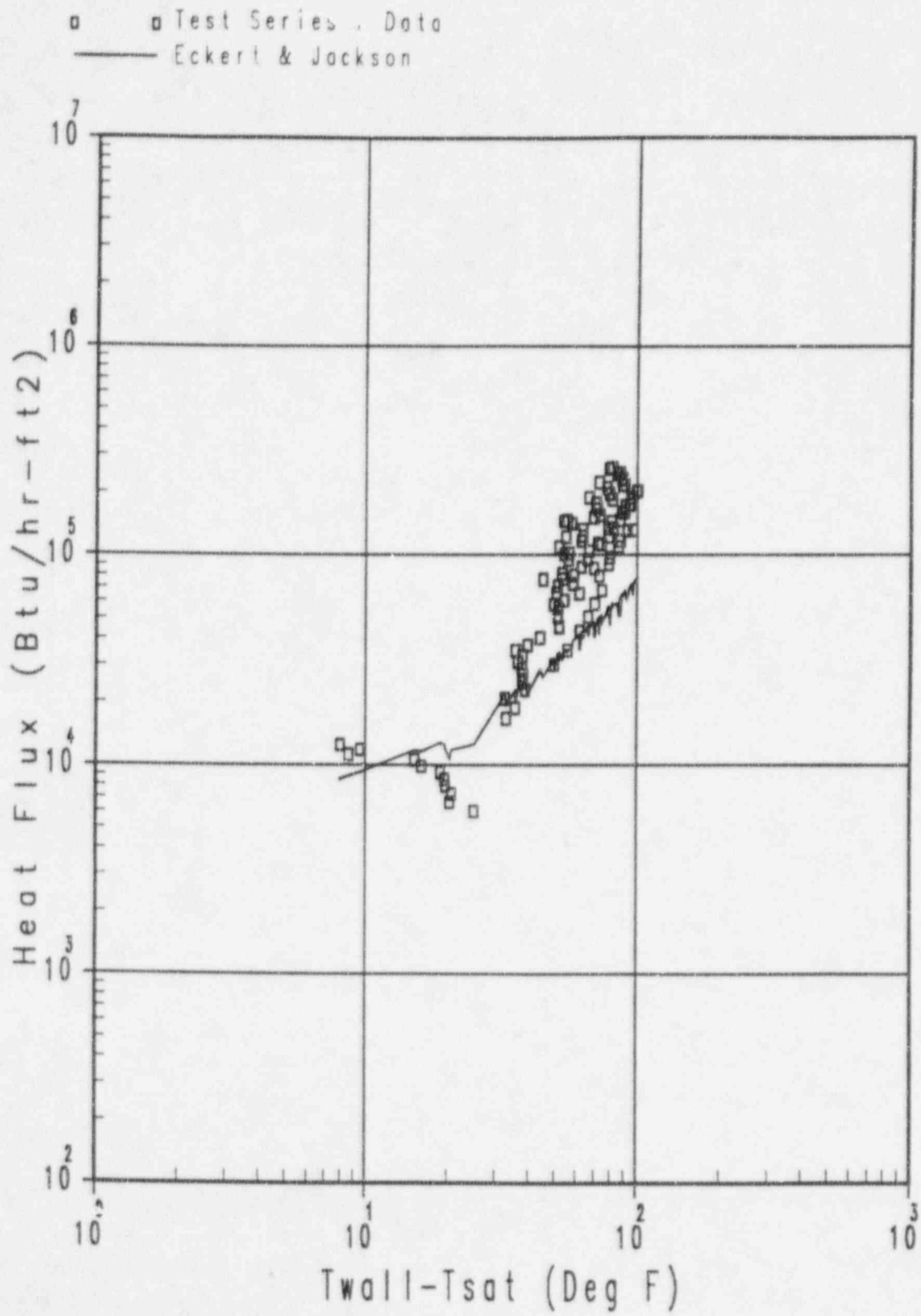

Figure: 10 Test Series 7 Versus Eckert and Jackson

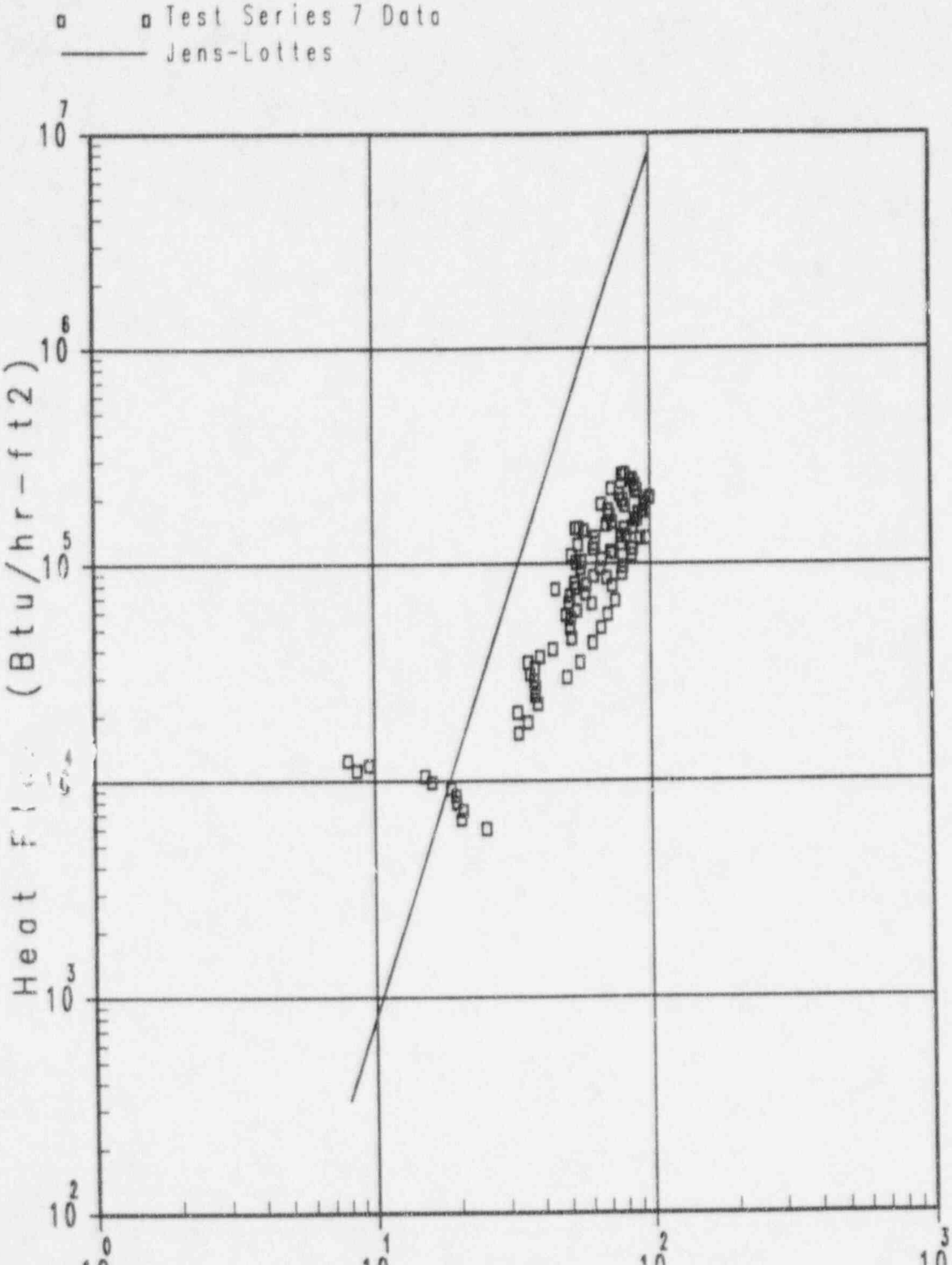

Figure: 11 Test Series 7 Versus Jens-Lottes

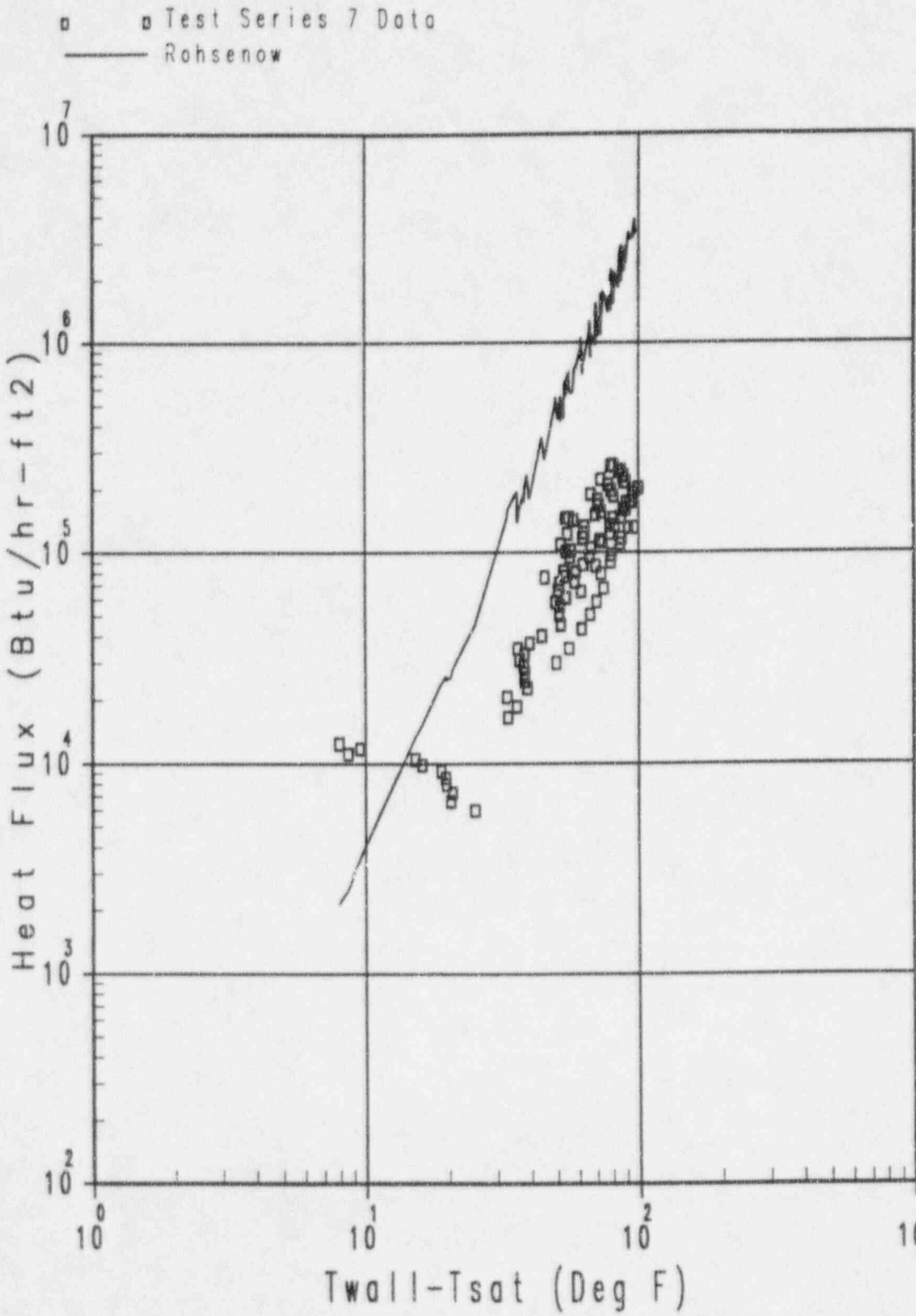

Figure: 12 Test Series 7 Versus Rohsenow

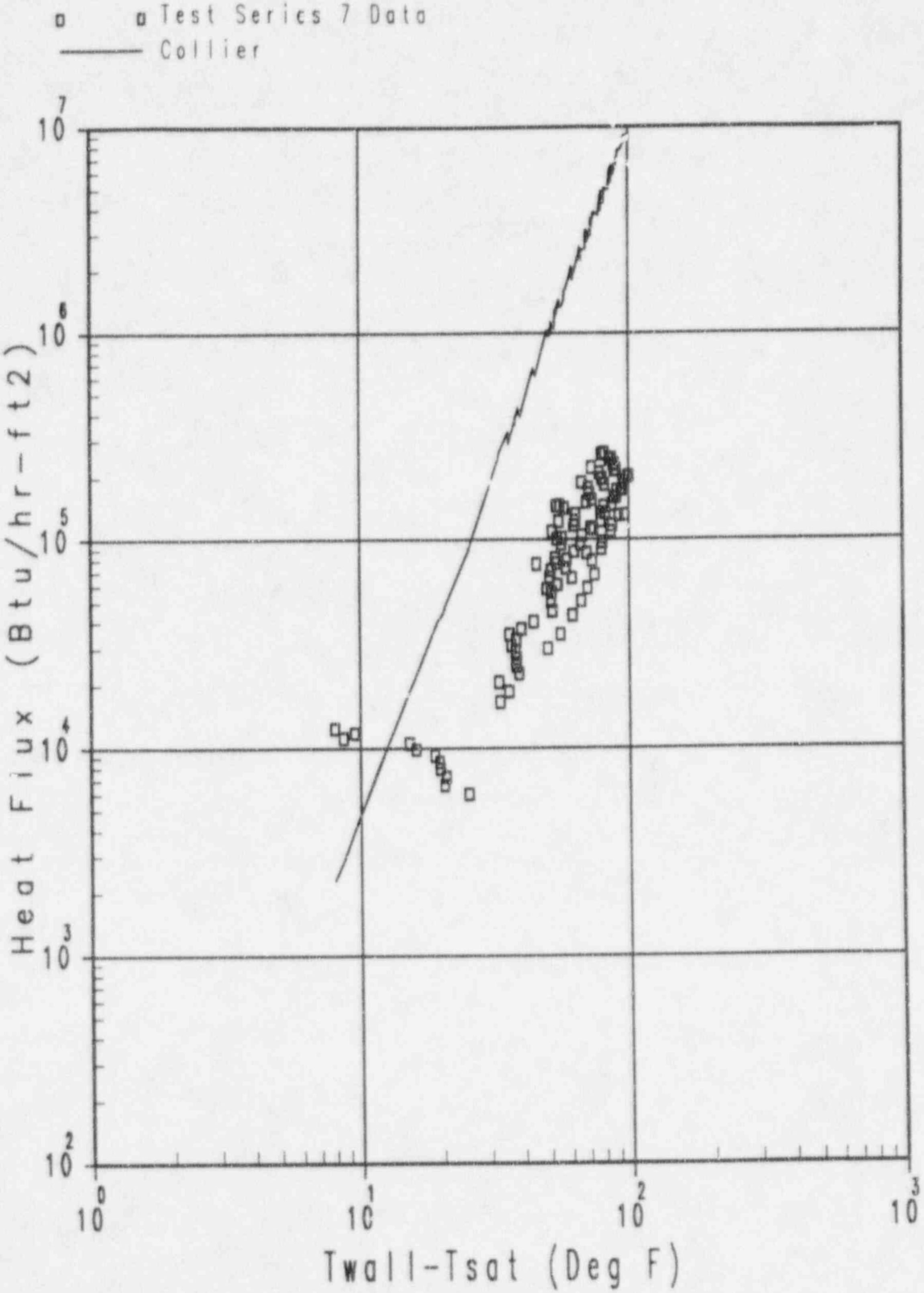

Figure: 13 Test Series 7 Versus Collier

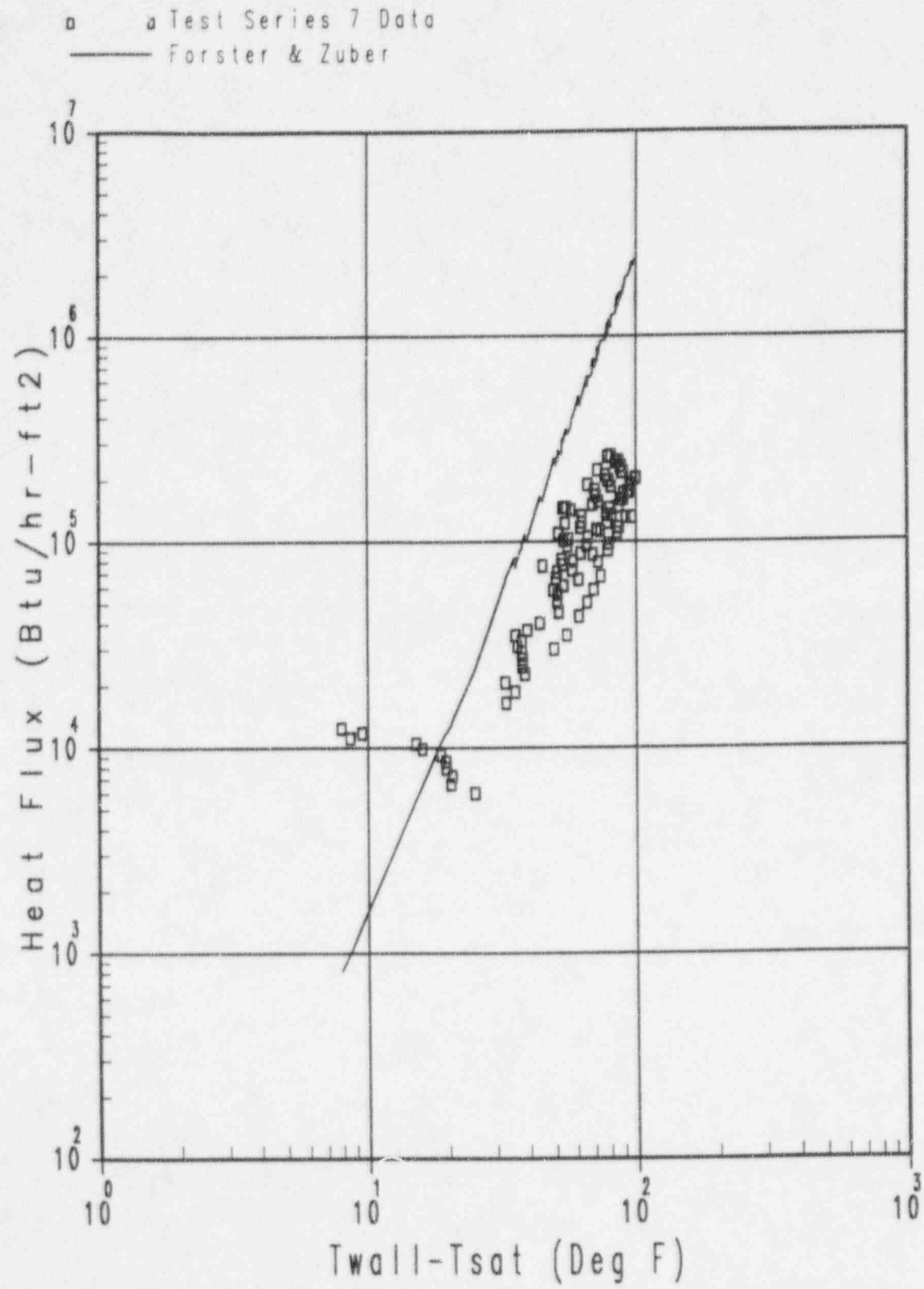

Figure: 14 Test Series 7 Versus Forster and Zuber

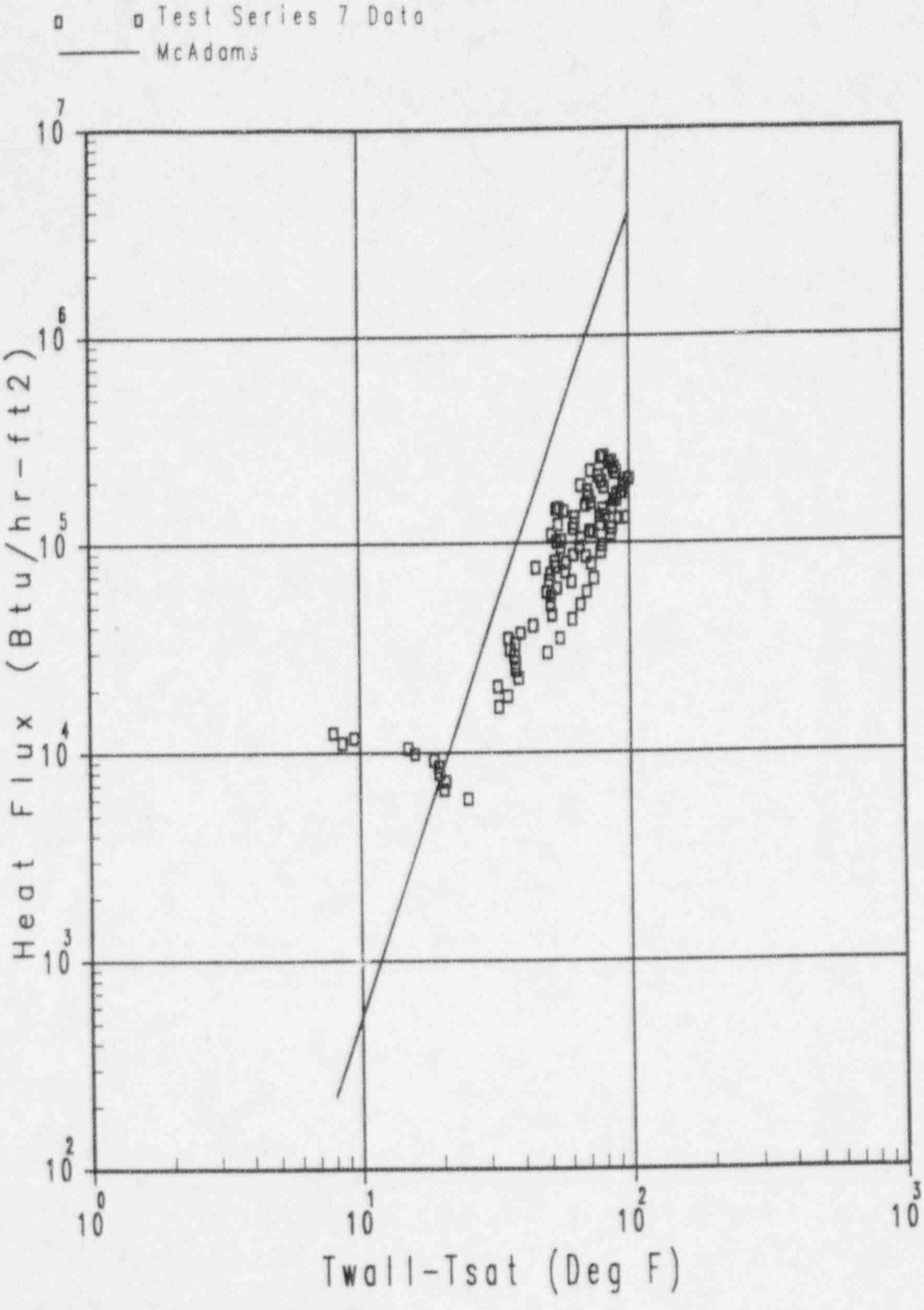

Figure: 16 Test Series 7 Versus McAdams

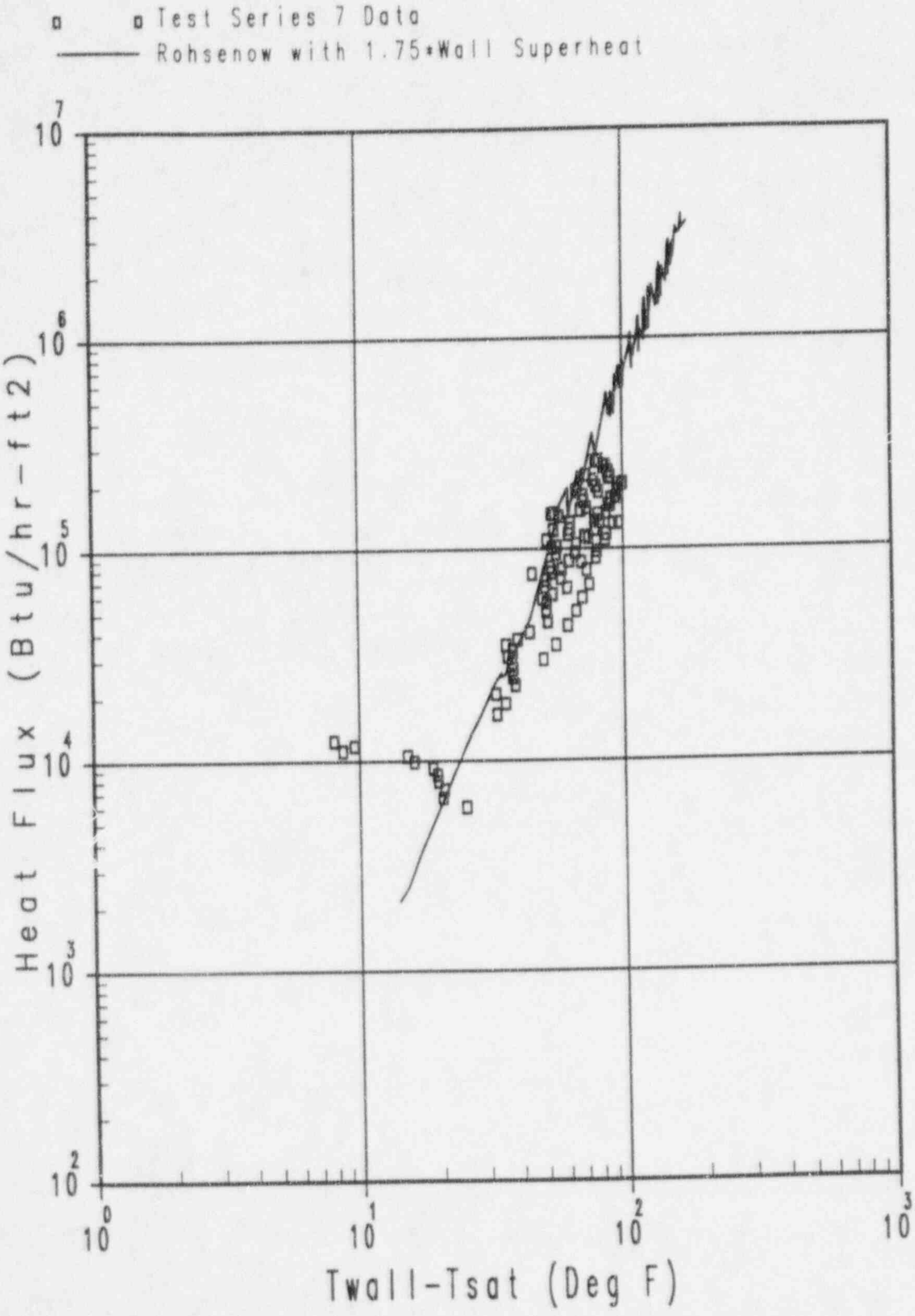

Figure: 43 Test Series 7 Data versus Rohsenow with Modified Wall Superheat

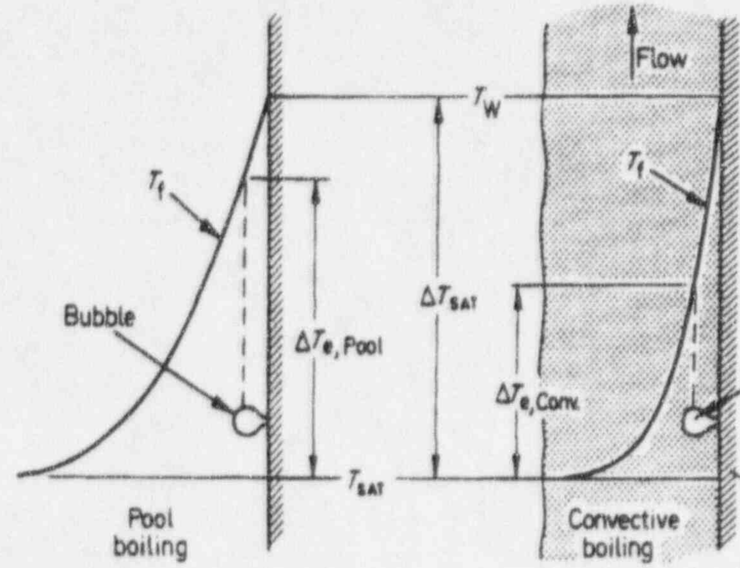

Fig. 7.4. Temperature Profiles for Pool Boiling and for Convective Boiling with Same Superheat (Chen)

Figure: 41 Figure 7.4 from Collier[15]

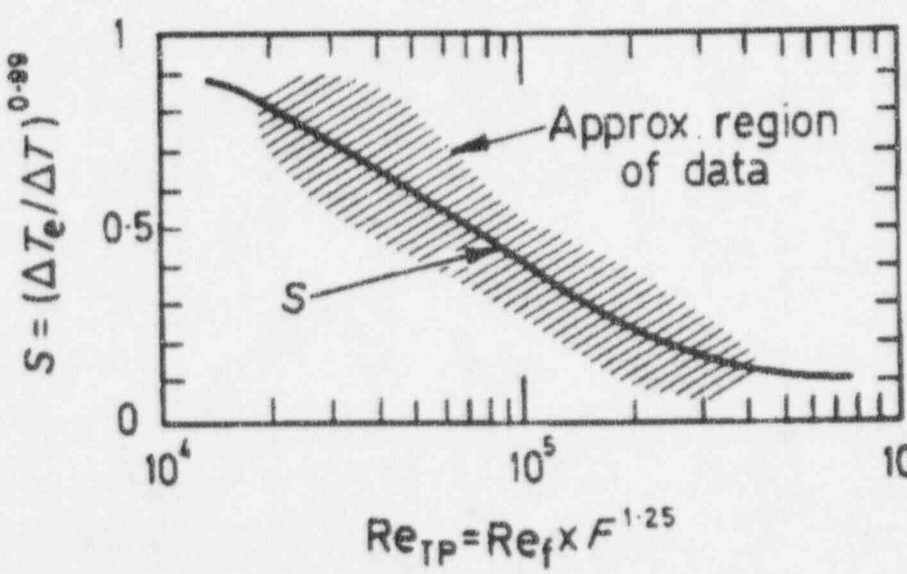

Fig. 7.6. Suppression Factor, S (Chen)

Figure: 42 Figure 7.6 from Collier[15]

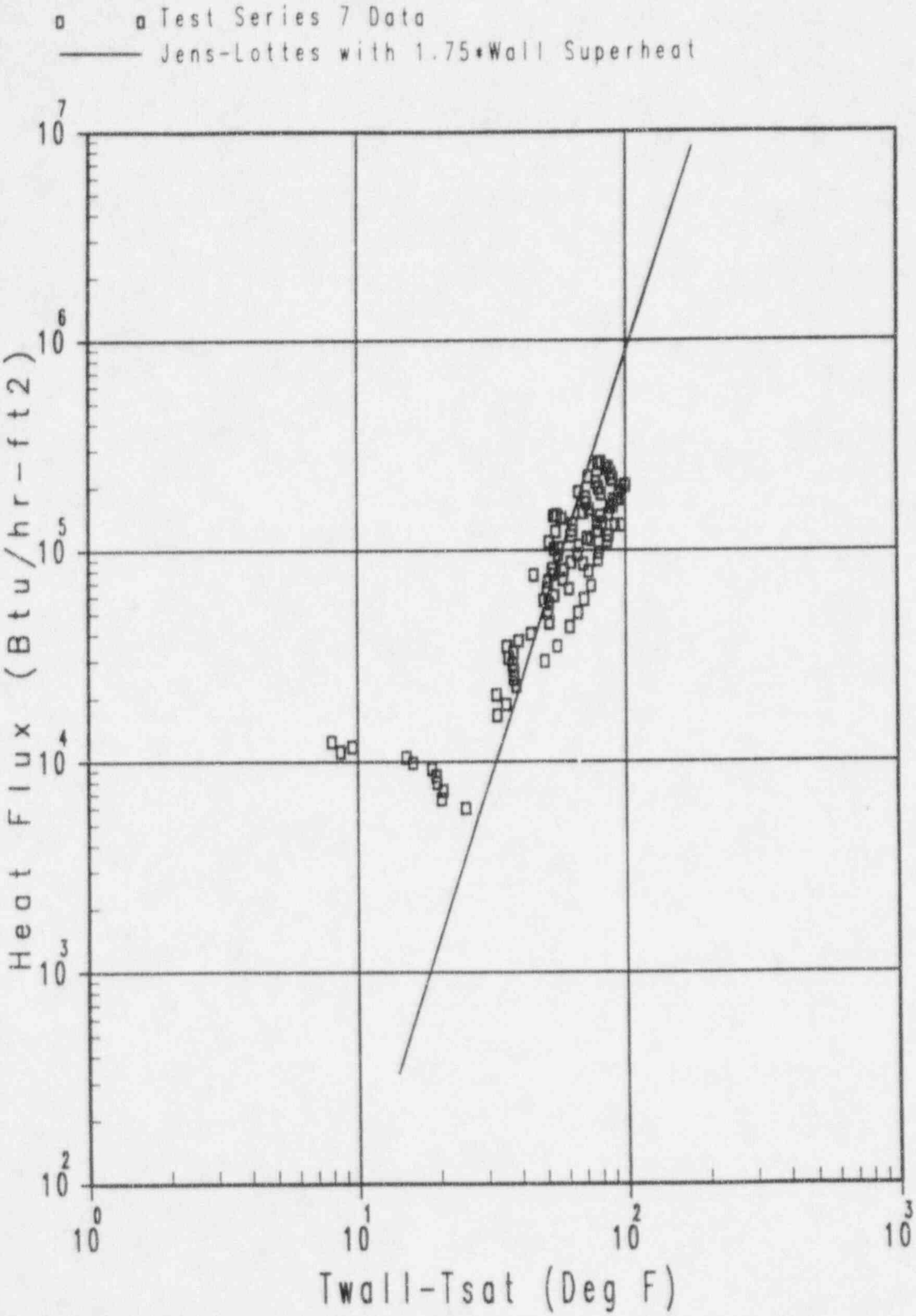

Figure: 44 Test Series 7 Data versus Jens-Lottes with Modified Wall Superheat

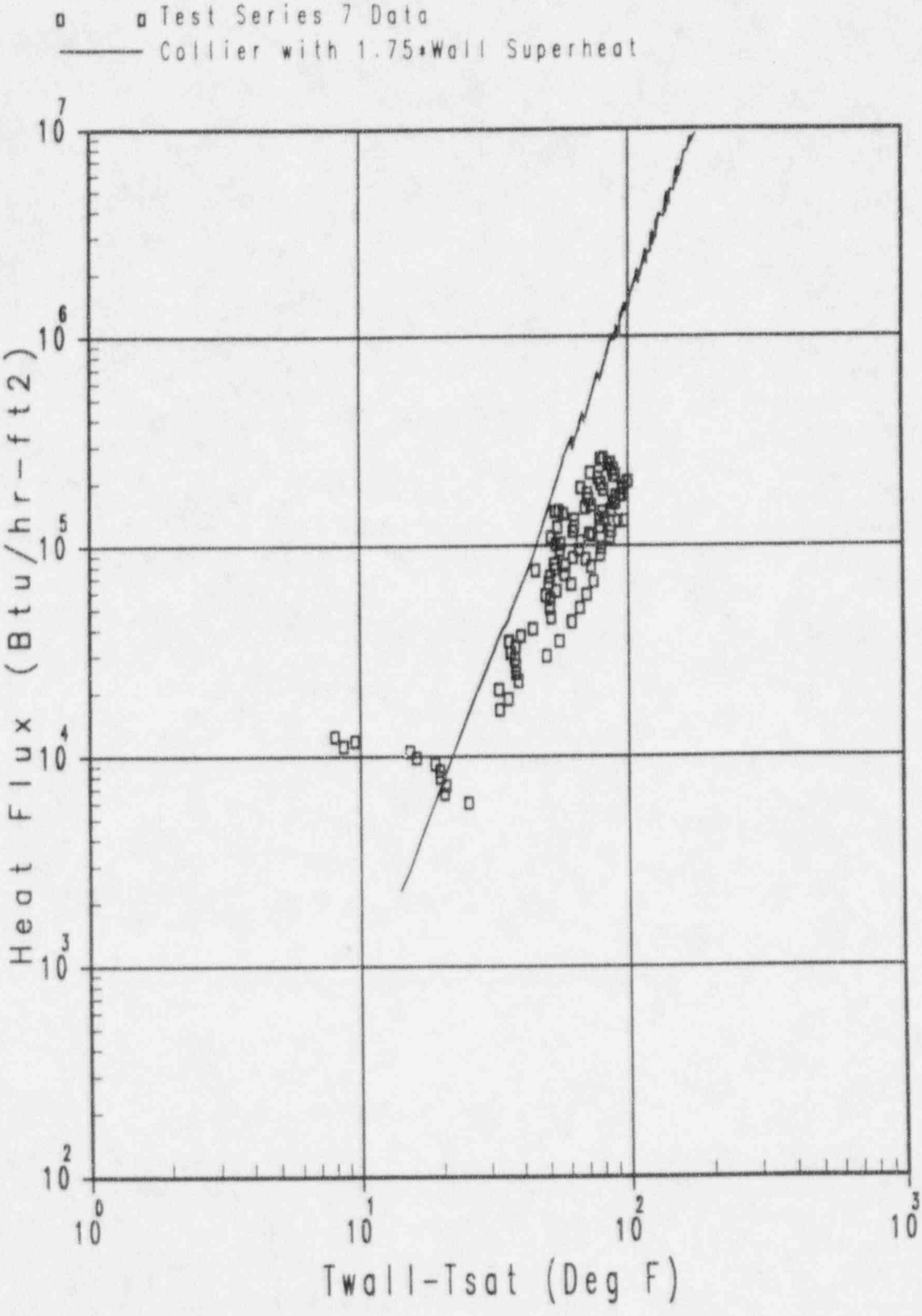

Figure: 45 Test Series 7 Data versus Collier with Modified Wall Superheat

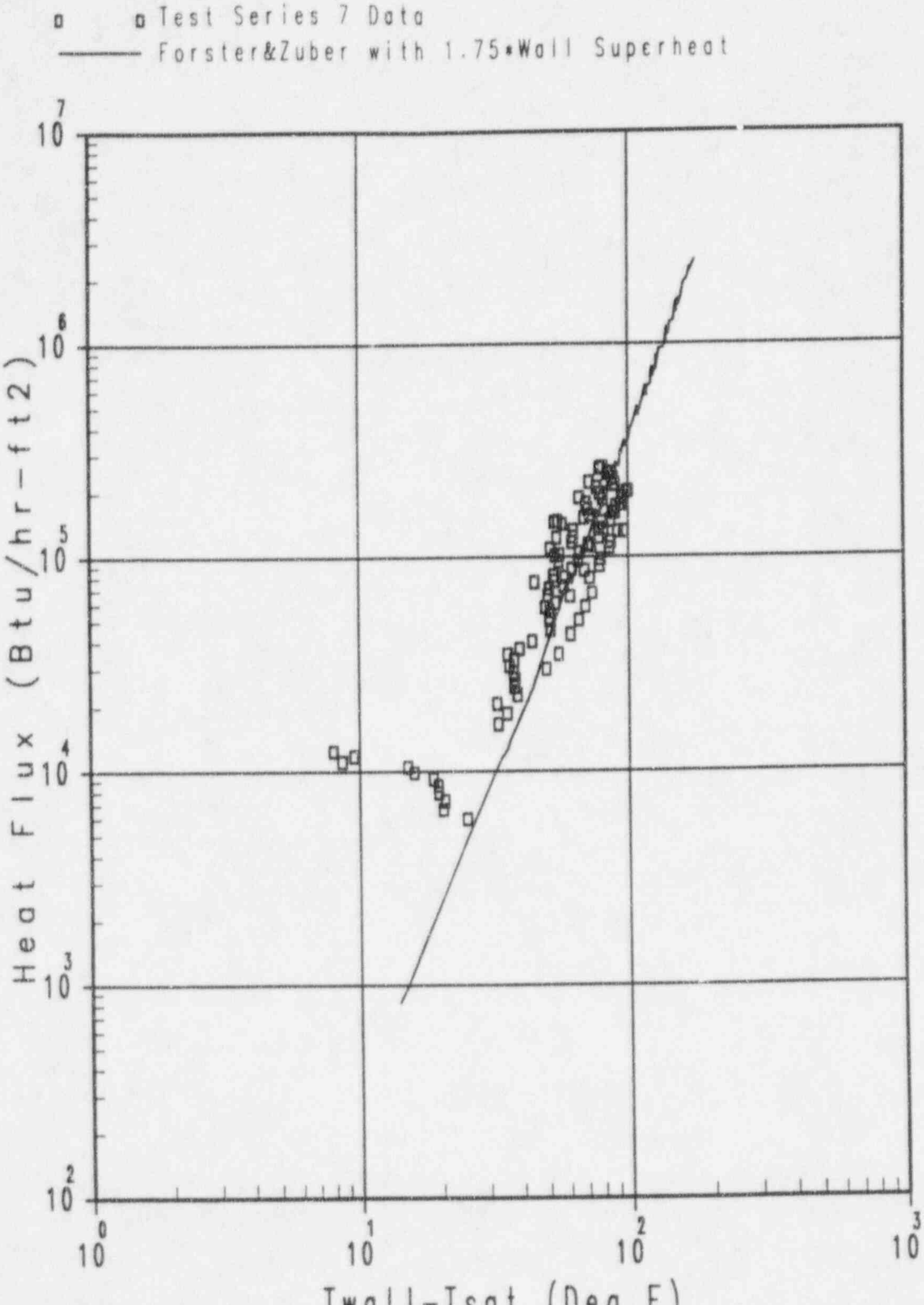

Figure: 46 Test Series 7 Data versus Forster-Zuber with Modified Wall Superheat

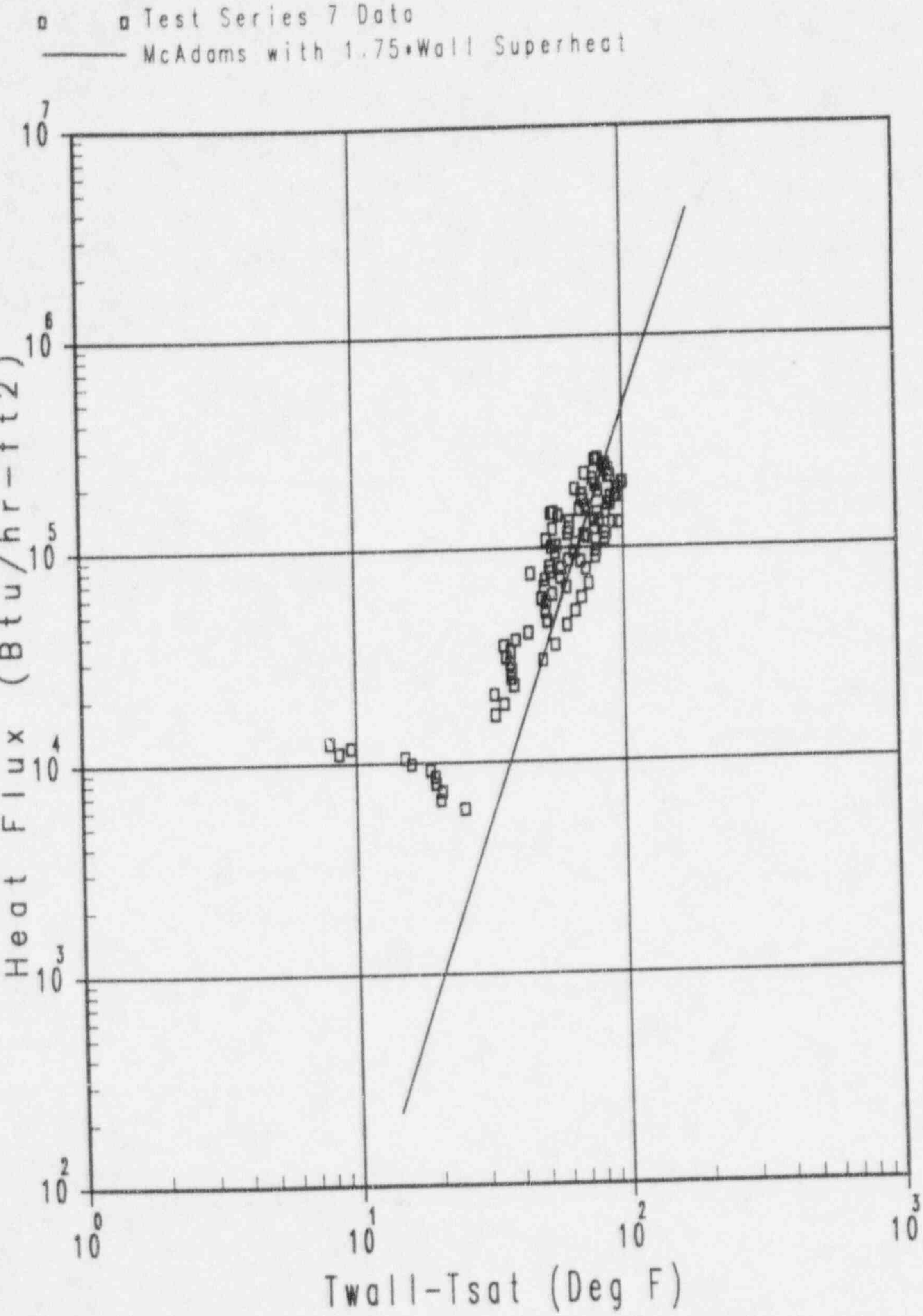

Figure: 47 Test Series 7 Data versus McAdams with Modified Wall Superheat

QUESTIONS, COMMENTS, AND DISCUSSION ITEMS CONCERNING THE WESTINGHOUSE AP600 TEST REPORTS

PRHR Items

Q1. The staff has previously requested that Westinghouse provide a technical justification for the use of the database established from the straight-tube passive residual heat removal (PRHR) heat transfer tests to model the performance of the current "C-tube" PRHR heat exchanger (HX) design. The staff's concerns have related primarily to the modeling of dryout in tube bundles, especially in the upper horizontal portion of the HX, where heat fluxes are expected to be the greatest. In addition, recent evaluation of test data from the PRHR test program has raised questions about the reliability of all of the data from the test program, due to possible errors in conversion of instrument output to engineering units, and the apparent deviation of the test data from conventional correlations for calculating heat transfer coefficients. Accordingly, the staff requests that Westinghouse:

a. Fulfill the earlier request for technical justification for modeling "C-tube" behavior using straight-tube data;

b. Reexamine the data from the PRHR test program to determine if the conversion of instrument data was done properly;

c. If the evaluation for (b) above shows that data conversions were not done properly, reconstitute the millivolt data, correct the conversions to engineering units, and demonstrate the overall reliability of all of the test data; and

d. Provide a detailed explanation of the analytical models used to calculate heat exchanger performance, for the purposes of both unit design and accident and transient analyses; and show that these models (i) are validated over the range of thermal-hydraulic test data and expected AP600 performance, and (ii) can be shown within an acceptable error to calculate conditions representative of the design certification data for the PRHR system.

R1. NRC to revise the discussion item and issue as an RAI to address parts a) and d) only. Also redraft the opening paragraph and remove discussion of issues with respect to data reliability since these issues were resolved during the meeting. Pending issuance of Revision 2 of the PRHR Final Data Report and subsequent staff review, parts b) and c) related to test data conversion have been adequately addressed.

Q2. In view of the problems identified with the test data, the staff questions the adequacy of the PRHR Test Program Final Report. The report does not conform with the format of other AP600 test programs, nor does it provide all of the test data and associated analyses, on a test-by-test basis, for staff review. The report also lacks a detailed error/uncertainty analysis commensurate with those done for the other test programs.

R2. Westinghouse has committed to issue Revision 2 of the PRHR Final Data Report to conform with the format of other AP600 test program reports, and provide relevant test data and associated analysis on a test-by-test basis, and a detailed error/uncertainty analysis commensurate with other test programs. An electronic file of all test data in engineering units will be provided with the report.

ADS Phase B1 Final Data Report (FDR) and Test Analysis Report (TAR)

Q3. In the FDR, in Chapter 4, the pressure drop data are used to indicate where "choking" is deemed to have occurred. What quantitative criteria were used to determine the locations where choking occurred? Are they the same as described in the TAR?

R3. A nominal criteria of ≥ 50 percent pressure drop was used to estimate whether choking across a particular component had occurred. This was intended as a qualitative evaluation only for the FDR. A quantitative analysis was performed in the TAR.

Q4. There appear to be significant inconsistencies in the parameters presented for Test 120 in the FDR. In Table 1.2-1, the nominal test pressure is shown as 1600 psig, and in the text in Chapter 4 (Section 4.1.2.2) the pressure is given as 1581 psig. However, in Table 4.1.1, the pressure is listed as 158 psia (inconsistent both as to value and to psia vs. psig), and the pressure plot on page 4-12 shows the initial pressure as about 95 psig, which is inconsistent with everything else. Please explain and correct this information.

R4. Table 1.2-1 identifies the pretest pressure objective (1600 psig of the test). The Day of Test Report indicates that the test pressure was 1601 psia prior to the start of the test; PT4 and PE1W average to 1565 and 1575 psig respectively before the start of the test. Table 4.1.1 pressure should read 1580 psia (using PT4). Section 4.1.2.2 should also read 1580 psia.

Pressure plot on page 4-12 was inadvertently plotted in bar units and labeled psig. The figure will be replotted in the appropriate units.

An errata sheet will be issued to correct.

Q5. The analysis for Test 120 in the FDR states that the major pressure drops occur across VAD-1 and VAD-2. However, the data in Figure 4.1-6 appear to show that the latter pressure drop occurs not across the valve alone, but rather across the entire stage 2 section (valve and orifice). Please explain these differences.

R5. The major pressure drops in test 120 are across globe valve VAD-1 and the orifice element of ADS-2. PE12W is not functional for this test but PE16W should be relatively close in magnitude to what PE12W would be since it is directly downstream of the ADS package.

The sentence will corrected in an errata sheet.

Q6. Similar to the previous question, data from Tests 130 and 140 appear to indicate that large pressure drops occur across the stage 3 (Test 130) and stage 2 and 3 (Test 140) orifices rather than the valves themselves. For Test 250, choking appears to occur across the stage 2 orifice rather than the valve. Explain these apparent discrepancies or, alternatively, demonstrate that the data support your analyses.

R6. The orifices are substituting for globe valves in stages 2 and 3, whereas VAD -2 and -3 are gate valves. The gate valves offer significantly less resistance to flow than the globe valves and therefore the smaller pressure drops.

The statement will be clarified in an errata sheet.

Q7. Figure 4.2-1 in the FDR and Figure 4-170 in the TAR purport to show the same tests (210, 211, and 212). However, the actual flow and quality shown for the tests are substantially different in the two figures.

a. Please explain the apparent discrepancy between the two figures.

b. The actual test conditions shown for these tests appear to fall substantially outside of the range shown as "intended." Explain why these tests are considered to be "acceptable," and how the necessary thermal-hydraulic range for AP600 is covered if the tests differ so much from the conditions specified in the matrix.

c. How are code models to be validated over the range of operating qualities above around 20-30 percent? There appear to be no data, either intended or actual, in the upper portion of the range.

R7a The calculation of steam quality in the FDR was performed with a simple relationship. The TAR steam quality was calculated with a rigorous expression and is more accurate.

R7b The test data was deemed to be valid data and suitable for analysis but the tests did not bound the range of expected ADS operation. Test 210 was repeated later after the substitution of the orifices with the complementary ADS valves. The opening of VLI-2 was reduced for this test to further reduce the mass flow and increase the steam quality to bound the operating conditions of interest.

R7c There was no intention to perform tests or validate analysis for steam qualities >20 to 30 percent, since these conditions exist during blowdown for very small time periods (seconds).

Q8. The previous question is relevant to other tests shown in the FDR and the TAR, with regard to discrepancies in flow/quality between the plots in the two reports, test acceptability where test conditions appear to be substantially outside of the specified ranges, and the coverage of the entire range of operating conditions. Examples include:

a. Test 250: a single test is not representative of the entire range of operating conditions.

b. Tests 330, 331 (multiple runs), 320, 321, 322, 350, 351: discrepancies between FDR and TAR; acceptability of tests not meeting "intended" conditions; tests lying outside of envelope of operating conditions.

Please provide a discussion of the relationship of ADS test data to projected AP600 operating conditions, and explain the (i) acceptability of tests nominally outside the range of projected operating conditions and (ii) adequacy of the test program to provide data to model AP600 ADS operation.

R8. NRC - Action (combine questions 7 and 8)

Q9. In FDR Sections 4.2.3 and 4.3.3, it is stated that quench tank <u>volume</u> increased by 85 percent and 85-90 percent of the change in supply tank <u>mass</u>, respectively (emphasis added).

a. What is meant by these statements?

b. Assuming that the intent of these statements is to compare quench tank <u>mass</u> change to supply tank mass change, what are the implications of apparent mass balance errors of 10-15 percent? Since flows are inferred by supply tank mass changes, are these errors/uncertainties acceptable for the test data?

R9a The sentence should be restated. The inventory of the quench tank increases by an amount equal to 85 percent of the mass discharged from the supply tank.

Westinghouse agreed to issue an errata sheet for clarification.

R9b The estimate of quench tank inventory was based on review of pool pressure transducer outputs and is not meant as a rigorous treatment for the mass balance. The accuracy of the flow measurements based on the measurement of mass in the water supply tank (for water tests) which is estimated at <0.4 percent or 128 lb (Table E-2).

Q10 The discussion in Section 4.2.2.10 states that the flow in Test 242 "is no greater than the flow in Test 241...." This is not borne out by the plots in Figures. 4.2.37 and 4.2.41, which show Test 242 mass flow (peak and plateau) is substantially more than Test 241. Please reconcile the discussion and the data.

R10 The comment referred to the maximum flow rate achieved during the test whereas the table refers to the "plateau" value at 20 seconds. At the peak flow rates Test 242 has a flow of approximately 545 lb/sec versus approximately 525 lb/sec for Test 241, therefore approximately equal. The sentence needs to be rephrased to "Despite a larger flow area on VLI-2, the steam/water maximum flow is approximately equal to that of Test A033241 with similar supply pressures with a lower steam quality." **Westinghouse agreed to issue an errata sheet for clarification.**

Q11 The criteria for determining test acceptability are not clear, especially for tests where no quasi-steady (or "plateau") region was seen in the mass flow. For instance, Test A046340 is considered "acceptable," but its flow vs. time does not exhibit any real plateau, and looks substantially different from A006340, which is a similar test. Please elaborate on how test acceptability was determined, and how the tests with no "plateau" region were evaluated.

R11 The primary test acceptance is that the instrumentation was working properly and the data accurately represents the test performed. The presence of a plateau was not a necessary condition for test acceptance. The tests were designed to either bound the expected ADS operating conditions or be within the expected ADS operating conditions. The primary difference between A006340 and A046340 is that the flow area of VLI-2 is approximately doubled in A046340. Tests without a "plateau" region were evaluated at about 20 seconds into the test after peak flow after the control valve was full open.

Q12 In several "hot quench tank" tests, water was apparently ejected from the quench tank. While the staff recognizes that the VAPORE quench tank is in no way scaled to the AP600 IRWST, this does raise a question about IRWST response if it has been heated for a long period prior to ADS actuation. How is the AP600 IRWST expected to respond if the ADS is actuated when the IRWST is at substantially elevated temperatures?

R12 The observed blowdown behavior of the VAPORE with the quench tank water initially at 212F is that the upward flow from the sparger arms has sufficient momentum to lift a portion of the water in the region above the sparger, out of the VAPORE tank. A volume of approximately 1500 ft3 was the maximum amount of water lost from the 25 ft diameter VAPORE tank.

In the AP600, discharge into a heated IRWST could displace as much as 3000 ft3 of water which would cause the IRWST water level to rise approximately 1 ft. The IRWST wall adjacent to the refueling canal has six, 3 ft wide by 1.25 ft high, spillways. The nominal IRWST water level would be about 9 inches below the spillways

When the IRWST water is heated and expands, the water may reach the bottom of the overflows (depending on the initial IRWST water level assumed), and some water may spill into the refueling canal. When ADS begins the water pushed away from the spargers by the steam/water leaving the sparger arms will cause additional overflow into the cavity. Steam added to the IRWST via the ADS spargers will vent via both the overflows and the vents through the roof of the tank. Water added to the IRWST via the ADS spargers will flow into the refueling canal via the overflow spillways.

The water which spills to the refueling canal remains available for cooling via long term recirculation.

Q13 In FDR Section 5.0, there seem to be two conflicting statements about the coverage of the ADS Phase B1 tests. The first paragraph states that the tests "closely match the limits of the AP600 operating envelope when the peak flow rates are considered." Two paragraphs later, though, the first bullet refers to "data...over a wide range of quasi-steady-state flow rates."

a. Are the tests evaluated in terms of the peak flow, the quasi-steady (plateau) flow (where it exists), or both? If peak flow is a significant aspect of the test, why is the test mass flow rate (e.g., Table 4.4-1) evaluated at 20 seconds, which is well past the peak in most cases?

b. How does the relative brevity of the tests affect the usefulness of the data?

c. While the plots such as Figure 4.3-3 indicate that the AP600 operating range includes qualities between 26 percent and 99 percent, no tests covered that range, at least at the inlet. How will the operating envelope in the range of intermediate qualities be covered by test data? If that range will not be covered in tests, explain why the database is sufficient.

R13a The performance of the tests were evaluated based on the quasi-steady state (plateau) flow at 20 seconds, since the peak flow results from filling the supply piping between the VLI-1 and VLI-2 valves as the VLI-1 valve opens. High flow through the restricted opening of VLI-2 continues until the ADS piping to the valve package and discharge linefill and impose a back pressure on VLI-2. This same behavior affects the apparent quality of the fluid which is measured just upstream of the ADS valve package. The initially high fluid quality is based on the initial fluid enthalpy and the local pressure which is still approaching the quasi-steady state condition. The selection of 20 seconds is somewhat arbitrary in that at 15 seconds the facility has reached a plateau of flow and fluid quality.

Peak conditions were reviewed to determine how the test conditions were affected by the system tested, i.e., review of high flow, low quality tests indicated that the system has a limit to the maximum flow that it can be provided due to the tank inventory and the valve opening times of VLI-1.

R13b It does not. The fact that the facility has reached a "steady state" at a wide range of flow, qualities, and pressures upstream of the valve package is the important issue. The length of time this condition exists, e.g., 10 seconds versus one minute, is not important from a data collection or test analysis standpoint. Also, the tests are modeled as a transient from inception of the opening of the control valve.

R13c Figures 4.3-3 indicates the range of flow rates and qualities calculated to occur following an inadvertent actuation of stage 2 or 3 of the ADS at full plant pressure. The plot obviously starts at very low flow and nearly 100 percent quality that occurs when the ADS valve starts to open and the top of the pressurizer is full of steam. As the valve opens the flowrate increases and more importantly the pressurizer rapidly fills, and the quality of the mixture to the ADS package decreases in a few seconds. The peak mass flow and minimum quality typically occurs before the valve has fully opened. Then as the pressure decreases flow and quality decrease. Therefore most of the discharge occurs in the region where the tests were conducted. The portion of the curve at low flow and high quality is very short with respect to time, and relatively unimportant with regards to the overall venting of mass from the plant. Note, however, that we did obtain data using steam flow only in order to obtain data at high quality and thereby bracket the range of flow and quality conditions expected.

Q14 The ADS Phase B1 TAR does a reasonably good job in explaining the kinds of analyses that were performed on the data, e.g., two-phase multipliers, critical flow, etc. What is not clear is how this information is going to be used. Are specific models for two-phase subsonic and critical flow in piping networks and valves going to be validated for use in the AP600 accident analysis codes? Or is the analysis simply an aid to better understanding of the behavior of the system during these tests?

R14 RAI

Q15 On page 4-22 in the TAR, it is stated that "it is not essential to make a determination of whether choking occurred in the ADS test components. The pertinent issue is whether the computer models used to analyze the AP600 plant ADS can correctly predict the two-phase pressure drops and flow measured in the tests." The data from these tests establish a basis for validation of analytical models. However, the implication of the statement seems to be that if the calculations of overall pressure drops and flows through the piping/valve network are acceptably accurate, details of the various component pressure drops and flows do not matter. This would seem to provide little confidence that the code models would be able to predict accurately any conditions that fell outside the relatively narrow range represented by the ADS tests that were analyzed (including those of the second train of ADS in the plant, since the piping network is somewhat different from the first ADS train). This is especially true considering that flow splits in the ADS tests were inferred, not measured, and there appears to be no way to confirm the inferred flow distribution. Since flow splits depend on pressure loss characteristics of the various network components and the condition of the flow passing through those components (choked or unchoked). Westinghouse should explain how the models can adequately differentiate between choked and unchoked flow.

The staff takes note of the discussion in Section 4.4.3, e.g., the tendency of orifices not to "choke" in the classical sense. However, no quantitative evidence is presented to support the conclusion that the ADS gate valves would tend to behave as orifices in critical flow; in addition, while there are models that predict the limiting flow condition in orifices, no comparison to such models is presented in the TAR. Westinghouse should (a) present a quantitative analysis of the data to substantiate its conclusions (possibly including comparison to data from the Phase B2 series of tests), and (b) explain how the models used to calculate ADS 1/2/3 performance represent the thermal-hydraulic conditions in the piping/valve network.

R15 Westinghouse requested Clarification

- comparison of orifice performance with respect to valves?
- stage 1 orifice represents a gate (is this the staff's understanding?)

RAI to be issued

Q16 The implications in Sections 1 and 5 of the TAR are that the gate valves for stages 2 and 3 were of substantially different design and configuration. How do the differences between these two valves contribute to the variations in the data (and derived quantities).

R16 These valves were supplied by two different manufacturers. The opening area of the gate valve for stage 2 is .213 ft3 and that for stage 3 is .2003 ft3. The difference is small. Therefore, it is difficult to see the variations in the data due to this small difference considering the uncertainty in the tests.

Westinghouse agreed that the TAR will be revised to reflect this information.

<u>OSU Final Data and Test Analysis Reports</u>

A set of questions based on the preliminary versions of the FDR and the TAR were provided to Westinghouse previously. The following questions reflect more detailed reviews of the final versions of the reports.

FDR Related Questions

Q17 Recent staff evaluation of OSU data indicates that a check valve failure in the normal RHR line opened a flow path between the two DVI lines. The largest potential impact of this occurrence appears to be in DVI-line break tests, in which flow from the intact DVI line could be diverted to the broken line. Explain how this condition affects reliability of test data from OSU for these events, and how the flow path is accounted for in analyzing the data. The tests' ability to meet Westinghouse's established acceptance criteria should also be discussed.

R17 Westinghouse has reviewed the OSU data and concluded that the check valve in the normal RHR line was open during the DVI line break tests. An evaluation has been performed assessing the impact of this failure on the test results which will be used to answer the staff's questions on this issue.

Q18 The "sequence of events" specifies event timing with much higher precision than the facility's normal data acquisition rate would appear to support. How were the times determined?

R18 The sequence of events tables were taken from the Wonder Ware output which recorded the actions of the PLC's in the OSU test. The actual times of these events were recorded by this program to the nearest tenth of a second, which is more frequent than the DAS sampling times used to collect test data.

Q19 All of the test descriptions include sections on "Inoperable Instruments." For several of the tests, the cold leg flow meters were damaged and inoperable (see, for example, Section 5.4.1.2). It is stated that differential pressures were used to infer cold leg flows. However, the relevant instruments are not plotted for these tests.

a. Why are the instrument readings not included in the FDR?

b. These types of readings can only be correlated with flow in single-phase conditions. How was the flow measured (or, was the flow measured) in two-phase conditions? Are the data considered to be reliable for single- and/or two-phase flows?

c. Explain how the necessary information on cold leg flows can be derived from the available data.

R19 a. The differential pressures that can be used to infer flow in the cold legs are included in the electronic data files supplied with the Final Data Report.

b. Two-phase flow in the cold legs was not measured since the data is only reliable during the liquid phase. However, the liquid and vapor mass is calculated in the TAR, analyzed and given in Plots 59 and 60 for each test.

c. Cold leg flows can be inferred from the data available from the flow meters which were operational during test SB01. Section 4.17.2.1 of the TAR describes how these flow can be derived from the liquid phase using the relevant instrumentation listed in Tables 4.17-3 through 4.17-3.

Q20 Over a range of several thousand seconds in many tests, the PRHR HX wide range level appears to drift upwards considerably. Explain what is occurring: is this an actual change in level, or is an instrumentation problem?

R20 RAI - requires additional review/research.

Q21 Figure 5.4.2-72 presents calculated break flow from the reactor vessel for Test SB13, presumably because the total break flow includes contributions from other components. Are other such plots available for tests where such a differentiation is relevant? Also, in Section 6, there are comparison plots (with varying time scales) of total break flow for 4 tests. Since the tests have breaks in various locations, and the total break flow can include contributions from more than just the reactor vessel, depending on break location, please elaborate on the significance of these plots.

R21 Figure 5.4.2-72 represents an estimate of the liquid flow from the reactor vessel for test SB13 calculated by subtracting the measured liquid flows from the CMT (FMM501) and ACC (FMM401) from the measured break liquid flow (FMM905). A comparison of the break liquid flows for the DVI line break tests was made in Section 5.4.2. No other plots of liquid flow are relevant and therefore were not presented in other sections of the FDR.

Section 6.0 examines the effect of the location of various 2 inch breaks within the test matrix. Section 6.1.1 simply examines the possible influence on the break liquid flow meter readings for the four tests in this category in order to ascertain if this data appears reasonable from test to test as a method of test data validation.
Westinghouse will examine if DVI check valve leakage described in question #17 has any impact in this area.

Q22 Please explain fully what calibration procedures were followed for the BAMS. How is uncertainty in the break flow rate determined? Is there any attempt to compare integral break/ADS flow with the total flow collected in the BAMS and the sump(s)?

R22 The instrumentation located in the BAMS were individually calibrated in accordance with the OSU Test Calibration Procedures. No system wide calibration of the BAMS was performed, however, the hot preoperational tests were performed, in part, to test the operation of the BAMS and its instruments.

An uncertainty in the break flow rates was not estimated, however, the break flow rates and the overall mass and energy balance for each test are examined in the TAR.

The integral break/ADS flow as determined by the BAMS measurements was not compared to the sump(s) inventory.

Q23 How were actual operating conditions factored into the measurement uncertainty analysis; in other words, were there conditions during the tests that could affect instrument accuracy (e.g., voiding in sense lines) that were not represented in the as-calibrated uncertainties, and if so, how were these conditions included in the uncertainty analyses? Were historical data--based on instrument responses from earlier tests--used to help estimate uncertainties?

R23 The operating history of the instrumentation is not directly accounted for in the error analysis presented in Appendix D. However, an error contribution due to instability of the sensor over a time period of 1 year (calibration period) is estimated and included in the overall total probable error. This factor is intended to cover conditions that affect sensor performance. Historical data was therefore not used to help estimate the instrument error.

The following questions are related to the detailed presentation of data for Test SB01 in Section 5.1.1 of the FDR.

Q24 In Test SB01, the low accumulator pressure is attributed to cooling in the accumulator by the nitrogen. Could changes in gas solubility also affect the pressure?

R24 Changes in solubility of gas in the accumulator inventory over the range of conditions observed is small and not considered to have a noticeable affect on accumulator gas overpressure.

Q25 In the brief table in Section 5.1.1.1, is the "dimension" for each CMT thermocouple its axial distance from the top of the CMT? If not, what does "dimension" mean?

R25 Yes. The "dimension" referred to in the brief table given in Section 5.1.1.1 is referenced from the top inside surface of the CMT as described in the text immediately preceding the table.

Q26 Section 5.1.1.2 presents a very good discussion on compensation for inoperable instruments. The one exception is for PT-201, which is identified as being unreliable; the statement is made that "a sufficient amount of other pressure data are available," but the sources of those data are not identified. Please specify the data that were used to compensate for this instrument.

R26 The location of the PT-201 measurement is the top of SG 1 tubes. The pressure at this location may be calculated from combining the measurements, after appropriate operations to convert levels (inches of water)

to pressure (psia), from PT-201, LDP-207, LDP-209 and LDP-215. An alternative approach is to combine the measurements from instruments LDP-207, LDP-209, DP-211, LDP-213 and LDP-219.
Westinghouse will provide clarification in a revision to this report.

Q27 Please explain the sequence of events for the test on page 5.1.1-5. Table 5.1.1-3 shows that accumulator injection actually began shortly before ADS-1 actuation, while the description implies the ADS actuated first, followed by accumulator injection.

R27 The text of page 5.1.1-8 and the data of Table 5.1.1-5 are consistent in their description of the sequence of events for the accumulator and ADS actuations.

Note that there is a 16 second delay between the ADS actuation signal being generated and the opening of the ADS-1 valve. This is consistent with the time of ADS-1 valve opening listed in Table 5.1.1-5.
Westinghouse will provide a description of the delays in Section 2.6.

Q28 While the problems with the steam generator U-tube instrumentation are described well, it is not clear precisely why an indicated level of +20" corresponds to empty tubes at about 300 seconds (page 5.1.1-7). Are there alternative instruments that can be used to verify this timing?

R28 The LDP readings across the inlet and outlet plena (LDP-209, LDP-211 and LDP-213 for SG 1, LDP-210, LDP-212 and LDP 214 for SG 2) provide a redundant indication of dry SG tubes; when the water level in the SG plena begin to drop, the tubes must be voided.

Q29 The "trends" that are cited for some inoperable level instrumentation in the steam generators (e.g., LDP-207, -208) are somewhat difficult to spot, for instance, discerning the draining of the hot legs. HL-2 is asserted to begin to drain around 288 seconds; the associated curve (Figure 5.1.1-11) barely seems to wiggle at that time. Please explain what corroborating instrument readings or qualitative insights from the facility response were used in verifying the described events.

R29 An alternate indication that the hot leg is draining is obtained from LDP-209 and LDP-214, the levels transducers monitoring across the hot leg / hot leg plena. When the indicated level drops below the hot leg / channel head junction, the hot leg is taken to begin draining.

Q30 Please clarify the discussion of timing in the two sections on "Initial Depressurization Phase" and "ADS Phase" (on page 5.1.1-8). The last paragraph of the first section states that ADS-1 was opened at about 461 seconds. However, the second paragraph of the second section seems to imply that the ADS was already open at 450 seconds, when accumulator injection began.

Some additional apparent inconsistencies were also noted in the description of the ADS phase:

a. 2nd paragraph, page 5.1.1-9: DP-114 is stated to sharply increase to -10" at 602 seconds. It actually appears to decrease to that reading. A similar statement is made at the bottom of page 5.1.1-15.

b. 2nd paragraph, page 5.1.1-10: Figure 5.1.1-24 is cited as evidence of the pressurizer temperature increasing above saturation conditions after 26,500 seconds. This figure shows no such increase.

R30 The description given in the second paragraph of ADS Phase given on pg. 5.1.1-8 does not mean that the depressurization of the system to accumulator actuation was due to ADS actuation. Rather, the depressuriza tion to this point in time was due to inventory loss through the break simulation only.

a. The reviewer is correct in his observation that the term "increased" is used to describe the change in differential pressure associated with the condensation event. The intent of this terminology was to characterize the change in pressure drop as indicating that the direction of flow reversed and increasing to a significant value. **Westinghouse will issue an errata to clarify in all cases.**

b. The reviewer is correct in his observation that Figure 5.1.1-24 does not clearly show that the local vapor temperature displayed, TF-605, begins to rise to the superheated range at about 26,500 seconds. To discern this, values of the individual data must be reviewed. It is noted, however, that the pressurizer heater rod temperatures rise well above saturation after about 27,000 seconds, Figure 5.1.1-21. Recalling that, this late in the event, only steam is in the pressurizer, one may readily infer that the steam inventory in the pressurizer does indeed become superheated.

Q31 In the description of the IRWST injection phase (page 5.1.1-10), reflood of the surge line and pressurizer is supposedly confirmed by the HL, surge line, and pressurizer temperature indications. The hot leg temperatures in Figure 5.1.1-14 appear to subcool when they are stated to do so, but the pressurizer and surge line temperatures in Figure 5.1.1-27 do not indicate subcooling. Please explain.

R31 The saturation temperature plotted in Figure 5.1.1-27 is based on measured pressure near the top of the pressurizer (PT-603), while the saturation temperature in plotted in Figure 5.1.1-14 is based on the pressure measurement in the reactor vessel (RV) simulation (PT-107). For the purposes of observing reflood of the surge line, the local pressure in the RV simulation is more appropriate than a measurement taken along an exhaust path at a higher elevation than the hot leg, surge line, or bottom of the pressurizer. When compared to T-SAT based on pressure measurements from PT-107, both the surge line and lower pressurizer fluid temperatures are noted to drive towards saturation.

Q32 The description of events near the end of IRWST injection, referenced to Figure 5.1.1-34, is somewhat confusing. What is the significance of the so-called "negative pressure remaining in the CMTs" on the indicated level? Are the CMTs actually empty at that time, or are they simply indicating zero level due to a slight relative vacuum in the tanks?

R32 The observed "negative pressure" in the CMTs indicates a slight vacuum relative to ambient and had no impact on the measured levels. The level in the CMTs was as indicated by the LDP readings taken at that time.

Q33 What is the significance of the large spike at the inception of sump injection flow (FMM-901, Figue 5.1.1-37)? (Note: this same behavior was observed in many SBLOCA tests.)

R33 The observed volumetric flow spike shown in Figure 5.1.1-37 is the transient response of the affected flow meter in the sump injection line to the switching from IRWST injection to sump injection. This shows the effect of valves opening and closing. Integrated over the time interval of the spike itself, the net effect in total flow delivered is minimal.

Q34 Is there additional information beyond that in Figure 5.1.1-39 that supports the description of events at 15,786 seconds and beyond (i.e., sump injection valves opening, DVI flows decreasing, and equalization of sump and IRWST levels)?

R34 Section 5.1.3 of the TAR describes the events and presents analysis of the long term cooling transient for test SB01 and includes plots of the relevant phenomena beyond 8000 seconds.

Q35 Some of the (derived) values of steam percentage shown in Figures 5.1.1-3 and -4 fall either below zero or above 100 percent. Explain why this occurred and what, if any, significance these values have.

R35 The reason for values of per cent steam greater than 100 percent or less than 0 percent is a result of the dynamic effects of flow on the use of a differential pressure transducer to measure levels in the calculation. These values have no other significance.

Q36 The pressurizer heater power spikes sharply around 600 seconds (Figure 5.1.1-24). This appears to correlate to a sharp down-spike in pressurizer level on Figure 5.1.1-58. Is this just "noise," or is there a correlation between these two events.

R36 The apparent power spike observed in Figure 5.1.1-24 is taken to be noise as its duration is one data scan. The noted downspike in pressurizer level occurs over several data scans. The thermal energy required to cause the water level to drop in the pressurizer cannot be delivered in the time of the observed spike, nor would the surge line be expected to see a corresponding change in level. Thus, the two events are not considered to be coupled.

Q37 Explain why the flow indication for the IRWST overflow (FMM-703, Figure 5.1.1-25) goes negative between about 250 and 750 seconds.

R37 The significance of the apparent negative flow through the IRWST overflow line is that the direction of flow is from the sump to the IRWST tank during this time period. This is possible when the local pressure in the sump is greater that in the IRWST. It is noted that the indication of negative flow begins at about the time the pressure at the top of the sump tank is greater than that at the top of the IRWST tank.

Q38 It appears that the break separator loop seal flow peaked around 50 seconds, not at 24 as indicated (page 5.1.1-29). The description of the flow variation with time in the text would lead one to expect a monotonically decreasing flow until about 978 seconds, which is not the case; for instance, the loop seal flow appears to increase significantly just prior to ADS-1 initiation, and again before ADS-4. Also, what is the significance, if any, of the "bump" just prior to 1000 seconds, lasting for about 150 seconds? The flow does indeed fall momentarily to zero, as described on page 5.1.1-29, but it recovers immediately to about 2 gpm. Please discuss the significance of these deviations.

R38 The correct reference for break separator flow is Figure 5.1.1-28. Agree with comment; value of peak flow is about 24 gpm, time of peak flow is about 50 seconds into event.
Westinghouse will revise the report as stated.

The text states only that the flow decreases; it says nothing about the nature of the decrease, be it monotonic or otherwise. The text of the report will be modified to clarify this point.

The noted "bumps" in break separator flow are evaluated to be the consequence of the venting characteristics of the system at this time. Cool accumulator flow has been injected and warmer flow from the CMT into the RV is established. The warmer water provides for higher steam generation rates which, in turn, provides for additional liquid to be carried out the break.

The liquid flow through the break remains at zero from about 1100 seconds to 2700 seconds and then returns to ~2 gpm when the primary sump level has increased to that of the BAMS.

The following questions are related to the detailed presentation of data for Test SB18 in Section 5.1.2 of the FDR.

Q39 Please discuss why the times of certain events and values of some parameters differed substantially from SB01. For instance, why did CMT-1 drain faster in SB18, resulting in ADS actuation some 71 seconds earlier? Note that this timing also affected accumulator injection, so that, even though the accumulators started at lower pressure in SB18 than in SB01, they began to inject earlier in the transient.

R39 The difference in timing of certain events for Tests SB-01 and SB-18 may be due, in part, to minor facility modifications implemented between the time the two tests were run. Two modifications include the installation of a vacuum breaker in the ADS1-3 discharge line and the removal of insulation on the vessel during heater rod replacement operations. This issue has not yet been fully evaluated.

Q40 The explanation for the holdup of CMT-2 injection is that the accumulator injection closed the CMT outlet check valve, thus preventing CMT-2 from draining. However, Figure 5.1.2-6 shows CMT-2 level hanging up between around 125 and 350 seconds, while Figure 5.1.2-16 does not show significant accumulator injection until about 400 seconds, by which time CMT-2 is draining at roughly the same rate as CMT-1. Is there another possible explanation for this behavior, such as condensation at the top of CMT-2?

R40 This issue requires further investigation.

Q41 At the top of page 5.1.2-6, it is stated that minimum core barrel level occurred at 1000 seconds later than in SB01. Is this correct? If so, why is there such a discrepancy in the two tests when other parameters seem to be in fairly close agreement?

R41 Strictly speaking, yes. However, comparison to Figure 5.1.1-15 shows that the minimum level in SB01 which occurs at 280 seconds is only a few inches below that of SB18 at the same time. The water level behavior is consistent between the two tests.

Q42 Is there a correlation in the actual readings of the level instruments (shown as steam percent) in Figure 5.1.2-3 and the pressure differential sensors in Figure 5.1.2-19? That is, can one really discern the direction of flow into or out of the upper head, or are the spikes merely indicative of the condensation event without regard to real magnitude or direction of level and flow changes? The behavior of these sensors appears to be reasonably consistent over many tests in which similar events occurred (e.g., SB01, SB19).

R42 Expressing data as per cent steam is meaningful when fluid velocities are low; friction, form and acceleration losses are small compared to the gravitational head associated with liquid inventory in the region spanned by the instrument. Rapid changes in void or in measured differential pressure indicate a physical process is ongoing that affects the movement of fluid between the two taps. Changes in the differential pressure data are indicative of phenomena changes taking place at the time the measurement is made. The spikes should indicate a flow effect due to the condensation as well as the pressure decrease.

The following questions refer to specific tests as presented in Section 5 of the FDR.

Q43 In comparing Test SB19 to Test SB01:

a. Why is the transition from recirculation to draining in the CMTs later in SB19 than in SB01?

b. Is there a systematic explanation for differences in core levels and timing of events during the initial depressurization phase?

c. Why are break flows higher in SB19 for the first 400 seconds?

R43 The later transition from recirculation to draining of the CMTs is the result of containment backpressure simulation and the installation of a vacuum breaker after Test SB-01.

Again, differences in core levels and timing of events are the result of containment backpressure simulation and the installation of a vacuum breaker after performing Test SB-01.

Break flows are higher early in the transient due to the simulated high containment backpressure, which resulted in less flashing (larger liquid in the break flow) and thereby provided for more mass flow out the break for a given pressure drop.

Q44 For Test SB09:

a. In Figure 5.3.2-72, is the PRHR HX flow really negative, or there just a zero offset in the curve?

b. Why does accumulator #1 show negative flow at about 12,000 and 21,000 seconds?

R44 As noted in Table 5.3.2-2 on page 5.3.2-16, the readings of channels FMM-802 and FMM-804 are suspect after 50 and 500 seconds, respectively, due to formation of steam in those lines.

As noted in Table 5.3.2-2 on page 5.3.2-16, the readings of channel FMM-401 was suspect after 1500 seconds due to the accumulator being empty.

Q45 For Test SB12:

a. Explain why ADS1-3 flow becomes negative (Figure 5.4.1-18).

b. Following ADS-4 actuation at about 250 seconds, one would tend to expect pressurizer level to decrease. However, Figure 5.4.1-31 shows pressurizer steam percent decreasing, implying that level increases. Please explain this apparent inconsistency. This same behavior is noted for Test SB13.

R45 For part a) Westinghouse will check further.

The reviewer is correct in noting that the data Figure 5.4.1-31 suggests that the steam percent decreases following opening of the ADS 4 valves. However, the IRWST begins injection just prior to ADS 4 valves opening. This provides for generation of steam in excess of the capacity of the 4th stage valves alone; the excess is vented through ADS 1-3 valves. The increased vapor flow, possibly carrying with it some liquid, results in an increased pressure drop across the LDP instrument in the pressurizer, resulting in an apparent increase in liquid level in that component.

The same explanation generally holds for Test SB-13.

Q46 For Test SB13, Figure 5.4.2-72:

a. What is the difference between the "old" and "updated" figures?

b. Why does the break flow drop below zero in the first 40 seconds of the transient?

R46 **Westinghouse will issue errata as necessary to clarify item (a).**

The explanation for the apparent negative vessel break flow early in the transient is simply that more flow was supplied from the CMTs than was vented out the break.

Q47 Please explain the data for Test SB28, in Figure 5.4.3-1. Is this the result of a large zero offset for FMM-501?

R47 It appears that the reviewer is referring to Figure 5.4.3-4. As noted in Table 5.4.3-2, the output of FMM-501 is invalid after the CMT drains. From the levels plot of Figure 5.4.3-5, this is observed to occur at about 140 seconds into the test. All data after this time is suspect. Prior to that time, output from FMM-501 appears to be normal and valid.

Q48 Figure 6.1.21 presents a comparison of measured break flow for several tests. Are any calculated break flow results available that account for the effects of mass storage in the separator tank?

R48 Break flow that accounts for mass storage effects and is provided as part of the Test Analysis Report.

The following comments and questions concern the OSU TAR, including a review of the "general" sections and of two specific tests, SB01 and SB18. Additional questions on other tests will be provided to Westinghouse at a future date.

Q49 The discussion of the PIRT (Section 1.3) in the TAR is rather abbreviated, and the rationale for the selection of phenomena and their rankings is never really addressed. The PIRT appears geared largely to the NOTRUMP code, since it does not appear to include phenomena that the code is unable to represent (e.g., cold leg stratification). Other phenomena are simply not called out, irrespective of NOTRUMP's capabilities; for instance, flashing in the CMT as a means of causing the transition from recirculation to draining is not addressed. In addition, some of the rankings chosen do not appear to be well-supported by the data. For example, CMT recirculation is ranked "medium" for SBLOCAs. However, data from the test program appear to the staff to demonstrate that the recirculation phase of the transient--and transition to draining--is one of the determining factors in the timing of ADS initiation and subsequent system depressurization. The reasons for assigning it a "medium" ranking rather than "high" are not clear.

R49 The PIRT is consistent with the test objectives stated in Section 1.2. The reviewer is referred to the referenced reports for detailed discussion and rationale of the ranking of various phenomena.
RAI 440.325 also addresses this question. An inclusive response will be part of the scaling report

Q50 There is a slight inconsistency in the description of the scaling methodology on pp. 1.4-1 and 1.4-2. The "hierarchy" of evaluation at the top of p. 1.4-2 implies that a module is a part of a subsystem (this is also shown in Table 1.4-1). On p. 1.4-1 (third paragraph), the wording seems to indicate that a subsystem and a module are equivalent. Please clarify.

R50 The discussion of paragraph 3, page 1.4-1 might ber amended to read, "Each system can be sucessively divided as follows; first, into interacting subsystems; where appropriate, components of those subsystems; then interacting constituents (materials); and finally, into interacting phases (liquid, vapor, or solid)."

Q51 How are source and sink terms accounted for in the scaling equations (e.g., Eq. 1.4-1)?

R51 The formulation of 1.4-1 allows sources and sinks to be treated as boundary conditions on a control volume; the source or sink may be represented as a flux across a surface.

Q52 In Section 1.5, the OSU data and AP600 NOTRUMP calculations are compared. In Figure 1.5-6, what causes the oscillations observed in the test data? Can the physical mechanism be represented by the computer model? If not, what impact does this have on ability to model system behavior?

R52 These are original NOTRUMP calculations. Both are calculations. OSU calculations do oscillate.

Q53 Section 4.2, on level compensation refers to a "straight numeric average" of temperature is used to compensate some differential pressure level sensors (LDPs - see the second paragraph on p. 4.2-1). However, a general methodology for compensation is presented in Section 4.1. How do these procedures differ?

R53 The methodology of Section 4.2 is simply the calculation of a density using a straight numerical average of all thermocouple readings taken within the span of a levels transducer for a given time. The data channel IDs used in this simplified calculation are listed in Table 4.2-1.

Q54 In Section 4.3, please explain how Eqs. 4.3-11 and 4.3-12 were developed.

R54 Equations 4.3-11 and 4.3-12 were developed by applying the ideal gas law to an expanding volume of gas.

Q55 As noted in Section 4.4, that flowmeter readings for mass flow calculations are unreliable when two-phase flow is being measured. Mention is made of inferring mass flow from the CMT and CLBL mass conservation equations, but the specific methodology is not shown. Please provide detail on that methodology.

R55 Specifically for the cold leg balance leg one can calculate an inferred mass flow into the CMT by using the measured CMT exit flow and the transient mass in the tank derived from the delta P cells. The resulting calculation gives the net mass (either single or 2 phase) which would be flow up the cold leg balance line.

Q56 Section 4.4.6 describes the use of fluid thermocouples to obtain "pseudo-metal" temperatures. It is not clear from the material in the TAR how this is accomplished. Please clarify:

a. How the fluid thermocouple(s) representing the "pseudo-metal" temperature(s) is/are chosen; and

b. If the temperature of that fluid thermocouple is "adjusted" in any way to account for a metal-to-fluid temperature difference.

c. Also, how, if at all, are uncertainties in metal temperature as a result of this process estimated and propagated?

d. Please confirm that what is actually being done in this process is to indirectly calculate the first term on the right hand side of Eq. 4.4-68

R56 a. Two thermocouples per CLBL were identified. These were the only two thermocouples in those lines.

b. No "adjustment" was made to the fluid temperatures used in the metal energy calculation.

c. An error analysis for energy balance calculations for this component has not been done. The component is small and represents a small portion of the overall energy concerns of the facility.

d. The fluid temperatures are indeed used to calculate the change of energy of the CLBL metal; this is the left hand side of Equation 4.4-68 or, more specifically, the left hand side of Equation 4.4-70.

Q57 Are the effects of fluid accumulation between the ADS "valves" (at the pressurizer) and the separator considered? Also, is this part of the measurement system "pre-filled" with water?

R57 Although there is a loop seal in the ADS 1-3 separator, it is not accounted for in the calculations as the net change in liquid inventory of this piping is zero over the course of the test.

Q58 Is the differential term in Eq. 4.6-2 meant to apply to the liquid only or to both the liquid and the vapor?

R58 The differential form of Equation 4.6-2 was extended to both liquid and vapor phases of the working fluid.

Q59 On page 4.6-8, it is stated that the energy loss to ambient is zero because of the heat tracing on the system piping. Was it verified experimentally that energy loss and energy gain (from heat tracing to the fluid in the piping) was negligible? A similar question applies to Sections 4.7.5.4 and 4.7.5.5.

R59 The statement made on page 4.6-8 is that heat tracing "had the effect of off-setting any energy loss from the fluid to the ambient environment." The basis of this statement is that observed pipe metal surface temperatures remained essentially constant throughout the duration of the test. Thus, the change in metal energy was zero. This suggests that energy exchange, be it loss or gain, by the working fluid is essentially zero.

Q60 In the first lines of Eq. 4.7.21 (first term to the right of the equal sign) and Eq. 4.7.22 (term on the left-hand-side of the expression), the subscript "f" on c_p and T should be removed. In addition, the way in which these equations (and previous similar equations) are expressed implies that the liquid and the vapor are at the same temperature. Is this assumption confirmed by the data? If the liquid and vapor are found to differ significantly in temperature, the form of these equations needs to be changed to account for that fact.

R60 The reviewer is correct in his observation regarding the subscripts "f" and "g" for equation 4.7-21 and 4.7-22.

The formulation of the equation does not imply that the vapor and liquid phases are at the same temperature; by considering the full expansion of Equations 4.7--21 and 4.7-22, it is clearly apparent that vapor and liquid temperatures may differ when the equations are evaluated. **Westinghouse will issue an errata sheet to correct this.**

Q61 In the first paragraph of Section 4.8.1, what is meant by "an orifice was in place within the span of the level transducer." The staff has not been able to find any documentation related to this orifice or its function. Please clarify the purpose of this orifice and the correction procedure.

R61 The purpose of the orifice was to maintain the loop seal at a pressure that would preclude flashing of the separated liquid before it passed through the magnetic flow meter. Unfortunately, the orifice was installed upstream of the flow meter rather than downstream of it. The correction for this was to adjust the indicated level to account for the added differential pressure, using standard orifice pressure drop calculations found in any mechanical engineering handbook or industry reference.

Q62 Two "issues" are identified concerning the core fluid thermocouples in Section 4.11, but no subsequent analysis or explanation of the issues is provided. Specifically,

a. How did the fluid temperature histories at the center and perimeter differ?

b. The "best average core temperature" is asserted to be represented by the center-rod temperatures, without quantitative justification. Why is this procedure preferable to a weighted average of the core and perimeter rods?

c. The noise in the core fluid temperatures is asserted to be "unrelated to core thermal-hydraulic phenomena." How was this determined? To what was the noise related?

R62 a. As one might expect, the measured fluid temperatures in the center region of the core simulation were slightly higher than those at the periphery of the core simulation. The trend behavior of the periphery and center thermocouples, however, were similar.

b. Tests were conducted with a flow radial power profile; at a given elevation, all rods were at the same power. Thus, the only variable that might affect fluid temperature is the flow past the rod. The only location that the power to flow ratio varies is at the core periphery. Thus, only the fluid at the core periphery is affected. Once inside the core, fluid temperatures would be radially uniform at a given elevation.

c. The noise discussed in the text of the report was attributed to electrical interference or feedback in the monitored thermocouple signal. This conclusion was drawn based on signal characteristics and noting other phenomena taking place in the core at the time the noise was observed.

Q63 Please clarify the factor of 1/2 in Eq. 4.11-1. The implication in the opening paragraph of Section 4.11.2 is that two of the four KW-XXX instruments (Table 4.11.3) would sum to the total core power. Which instruments are redundant (e.g., do KW-101 and KW-102 indicate the same [nominal] power)?

R63 The reviewer is correct in his understanding the power measurements are redundant, instrument KW-103 is redundant to KW-101, and KW-104 is redundant to KW-102.

Q64 Do the "TFM" instruments in Table 4.15-3 appear in the P&ID? If not, please clarify their locations and measurements.

R64 The "TFM" instruments are actually part of the heat flux meters (HFMs) and are at the same location as the HFMs. While the TFM designation is not shown on the P&IDs, the HFMs are.

Q65 On p. 5.1.1-1, Figure 5.1.1-3 is described as showing "the calculated quantity of steam generated in the core" during the test. How was this calculated? What is plotted is a rate of steam production, expressed as a mass flow rate. Is this the net rate of steam flow leaving the reactor vessel?

R65 The reviewer is correct in his observation that the description of Figure 5.1.1-3 might best be amended to state that the plot is of the calculated steam generation rate in the core throughout the test. **Westinghouse will provide a clarification to the report.**

The calculation of the rate of steam production is detailed and explained in Section 4.11.

Q66 The refilling of the CMTs during the IRWST injection phase is covered in both the FDR and the TAR (Section 5.1.1 of each report); the discussions are essentially identical. The reason given for the failure of the CMTs to drain immediately after refill is that the check valves were held shut by the head of the IRWST. Is it possible that the CMTs remained at a partial vacuum after the refill? How would this affect evaluate of the data and the FDR/TAR explanations for the overall system behavior in these events.

R66 Will be addressed in the scaling closure report.

Q67 The CMT refill process is also discussed in Section 6.1.1 of the TAR. In that section, it is postulated that the CMT refill ends due to reduction of level in the cold legs. Staff analysis, however, indicates that the limiting factor may be the ability of the CMTs to maintain an adequate vacuum relative to the reactor vessel; i.e., refilling stops due to reduction of differential pressure, rather than the "breaking" of the siphon. How would this affect evaluation and explanation of the behavior provided by the TAR.

R67 Will be addressed in the scaling closure report.

Q68 Section 6.1.3 of the TAR discusses the late-phase flow oscillations in the OSU facility. The staff still believes that the explanation of the oscillatory behavior may be incomplete. While only one oscillatory mode is implied, lasting several thousand seconds, staff evaluation (including the results of confirmatory tests at OSU) has indicated that there are at least three separate types of oscillations. Aside from the mechanisms described by Westinghouse, there appears to be a connection between a second set of oscillations and the second draining (after refill) of the

CMTs; a third oscillation very late in the transient (e.g., 14,000-15,000 seconds in SB01) appears to be related to an interaction between the test loop and the BAMS (and is thus non-prototypic with respect to the AP600). The staff requests that Westinghouse reexamine the data in regards to the mechanisms for oscillatory behavior in the OSU facility.

R68 Will be addressed in the scaling closure report

Q69 There is no discussion in either the FDR or the TAR of the oscillatory behavior that occurs at the initiation of IRWST injection in most tests. This type of behavior has been seen, as well, in the NRC's confirmatory tests in both ROSA and OSU, and is believed to involve complex interactions between the IRWST, ADS-4 valves, and the pressurizer. The oscillatory behavior can be observed by examining, for instance, Figs. 5.1.2-5 and 5.1.2-48 in the FDR (Test SB18); note that the oscillations begin at the inception of IRWST flow and do not cease until the pressurizer level drops to zero (at which time the flow peaks). The staff requests that Westinghouse examine the data and explain the mechanism driving these oscillations, and discuss the potential for this mechanism to exist in the AP600 plant.

R69 Will be addressed in the scaling closure report

Q70 There is very little coverage overall in the TAR of the effect of uncertainties. Although the subject of data error analysis is discussed in detail in the FDR, the TAR should provide for considerations beyond instrumentation errors. Manipulation of the data is done in the TAR using the output of several instruments simultaneously or sequentially, such as adjusting level readings using density corrections derived from temperature data at discrete locations. Some energy balance calculations used fluid thermocouple data in place of wall temperatures. Assumptions were made in various calculations, which may or may not have been verified experimentally. With regard to heat transfer to the environment, for instance, heat traced components were assumed to be adiabatic, and heat losses for other components were calculated using simplified assumptions for convective and radiation heat transfer. Data were "filtered" (e.g., oscillations were smoothed), and, for core fluid temperatures, peripheral temperatures were disregarded as being "less representative" of core conditions. Furthermore, the staff's post-test evaluation of Westinghouse's data has, for example, noted component failures and systems interactions that may affect uncertainties in key parameters (e.g., failure of an RHR check valve to the DVI line and interaction between BAMS and the rest of the loop causing oscillatory behavior).

Although the overall mass and energy balances for each test provide a gross estimate of uncertainty for the system during these tests, it is not clear that the overall calculations are sufficient; the data will be compared with analyses performed with Westinghouse's design basis accident analysis codes on more than simply the basis of overall mass and energy conservation for the system. The overall uncertainties <u>may</u> bound the uncertainties associated with key parameters, e.g., core collapsed liquid level and mixture level; however, there is also the possibility that compensating errors could reduce the overall uncertainties compared to those related to individual parameters. The staff considers this to be an important issue, and requests that Westinghouse provide a discussion of estimation of uncertainties in view of (but not limited to) the points discussed above, with quantitative supporting information.

R70 RAI will be rewritten

Editorial Comments Related to the Testing Reports

ADS Phase B1 Final Data Report (FDR) and Test Analysis Report (TAR)

Q1 Section 4.2.5, states that Test A043331, "as expected, achieved a higher mass flow and steam quality than A003331." However, what was expected (as explained in the previous paragraph) was a lower steam quality in A043331, and that was, in fact, the case, as shown by Figs. 4.3-20 and 4.3-24. It would appear that the word "lower" should be inserted before "steam quality."

R1. Yes. ".....as expected, achieved a higher mass flow and a lower steam quality than A006331."
Westinghouse will provide an errata to correct this.

Q2. Figure 4.5.1 is useful as a summary of the test program. However, it would be useful to include the AP600 operating range, as is shown on (for example) Figure 4.3-3, to assist in ascertaining whether the database is sufficient (not just "acceptable") for code validation.

R2. The basic information is included in the individual sections of the report. However, a summary figure will be included in the discussion of the ADS test in the scaling closure report.

OSU Final Data Report

Q3. It would be valuable, in the FDR, if a table were included showing setpoints for the actuation of various control events. A table showing system configuration for each test would also be useful, especially where changes in equipment, component availability, and loop characteristics (e.g., different orifices in various lines) were changed.

R3. Appendix B, Data Acceptance Results, contains the equipment and break alignments along with other orifices used in each test performed. Section 2.6 describes the Facility Control Systems and a summary of the Programmable Control System and a summary of the Programmable Controller Setpoints in Table 2.6-1.
Westinghouse will provide actual setpoint values and delays in Table 2.6-1.

Q4. To assist the staff's analyses of OSU tests, several initial conditions should be provided for each test. These include:

Steam Generator Level (LDP-601)
PRHR Level
PRHR Inlet Temperature (TF-803)
CMT Pressures (PT-501, PT-502)

R4. Steam Generator levels, LDP-3-3 and LDP-304 are included in the Tables of Initial Conditions for each test as is pressurizer level, LDP-601. The other parameters were not included in this table based on the following rationale.

The PRHR is full at the start of testing as required in the OSU test Startup Procedures (Fill & Drain). The PRHR inlet temperature upstream of the inlet valve is the Hot Leg Temperature and the PRHR inlet header is at ambient conditions. CMT pressures PT-501 and PT-502 are near pressurizer pressure except for the elevation head difference.

These parameters are included in the electronic data files provided for each test.

Q5. Additional information is would be helpful on pressure tap elevations and elevation differences other than those already included for the reactor vessel. In fact, a table showing all instrument elevations would be especially valuable, rather than having to extract that information from the P&IDs.

R5. Tap elevations for the PT's and LDP's can be added to the Instrument Data Base given in Appendix C.

Q6. Some of the plots presented in the FDR are of failed or unreliable instruments. Although these instruments may be unreliable, the data could still be useful from a qualitative standpoint. These plots should be labeled such that it is clear the instrument is failed.

R6. Data from a failed or unreliable instrument can be misleading and result in misinterpretation of the results, therefore, as part of the data validation process, Westinghouse removes failed and clearly unreliable data channels from the electronic data base and does not include these plots in the FDR.

However, channels that provide valid data for a portion of the test are included in the electronic files and plotted in the FDR where appropriate. The time periods during which the data is suspect has been clearly identified in the FDR.

Q7. In the plots for SB28, collapsed level data for selected components (specifically, the pressurizer and surge line) are not included, although steam percent (based on indicated level) is plotted. This is inconsistent with the data sets for other tests, where the levels are included. Steam percent without a collapsed level is of minimal use. It would be useful to have collapsed liquid level and steam percent plots for all the tests.

R7. Plots of the pressurizer level and the surge line level will be provided for each test as well as steam percent plots where appropriate.

Q8. On p. 5.1.1-5, the reduction in pressurizer pressure relative to the IRWST is referred to as "negative pressure." If this is a differential (or gage) pressure, it should be appropriately noted. What is described in this specific case is a siphon effect, with the pressurizer pressure at a small vacuum relative to the IRWST, and, in the absence of the vacuum breaker (added to the ADS discharge line after this test), backflow of liquid through the sparger to the pressurizer. While the staff believes that Westinghouse understands well the events occurring in this phase of the test, the description could be stated more clearly. The phrase "negative pressure" is used elsewhere in the FDR, as well (e.g., pp. 5.1.1-11, 5.1.1-12). The same general comments apply to these instances.

R8. The FDR will be reviewed for the phrase "negative pressure" and the text will be clarified for each test.

Q9. In Figure 5.1.1-34, the CMT and IRWST levels, as plotted, really are not referenced to the same absolute elevation, but rather to the "zero" level in each component. Reading the text, one would expect that the CMTs would start draining when the IRWST level curve drops below the CMT level curves, which is not the case due to the offset in "zero" elevation between the CMTs and the IRWST. Putting the CMT and IRWST levels on different ordinates showing the offset would make interpretation of this plot much easier. The same general comment is relevant to Figure 5.1.1-35.

R9. The FDR plots illustrate data as measured in order to provide evidence of the correctness and appropriateness of the data for validation purposes. While a plot of CMT and IRWST levels referenced to the same elevation is useful, Westinghouse does not feel it necessary to include this plot in the FDR.

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Q10 In Eq. 1.4-10 and immediately following, should "Yo" be "Y_o"?

R10 Agreed. "YO" will be amended to "Y_0".

Q11 The use of orifice plates to adjust pressure drops in the test facility to correspond to the desired, scaled AP600 values, while a standard practice, does introduce some distortion in the facility, since the variation of an orifice's pressure drop with flow is not necessarily the same as that of the pipe or fitting represented. A full description of the orifice plates used, including size and location, would be useful.

R11 The TAR will be amended to reference the Facility Description Report and the Final Data Report to fully describe the orifice sizes and locations in the test facility.

Q12 With regard to the ADS 1-3 flow measurement system, it would help the reader understand the measurements if the TAR indicated that the loop seal in the liquid drain line is filled prior to a test. This is true for ADS-4, as well.

R12 The TAR will be revised to include a statement that the ADS 1-3 separator loop seal is filled prior to testing.

Q13 It should be noted that the use of temperature readings in Fahrenheit (p. 4.6-2) could lead to errors where actual temperatures, and not temperature differences, are needed (e.g., Eq. 4.6-2, where the derivative expands into two terms, one of which involves temperature only). In fact, following the convention established, for instance, in Eq. 4.4-59, it would be preferable to show this term as $(T-T_{ref})$. See Section 4.7.5.1 as well.

R13 **Westinghouse will review and clarify as required.**

Q14 In Step 5 on p. 4.6-3, the reference to "break separator tank" should be to the ADS 1-3 separator.

R14 Agreed. Westinghouse will amend the reference to "break separator" to "ADS 1-3 separator".

Q15 It appears that the subscripts on the mass differential terms on the right hand side of Eqs. 4.6-10 and 4.6-11 should be "ADS 1-3 SEP."

R15 Agreed. Equations 4.6-10 and 4.6-11 will be corrected to include "ADS 1-3 separator".

Q16 In Eq. 4.7-3, the specific heat should have an additional subscript "f." Also, it would be useful to provide a statement that the vapor term is neglected.

R16 Agreed. The subscript "f" will be added as well as a statement that the vapor term is neglected.

Q17 Why, in Section 4.8, does nomenclature (subscripts) for vapor and liquid change from "f" and "g," used previously, to "LIQ" and "STM?"

R17 Yes, nomenclature changed. The subscripts will be revised to be consistent.

Q18 In Section 4.8.1, first paragraph, it is stated that this is a procedure for calculating liquid mass in the "sump tanks." Should this be "separator tank?"

R18 Agreed. "Sump tank" will be amended to be "separator tank".

Q19 There appears to be an inconsistency in instrument identification between the OSU P&ID and the list in the reports. PT-905 (see Eq. 4.8-4) is not on the P&ID, though DP-905 is; PT-903 is on the P&ID, but not in the instrument list. The same comment applies to Eq. 4.8-24. Please clarify and/or correct.

R19 PT-905 is a valid channel number (Break Separator Pressure) and does appear in the latest revision of the OSU Test Facility Drawings. We will forward a copy of revised P&ID, Drawing No. OSU 600901. PT-905 is listed in Appendix C in the Instrumentation Data Base of the OSU Final Data Report.

Q20 For consistency, an additional subscript "f" should appear on c_p between the equal signs in Eq. 4.8-15.

R20 Agreed. The additional subscript "f" will be added to Equation 4.8-15.

Scaling RAI

440.566 As discussed at the meeting between Westinghouse and the NRC staff on December 18, 1995, the issue of scaling requires "closure" based on evaluation of the data from the design certification test program. While the specific procedure for accomplishing this closure is to be determined by the applicant, some of the technical areas that need to be addressed include:

a. "Validation" of the AP600 PIRTs; i.e., an examination of the PIRTs for the various events and phases thereof to determine if the test data support the phenomena and their associated importance (ranking).

b. Demonstration that the important phenomena are reflected in the scaling analyses for the test facilities, and that significant distortions suggested by the facility scaling analyses and/or observed during testing can be explained and accounted for. This is equivalent to "validating" the assumptions made in performing the scaling analyses.

c. Along with (b), demonstration that the appropriate dimensionless parameters, especially those representing phenomena determined to be of "high" importance, are within a thermal-hydraulic range in the test programs consistent with that expected in the AP600 plant. In addition, code models that address these phenomena must be shown to be validated over the appropriate thermal-hydraulic parametric range.

DISCUSSION ITEMS FROM JANUARY 23 AND 24, 1996 AP600 TESTING MTG TO BE ISSUED AS FORMAL RAI's

PRHR Items

Q1.

ACTION: Rewrite and condense to request RAI response to 1(a) and (d) only.

ADS Related Questions

Q7.

Q8.

ACTION: Combine 7 and 8 into a single RAI.

Q14

Q15

ACTION: Combine 14 and 15 into a single RAI.

FDR Related Questions

Q17

ACTION: Issue question as a formal RAI.

Q20

R20 RAI - requires additional review/study.

ACTION: Issue question as a formal RAI.

The following questions are related to the detailed presentation of data for Test SB18 in Section 5.1.2 of the FDR.

Q40

ACTION: Issue question as a formal RAI.

The following question refer to specific tests as presented in Section 5 of the FDR.

Q43

<u>ACTION</u>: This will be rewritten to discuss SB18 differences with SB19 because of changes made for SB18 (removal of vacuum breaker) that make it a better reference point.

Q45

<u>ACTION</u>: Issue question as a formal RAI.

The following questions concern the OSU TAR, including a review of the "general" sections and of two specific tests, SB01 and SB18.

Q62

<u>ACTION</u>: Rewrite and condense to request RAI response to 62(a) and (b) only.

Q70

<u>ACTION</u>: Rewrite and condense to be more specific and issue as RAI.

RAI'S TO BE HELD FOR LATER CONSIDERATION OF ISSUANCE

The following question relates to the detailed presentation of data for Test SB01 in Section 5.1.1 of the FDR.

Q24

ACTION: Staff to review concerns based on Westinghouse response.

The following question is related to the detailed presentation of data for Test SB18 in Section 5.1.2 of the FDR.

Q39

ACTION: Staff to review Westinghouse discussions on this item in the TAR.

The following are OSU TAR related questions

Q51

ACTION: Staff to withhold issuance of RAI pending review of scaling closure report.

Q52

ACTION: Staff to reconsider question based on Westinghouse response.

Q66

Q67

Q68

Q69

ACTION: Staff to withhold issuance of RAI's on questions 66, 67, 68, & 69 pending how they are addressed in the scaling closure report.