Westinghouse Non-Proprietary Class 3

WCAP-14135
Rev. 1

Final Data Report for PCS Large-Scale Tests, Phase 2 and Phase 3

Westinghouse Energy Systems

Westinghouse
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This package contains Revision 1 of the *Final Data Report for PCS Large-Scale Tests, Phase 2 and Phase 3*. Replace the Revision 0 cover and spine with the Revision 1 cover and spine and replace the Revision 0 title page with the Revision 1 title page. Each change is listed in the transmittal letter along with the reason for the change. All the change pages are double-sided, and the page numbers match up with the Revision 0 report; therefore, all change pages in this package should replace the same page numbers in the Revision 0 report (i.e., replace Revision 0 p. 2-47, 2-48 with Revision 1 2-47, 2-48).

WCAP-14138

Rev. 1

FINAL DATA REPORT

FOR

PCS LARGE-SCALE TESTS,

PHASE 2 AND PHASE 3

April 1997

TABLE OF CONTENTS (Cont.)

TABLE 2.3-1 (cont.) LIST DATA CHANNEL ASSIGNMENT				
Fluke Channel No.	Sensor Tag No.	Sensor	Description	Location
198	199	TC	DOME BAFFLE	DO-90
199	200	TC	DOME BAFFLE	DO-0
200	201	TC	DOME BAFFLE	DO-270
201	202	TC	ANNULUS BAFFLE	B-203
202	203	TC	ANNULUS BAFFLE	D-203
203	204	TC	ANNULUS BAFFLE	A-113
204	205	TC	ANNULUS BAFFLE	B-113
205	206	TC	ANNULUS BAFFLE	C-113
206	207	TC	ANNULUS BAFFLE	D-113
207	208	TC	ANNULUS BAFFLE	E-113
208	209	TC	ANNULUS BAFFLE	B-23
209	210	TC	ANNULUS BAFFLE	D-23
210	211	TC	ANNULUS BAFFLE	B-293
211	212	TC	ANNULUS BAFFLE	D-293
212	213	TC	AIR INLET "B"	AI-203
213	214	TC	AIR INLET	AI-113
214	215	TC	AIR INLET "C"	AI-23
215	216	TC	AIR INLET	AI-293
216	217	TC	STEAM INLET VESSEL "H"	S-1
217	218	TC	CONDENSATE OUT #2 "G"	
218	219	TC	COOLED CONDENSATE	
219	220	TC	FILM WATER IN "D"	
220	221	TC	FILM WATER OUT "E"	
221	222	TC	TRAVERSE KNUCKLE	TK-203
222	223	TC	TRAVERSE KNUCKLE	TK-113

TABLE 2.3-1 (cont.) LIST DATA CHANNEL ASSIGNMENT				
Fluke Channel No.	Sensor Tag No.	Sensor	Description	Location
223	224	TC	TRAVERSE KNUCKLE	TK-23
224	225	TC	TRAVERSE KNUCKLE	TK-293
225	226	TC	TRAVERSE MID	TM-203
226	227	TC	TRAVERSE MID	TM-113
227	228	TC	TRAVERSE MID	TM-23
228	229	TC	TRAVERSE MID	TM-293
229	230	TC	TRAVERSE LOWER	TL-203
230	231	TC	TRAVERSE LOWER	TL-113
231	232	TC	TRAVERSE LOWER	TL-23
232	233	TC	TRAVERSE LOWER	TL-293
233	234	TC	STEAM PIPE	S-2
234	235	TC	STEAM PIPE	S-3
235	236	TC	STEAM PIPE	S-4
236	237	TC	STEAM PIPE	S-5
237	238	TC	STEAM PIPE INLET	S-6
238	239	MV	VESSEL PRESSURE	P-1
239		TC	CONDENSATE OUT #1	
240		MV	WIND VELOCITY **	
241		MV	WIND DIRECTION **	
242		MV	WATER FLOW METER **	
243		MV	FILM WATER OUT	
244		MV	3-INCH STEAM METER	Vortex
245		TC	INTERNAL TC RAKE	DO-9 in.-0 in.-0
246		TC	INTERNAL TC RAKE	DO-28 in.-18 in.-180
247		TC	INTERNAL TC RAKE	DO-28 in.-0 in.-0

3.0 DATA REDUCTION

This section describes the data handling activities and test evaluations performed on the PCS Large Scale Test data.

3.1 Data Acquired

The data is accumulated during the tests in the following forms:

1. The Test Record Book, which provides documentation of the conduct of the test, includes any anomalies that may be experienced during the conduct of the test, and contains a record of the history of the test facility.

2. The Fluke Data Acquisition System (DAS) output, which is stored directly to disk (note that no data reduction is performed during these operations. The thermocouples are directly recorded in degrees Fahrenheit and all others in actual millivolt or volt signals.

3. Strip Chart recorders which provide a qualitative description of the conduct of the test for selected channels.

4. Data recorded by hand on data sheets and on the individual test procedures. This data includes gas sampling data, helium concentration data, atmospheric pressure and weather conditions.

3.2 Data Handling

The primary source of the test data is that recorded on the Fluke DAS. The Fluke data is an ASCII file containing the values of the 335 channels used for each data recording. The data is recorded in two modes as described in Section 2.3. The computer data is separated at the times where data acquisition on the internal floppy takes over. The separated data is then rejoined to produce the complete test record file using the unique time-indexed records. Data relating to the hand input data is inserted at the beginning of the test file. There are two types of hand input data. Test identification and prerequisite data, which must be included in each hand input data set; and recorded data, which is data recorded by the test engineer and may or may not exist for a given test. Only the initial set of conditions is recorded in the hand input data. Failed channels are identified and are zeroed out by the Fortran code to avoid misinterpretation of the data.

The LPCCS Fortran code is written to transform the data recorded by the Fluke data acquisition equipment of the test facility into a Foxpro data base and/or Lotus spreadsheet format. Figure 3.2-1 shows a simplified flow chart of the operations performed. A final data base provides the reduced data calculated on the basis of the equations noted in Section 2.2.

The reduced data from start to completion of these tests is presented as compressed ASCII files in Appendix D of this document. The data files are identified as "RC0xxF1.PRN", "RC0xxF2.PRN", "RC0xxF0.PRN", and (where appropriate) "RC0xxTR.PRN" and are contained within the archive file "RC0xx.ZIP", where the "xx" identifies the specific run number of the test in question. Files ending in "F1" contain reduced data from channels 0 through 243; files ending in "F2" contain reduced data from channels 244 through 335; files ending in "F0" contain selected manually recorded data and test descriptions, and average, maximum and minimum temperatures for each level as a function of time. A definition of the outputs and their units is contained in Appendix C, Table C.1-3.

The non-DAS (noncondensible) data is collected and where appropriate is entered into files with the DAS-generated data. Noncondensible data is acquired separately and evaluated in accordance with the procedure identified in Appendix B.

(Table 3.3-1) obtained by monitoring the vessel over a 48 hour period at ambient conditions. Data recorded in the "FO" files of Appendix C and D also contain maximum, minimum, and average temperatures and differential temperatures as a function of time. The differential temperatures reported in the "FO" files were not corrected for the calibration offset of Table 3.3-1.

Table 3.3-2 presents a summary of the tests performed during Phase 2 and Phase 3 of the PCS test program. Repeat test runs were performed where tests did not meet the test requirements or pertinent test data was missing. The reasons for repeating tests are also indicated in Table 3.3-2.

3.3.2.1 Heat Balance

Table 3.3-3 provides a rough comparison of the heat loads as calculated from the various measurements listed below:

- Condensate mass flow rate
- External heat loss (water, air and radiation)
- Heat flux across the wall

Figure 3.3-1 illustrates the various heat balance calculations relative to the heat loss calculated from the condensate measurement. Table 2.0-1 provides estimates of the test vessel and baffle surface areas and the applicable flow areas for use in evaluation of the test data. The indicated position of the area is approximately at the middle of the identified area. The condensate heat load was calculated from the enthalpy of the steam entering minus the enthalpy of the condensate leaving while the system was at steady state; condensate flow was used for both the steam flow into the vessel and the condensate flow out of the vessel. The external heat loss sums the heat pickup of the cooling water, the heat of vaporization of water, the heat pickup of air and the estimated heat losses to the environment due to convection and radiation from the vessel bottom and baffle sides using the ambient temperature as T_∞. The convection losses were estimated using a heat transfer coefficient of 1 BTU/(hr*ft^2*°F). The convective and radiation heat losses from the bottom of the vessel were assumed negligible for all tests with an insulated bottom (Test runs less than RC053). The equations used are shown below:

$$q_{cond} = W_{cond} \left(H_{steam} - H_{cond}\right) \tag{1}$$

$$q_{env} = q_{air} + q_{water} + q_{bottom} + q_{baffle} \tag{2}$$

$$q_{wall} = \frac{k}{l} \sum_{N} A_i \left(f_{wet}\, \Delta T_{max,i} + (1 - f_{wet})\, \Delta T_{min,i}\right) \tag{3}$$

$$q_{air} = W_{air}\, C_{p,air} \left(T_{air,out} - T_{air,in}\right) + H_{water\,vapor,out} \left(W_{water,in} - W_{water,out}\right) \tag{4}$$

$$q_{water} = H_{water,out} W_{water,out} - H_{water,in} W_{water,in} \quad (5)$$

where:

q_{cond}	=	heat loss calculated from the condensate flow (BTU/hr)
W_{cond}	=	mass flow of condensate (lb/hr)
H_{steam}	=	enthalpy of steam into vessel (BTU/lb_m)
H_{cond}	=	enthalpy of condensate leaving vessel (BTU/lb_m)
q_{env}	=	estimate of heat lost to environment via air and water (BTU/hr)
q_{air}	=	estimate of heat lost to air in annulus (BTU/hr)
q_{water}	=	estimate of heat lost to water flowing over the vessel and collected in the gutter (BTU/hr)
q_{bottom}	=	estimate of heat lost from convection and radiation on the bottom of the vessel (BTU/hr)
q_{baffle}	=	estimate of heat lost from convection and radiation on the outside surface of the baffle (BTU/hr)
q_{wall}	=	the heat loss calculated from temperature drop across the wall (BTU/hr)
W_{air}	=	mass flow of air through the annulus (lb/hr)
A_i	=	area of the cross section of interest (ft^2)
k	=	thermal conductivity of steel ($BTU*in/(ft^2*hr*°F)$)
l	=	thickness of vessel wall (in)
f_{wet}	=	estimate of the fraction of circumference that is wetted
$\Delta T_{max,i}$	=	maximum temperature difference of cross section i (°F)
$\Delta T_{min,i}$	=	minimum temperature difference of cross section i (°F)
$C_{p,air}$	=	heat capacity of air (BTU/(lb*°F))
$T_{air,in}$	=	temperature at inlet to baffle
$T_{air,out}$	=	temperature at outlet of baffle
$H_{water\ vapor,out}$	=	enthalpy of water vapor leaving the annulus (BTU/lb)
$H_{water,out}$	=	enthalpy of water leaving the vessel outside gutter (BTU/lb)
$W_{water,in}$	=	mass flow of water to the top of the vessel (lb/hr)
$W_{water,out}$	=	mass flow of water out of outside vessel gutter (lb/hr)
$H_{water,in}$	=	enthalpy of water onto the top of the vessel surface (BTU/lb)

Equation 3 assumes that the maximum and minimum temperatures differences for a cross section are representative over the cross section and that the percentage of wet versus dry surface stays constant from top to bottom. Equation 4 assumes that all evaporated water leaves the annulus as vapor and therefore does not provide any correction for condensation of water vapor prior to exit from the annulus. The heat losses calculated from the condensate (equation 5) are considered to be the most reliable since they depend on the least number of assumptions and represent a closed system. These values are used as the abscissa on Figure 3.3-1.

The overall behavior of the internal velocity meters is indicated in Table 3.3-6. In general the internal flow path was observed to be down along the wall and up along the wall in the dome area. Available data indicates that both the anemometers located in the dome were in agreement in speed and direction of the gas movement.

No consistent flow indications were observed from the meter located at E-90°.

3.3.3 Test Summary

Table 3.3-7 presents a summary of the channels that are considered as failed during Phase 2 and Phase 3 testing. Table 3.3-2 presents a summary of all the test runs performed during Phase 2 and Phase 3 of the PCS test program. Test runs identified with an asterisk identify the qualified matrix tests reported herein. In addition, tests identified by "‡" contain partially completed tests that did not meet the specific test requirements but do contain useful test data. The reduced data from these tests is also presented in Appendix D.

TABLE 3.3-1
DIFFERENTIAL TEMPERATURE CALIBRATION

Location	Inside CH	Outside CH	Delta T Cal
DO-180-21 in.	CH0	CH1	-0.015
DO-210-42 in.	CH2	CH3	0.283
DO-180-42 in.	CH4	CH5	-0.573
DO-150-42 in.	CH6	CH7	-0.485
DO-210-63 in.	CH8	CH9	-0.025
DO-180-63 in.	CH10	CH11	
DO-150-63 in.	CH12	CH13	0.110
DO-210-84 in.	CH14	CH15	0.212
DO-180-84 in.	CH16	CH17	0.515
DO-150-84 in.	CH18	CH19	0.021
DO-120-21 in.	CH20	CH21	-0.090
DO-120-42 in.	CH22	CH23	0.302
DO-60-42 in.	CH24	CH25	-0.435
DO-105-63 in.	CH26	CH27	-0.433
DO-90-63 in.	CH28	CH29	-0.094
DO-60-63 in.	CH30	CH31	0.010
DO-120-84 in.	CH32	CH33	0.285
DO-60-84 in.	CH34	CH35	
DO-0-00 in.	CH36	CH37	-0.017
DO-0-21 in.	CH38	CH39	-0.015
DO-0-42 in.	CH40	CH41	-0.531
DO-30-63 in.	CH42	CH43	-0.438
DO-0-63 in.	CH44	CH45	-0.067
DO-330-63 in.	CH46	CH47	-0.027
DO-0-84 in.	CH48	CH49	0.233
DO-210-21 in.	CH50	CH51	0.096
DO-300-42 in.	CH52	CH53	0.300
DO-240-42 in.	CH54	CH55	-0.423

TABLE 3.3-5 COMPARISON OF STEAM FLOW MEASUREMENTS			
Run Number and Test	Condensate	Vortex Meter	Gilflo Meter
	(lb_m/sec)	(lb_m/sec)	(lb_m/sec)
RC039-202.3	1.206	1.2	1.06
RC041-203.3	1.52	1.54	1.38
RC044A-214.1	1.176	1.14	1.00
RC044B-214.1	1.15	1.14	1.00
RC045A-215.1	1.085	1.14	0.99
RC045B-215.1	1.163	1.15	1.00
RC046A-216.1	0.612	0.6	0.5
RC046B-216.1	0.618	0.61	0.51
RC048A-212.1	0.365	0.36	0.25
RC048B-212.1	0.551	0.56	0.5
RC048C-212.1	0.854	0.84	0.73
RC050A-213.1	0.342	0.34	0.27
RC050B-213.1	0.554	0.54	0.49
RC050C-213.1	0.851	0.84	0.72
RC052A-217.1	1.15	1.14	1.00
RC052B-217.1	1.135	1.14	0.98
RC053A-218.1	1.16	1.14	0.99
RC053C-218.1	1.09	1.16	1.00
RC056A-221.1	0.159	0.15	0.1
RC056B-221.1	0.163	0.16	0.11
RC056C-221.1	0.161	0.17	0.12
RC057A-219.1	0.125	0.11	0.07
RC057B-219.1	0.127	0.12	0.08
RC057C-219.1	0.123	0.12	0.08
RC067-224.1	0.265	0.27	0.21
RC068-224.2	0.606	0.59	0.5
RC069-223.1	1.26	1.36	1.56

TABLE 3.3-6
SUMMARY OF INTERNAL VELOCITY METER PERFORMANCE

Test Run No.	Test Matrix No.	Pacer E-90	Pacer D-180	Pacer Dome-345	Höntzsch A-90	Höntzsch Dome-165
RC039*	202.3	No Functional Output	No Functional Output	consistent - up	consistent - down	No Functional Output
RC040	203.3					
RC041*	203.3	No Functional Output	No Functional Output	No Functional Output	consistent - down	No Functional Output
RC042‡	212.1					
RC043‡	213.1					
RC044*	214.1	No Functional Output	11 to 11.2 high value 27.7	magnitude consistent with do-165 early only	consistent - down	magnitude consistent with do-345 early only
RC045*	215.1	No Functional Output	No Functional Output	No Functional Output	consistent - down	early positive response
RC046*	216.1	No Functional Output	No Functional Output	No Functional Output	consistent - down	early positive response
RC047						
RC048*	212.1	No Functional Output	No Functional Output	magnitude consistent with do-165	consistent - down	magnitude consistent with do-345
RC049‡	217.1					
RC050*	213.1	No Functional Output	No Functional Output	No Functional Output	consistent - down	early positive response
RC051‡	217.1					
RC052*	217.1	No Functional Output	No Functional Output	No Functional Output	consistent - down	early positive response
RC053*	218.1	No Functional Output	wild swings throughout test more intensive after He addition	No Functional Output	consistent - down	early positive response
RC054‡	219.1					
RC055‡	221.1					

TABLE 3.3-6 (cont.)
SUMMARY OF INTERNAL VELOCITY METER PERFORMANCE

Test Run No.	Test Matrix No.	Pacer E-90	Pacer D-180	Pacer Dome-345	Höntzsch A-90	Höntzsch Dome-165
RC056*	221.1	No Functional Output	No Functional Output	activity on He addition and on stoppage of water cooling	No Functional Output	early positive response
RC057*	219.1	No Functional Output	No Functional Output	No Functional Output	consistent - down	early positive response
RC058						
RC059						
RC060						
RC061*	222.1	No Functional Output	No Functional Output	No Functional Output	consistent - down	No Functional Output
RC062*	220.1	No Functional Output	No Functional Output	consistent - up	consistent - down	No Functional Output
RC063‡	222.3					
RC064*	222.3	No Functional Output	No Functional Output	No Functional Output	consistent - down	No Functional Output
RC065*	222.2	No Functional Output	No Functional Output	No Functional Output	consistent - down	No Functional Output
RC066*	222.4	No Functional Output	No Functional Output	No Functional Output	consistent - down	No Functional Output
RC067*	224.1	No Functional Output	No Functional Output	No Functional Output	No Functional Output	No Functional Output
RC068*	224.2	No Functional Output	No Functional Output	No Functional Output	No Functional Output	No Functional Output
RC069*	223.1	No Functional Output	No Functional Output	No Functional Output	No Functional Output	No Functional Output
RC070	223.1					

TABLE 3.3-7
SUMMARY OF THE CHANNELS FAILED DURING PHASE 2 AND PHASE 3 TESTS

Channel No.	TEST IDENTIFICATION TEST MATRIX NUMBER AND RUN NUMBER																		
	202.3	203.3	214.1	215.1	216.1	212.1	213.1	217.1	218.1	221.1	219.1	222.2	220.1	222.3	222.2	222.4	224.1	224.2	223.1
	RC039	RC041	RC044	RC045	RC046	RC048	RC050	RC052	RC053	RC056	RC057	RC061	RC062	RC064	RC065	RC066	RC067	RC068	RC069
3				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
25	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
32					X														
33												X	X	X	X	X	X	X	X
34																			X
35			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
40							X	X	X	X	X	X	X	X	X	X	X	X	X
46												X	X	X	X	X	X	X	X
75	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
82	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
86	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
201									X	X	X	X	X						
234	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
270																	X	X	X
280												X	X	X	X	X	X	X	X
295	X[1]							New Sensor						X	X	X	X	X	X
296														X	X	X	X	X	X
297														X	X	X	X	X	X
298														X	X	X	X	X	X
299																	X	X	X
300														X	X	X	X	X	X
306									X	X	X	X	X	X	X	X	X	X	X
315												X	X	X	X	X	X	X	X

[1] Sensor was repaired after test.

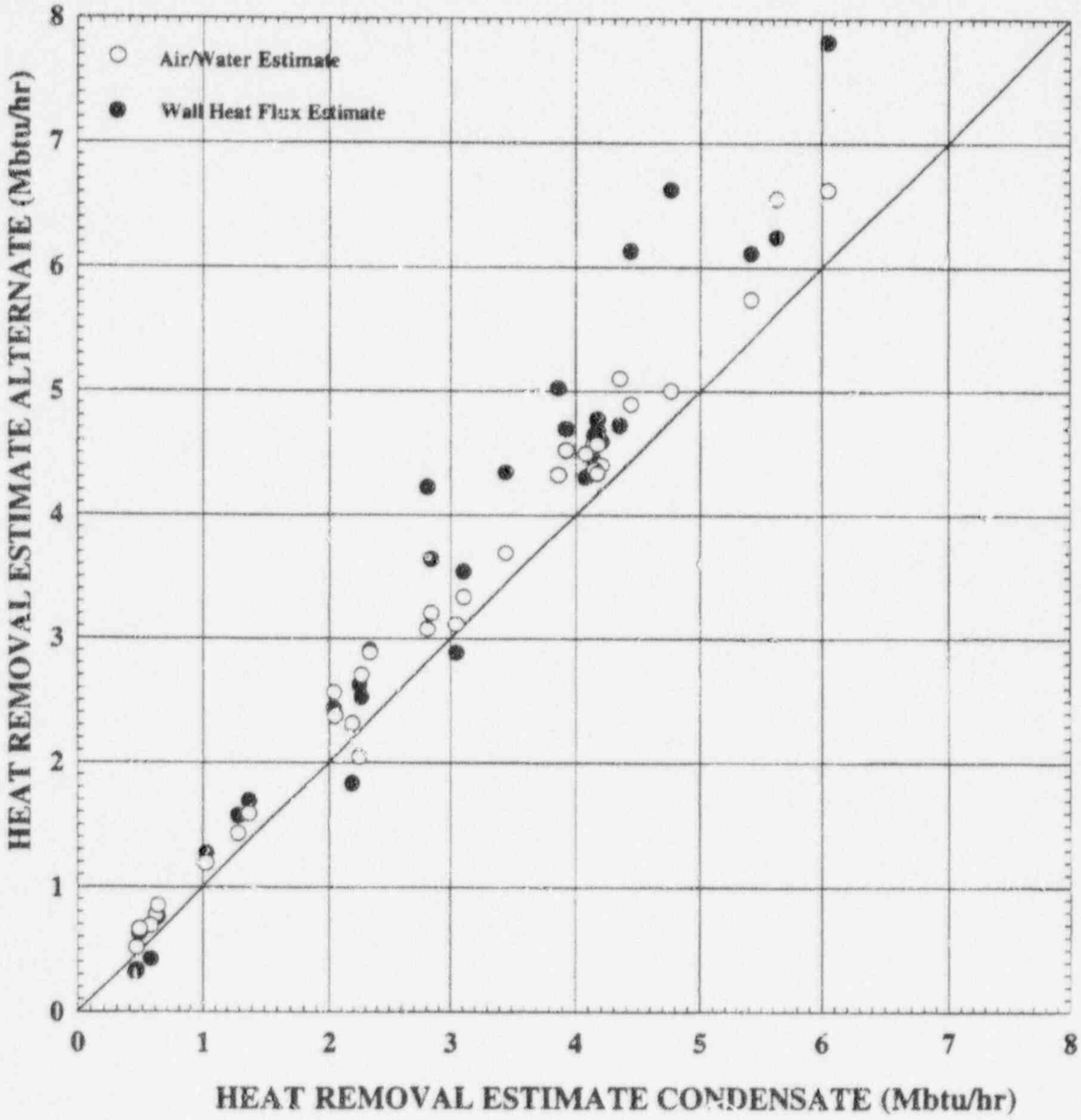

Figure 3.3-1 Comparison of Large Scale Heat Removal Rates

a,c

Figure 3.3-2 Comparison of Vortex and Gilflo Indicated Flows

4.0 TEST RESULTS

This section contain a summary of each of the completed matrix tests considered acceptable. Each of the following sections presents:

- description of the test performed
- plots of the steam flow rate
- plots of the vessel pressure
- plots of the noncondensible concentrations (when available)
- summary tables of the average of the steady state condition of the test vessel
- summary tables of the average, maximum and minimum vessel temperatures and differential temperatures during the steady state periods.

Electronic files of the test data are contained in Appendix D.

4.1 Test Results 202.3

Test 202.3 was a constant pressure test designed to repeat the previous tests performed in the Baseline Tests 202.1 and 202.2. The test featured an insulated vessel bottom, short term internal heat sinks and a steam generator volume located over the steam discharge nozzle. Additional instrumentation was added which includes:

- steam flow meter
- thermocouple rake
- internal velocity meters
- annulus differential pressure cell
- fixed annulus exit velocity meter.

The test was conducted by establishing a steam flow sufficient to achieve the required vessel test pressure (approximately 30 psig) with the air cooling fan at 530 RPM and water cooling to the vessel at a 75 percent water coverage level. The test continued until the vessel pressure was constant within ± 0.5 psi for a minimum of a half hour. The extent of water coverage on the vessel was measured during the steady state period of the test.

A history of the vessel pressure and steam flow are shown in Figure 4.1-1. The steady state period is defined from 13.006 to 13.856 hours and the steady state behavior is tabulated in Table 4.1-1 and Table 4.1-2. Table 4.1-2 presents a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel. Also included are the maximum, minimum and average differential temperatures for the same cross sections.

The exit air anemometer failed during the conduct of Test 202.3. Velocity values from the calibration of the exit fan were used to estimate the resulting air flow at 530 RPM. This is an acceptable accommodation since the exit velocity meter mainly provides an indication of the variation of the velocity through the annulus. Performance is confirmed throughout the test by the differential pressure cell located below the fan and by verification of fan RPM late in the test.

The Höntzsch anemometers were located at Dome-42"-165°-1.5" and A-90°-1.5". The Höntzsch anemometer located in the dome of the vessel provided outputs during the initial transient but provided no outputs above its velocity threshold during the steady state period whereas, the meter at A-90°-1.5" provided outputs that indicated that the velocities down along the sidewall while at steady state. Limited outputs were also available from the Pacer anemometers (Dome-42"-345°-1.5", D-180°-2" and E-30°-2"), but only the anemometer at Dome-42"-345°-1.5" provided outputs above the sensor threshold and sufficient enough to determine the direction as upward in the same manner as the Höntzsch anemometer at Dome-42"-165°-1.5". Table 4.1-3 contains a summary of the indicated flows for the velocity sensors and Figure 4.1-2 shows a history of their performance over the entire test. The negative values for the Höntzsch meter indicate downward flow.

Condensation collection during the steady state portion of the test was performed with the condensate collection to tank 1 (small tank) from the open and closed area in the heel of the test vessel and the remainder to condensate collection tank 2 (large tank).

Water distribution around the circumference at the bottom of the baffle was taken after steady state was established at 1325 hours. The distribution of dry stripes around the circumference total to a 89 percent water coverage with an average width of 3.1 in.

Figures 4.1-3 and 4.1-4 provide an indication of the average temperature history of the inside wall of the test vessel and the fluid adjacent to the vessel wall as a function of elevation throughout the test.

a,c

Figure 4.1-3 Average Inside Wall Temperature

a,c

Figure 4.1-4 Average Inside Wall Fluid Temperature

4.2 Test Results 203.3

Test 203.3 was a constant pressure test designed to repeat the previous tests performed in the Baseline Test series 203.1 and 203.2. The test featured an insulated vessel bottom, short term internal heat sinks and a steam generator volume located over the steam discharge nozzle. Additional instrumentation was added which includes:

- steam flow meter
- thermocouple rake
- internal velocity meters
- annulus differential pressure cell
- fixed annulus exit velocity meter.

A history of the vessel pressure and steam flow throughout the test are shown in Figure 4.2-1. The steady state period is defined from 11.615 hours to 12.590 and the steady state results for 203.3 are tabulated in Table 4.2-1 and Table 4.2-2. Table 4.2-2 presents a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel. Also included are the maximum, minimum and average differential temperatures for the same elevations. The data presented is representative of approximately one hour of test operation; plots of the pressure and steam flow (vortex meter) are shown in Figure 4.2-1.

Internal velocity meters were located in five internal locations in the test vessel as indicated in Table 4.2-3. The Höntzsch anemometer (A-90°-1.5") provided outputs that indicated that the velocities were down along the sidewall. All other velocity meter outputs were too low during steady state operation to evaluate the outputs. Figure 4.2-2 shows the history of the Höntzsch meters throughout the test. The Höntzsch anemometer located in the dome (Dome-42"-165°-1.5") initially provided both up and down velocities but produced no velocity indications during the steady state period.

Water distribution around the circumference at the bottom of the baffle was taken after steady state was established at 1340 hours. The distribution of dry stripes around the circumference that total to a 86 percent water coverage with an average width of 3.5 in.

Condensation collection during the steady state portion of the test was performed with the condensate collection to tank 1 (small) from the open and closed area in the bottom of the test vessel and the remainder to condensate collection tank 2 (large).

Figures 4.2-3 and 4.2-4 provide an indication of the temperature distribution on the inside wall of the test vessel and of the inside fluid temperature approximately 1 inch away from the wall as a function of elevation.

a,c

Figure 4.2-1 Vessel Pressure and Steam Flow History Test 203.3, Run RC041

a,c

TABLE 4.2-3
TEST 203.3 RUN RC041, INTERNAL VELOCITY TEST DATA

LOCATION	AVERAGE (ft/sec)	MAXIMUM (ft/sec)	MINIMUM (ft/sec)	STANDARD DEVIATION (ft/sec)	NOTES

4.3 Test 212.1

Test 212.1 was a constant flow test conducted by stablishing a steam flow at a constant rate and maintaining the flow until the vessel arrived at a constant pressure with the air cooling fan on at 530 RPM, with water cooling to the vessel maintained at a predetermined uniformly distributed water coverage. After the vessel reached a constant pressure the steam flow was increased and maintained until the vessel again reached a steady pressure. Again after the vessel reached a constant pressure the steam flow was increased to a third level and was allowed to come to a steady pressure. The extent of water coverage on the vessel was measured during each steady state period.

The steady state results for Tests 212.1 for each of the three flow levels are tabulated in Tables 4.3-1 through 4.3-6 and are representative of the average performance during approximately one hour of test operation. The tables are identified by the test run number "RC048" followed by an alpha suffix "A," "B" or "C" to indicate the intended steam flow rate of 0.25, 0.5 and 0.75 lbm/sec, respectively. The steady state times are defined as 8.722 to 10.307 hours for "A", 11.121 to 12.096 hours for "B," and 13.214 to 14.289 hours for "C." Tables 4.3-4 through 4.3-6 present a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel for each of the steam flow conditions. Also included are the maximum, minimum and average differential temperatures for the same elevations. The plots of the pressure and steam flow (vortex meter) are shown in Figure 4.3-1. The results of the non-condensible sampling are shown on Figure 4.3-2 at the two sampling locations (Dome-90°-63"-3" and F-0°-6"). The data shows that the air tends to concentrate below the operating deck level.

Internal velocity meters were located in five internal locations in the test vessel as indicated in Table 4.3-7. The Höntzsch anemometers (Dome-42"-165°-1.5" and A-90°-1.5") provided output that indicated that the velocities were generally upward, parallel to the dome wall, i.e. toward the center in the vessel dome and toward the center in the vessel dome and down along the sidewall while at steady state. The pacer at Dome-42"-345°-1.5" provided data of a magnitude consistent with the dome Höntzsch. The remaining pacer units either failed or had velocities below the current sensor threshold. Table 4.3-7 contains a summary of the indicated flows for the velocity sensors for the entire test run. Figure 4.3-3 presents the history of the anemometers for the test.

Condensation collection during the steady state portion of the test was performed with the condensate collection to tank 1 from the open and closed area in the bottom of the test vessel and the remainder to condensate collection tank 2.

Water distribution around the circumference at the bottom of the baffle was taken during each steady state portion of the test. During the two lower steam flow portions of the test the water distribution was measured at 100 percent; coverage reduced to 95.3 percent during the 0.75 lb/sec portion of the test at 13.75 hours. The distribution of dry strips around the circumference had an average width of 2.5 in.

a,c

Figure 4.3-2 Noncondensible Gas Sampling Results Test 212.1, Run RC048

a,c

Figure 4.3-3 Internal Velocity Measurements, Test 212.1, Run RC048

a,c

TABLE 4.3-1
TEST 212.1 SUMMARY DATA
RUN RC048A AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.3-1 (cont.)
TEST 212.1 SUMMARY DATA
RUN RC048A AVERAGE TEST DATA

a,c

TABLE 4.3-3 TEST 212.1 SUMMARY DATA RUN RC048C AVERAGE TEST DATA					
	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.3-3 (cont.)
TEST 212.1 SUMMARY DATA
RUN RC048C AVERAGE TEST DATA

4.4 Test Results 213.1

Test 213.1 was a constant flow test conducted by establishing a steam flow at a constant rate and maintaining the flow until the vessel arrived at a constant pressure with the air cooling fan on at 530 RPM with water cooling about 50 percent less than that employed in Test 212.1 to the vessel maintained at a predetermined uniformly distributed water coverage. After the vessel reached a constant pressure the steam flow was increased and maintained until the vessel again reached a steady pressure. Again after the vessel reached a constant pressure the steam flow was increased to a third level and was allow to come to a steady pressure. The extent of water coverage on the vessel was measured during each steady state period.

The steady state results for test 213.1 for each of the three flow levels are tabulated in Tables 4.4-1 through 4.4-6 and are representative the average performance during approximately one hour of test operation. Tables 4.4-4 through 4.4-6 present a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel for each of the steam flow conditions. The tables are identified by the test run number "RC050" followed by an alpha suffix "A," "B" or "C" to indicate the intended steam flow level of 0.25, 0.5 and 0.75 lbm/sec, respectively. The steady state times are defined as: 8.519 to 9.539 hours for "A," 9.950 to 10.871 hours for "B," and 12.280 to 13.030 hours for "C." Plots of the pressure and steam flow (vortex meter) are shown in Figure 4.4-1.

As noted on Table 4.4-3, the outlet velocity of the annulus air is low when compared to the other air velocities reported herein. The only significant variation from the other portions of the test was the increase in the water evaporated into the annulus. Review of previous tests would indicate a minimal impact on the air velocity at constant fan speed of 530 rpm. It is recommended that a nominal value of 13.9 ft/sec be used for the exit air velocity based on the fan calibration value at 530 rpm and the maintenance of an annulus ΔP of 0.11 in. H_2O.

The results of the non-condensible sampling are shown on Figure 4.2-2 at the two sampling locations (Dome-90°-63"-3" and F-0°-6"). The data shows that the air tends to concentrate below the operating deck level.

Internal velocity meters were located in five internal locations in the test vessel as indicated in Table 4.4-7. The Höntzsch anemometers (Dome-42"-165°-1.5" and A-90°-1.5") provided outputs that indicated that the velocities were generally up and toward the center in the vessel dome and down along the sidewall. No useable outputs were available from the Pacer anemometers. All these units have either failed or velocities below the current sensor threshold. Table 4.4-7 contains a summary of the indicated flows for the velocity sensors for the entire test run. Plots of the performance of the anemometers during the test performance are shown in Figure 4.4.3.

Water distribution around the circumference at the bottom of the baffle was taken after steady state was established at each of the required flow rates. Table 4.4-8 summarizes the water distribution around the circumference of the vessel at each of the steady state.

Condensation collection during the steady state portion of the test was performed with the condensate collection to tank 1 from the heel of the test vessel and the remainder to condensate collection tank 2.

Figures 4.4-4 and 4.4-5 provide an indication of the temperature distribution on the inside wall of the test vessel and of the inside fluid temperature approximately 1 in. away from the wall as a function of elevation.

a,c

TABLE 4.6-1
TEST 215.1 SUMMARY DATA
RUN RC045A AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.6-1 (cont.)
TEST 215.1 SUMMARY DATA
RUN RC045A AVERAGE TEST DATA

a,c

TABLE 4.6-2
TEST 215.1 SUMMARY DATA
RUN RC045B AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.6-2 (cont.)
TEST 215.1 SUMMARY DATA
RUN RC045B AVERAGE TEST DATA

a,c

Figure 4.8-1 Vessel Pressure and Steam Flow History Test 217.1, Run RC052

a,c

Figure 4.8-2 Non-Condensible and Helium Concentrations Test 217.1, Run RC052

a,c

TABLE 4.8-6 TEST 217.1, RUN RC052, DISTRIBUTION OF DRY STRIPS		
TEST CONDITION	WET (%)	AVERAGE DRY WIDTH (in)

4.9 Test 218.1

The constant flow tests reported herein were conducted by establishing a steam flow at a constant rate and maintaining the flow until the vessel arrived at a constant pressure with the air cooling fan on and with water cooling to the vessel set at a predetermined level. After the vessel reached a constant pressure, 20 mole percent of helium is injected into the test vessel over a half hour time period and the vessel is allowed to again reach a steady pressure. The extent of water coverage on the vessel was measured during the steady state periods and gas sampling was performed to determine the concentration of noncondensibles and helium. The insulation was removed from the bottom of the vessel below the open and deadend compartment areas to simulate long term heat sinks; insulation was left under the steam generator compartment.

The steady state results for 218.1 for the test before and after helium addition are tabulated in Tables 4.9-1 through 4.9-4 and is representative of approximately one hour of test operation. The tables are identified by the test run number "RC053" followed by a alpha suffix "A" or "B" to indicate the steady state conditions before and after helium addition, respectively. The steady state times are defined as 9.064 to 9.971 hours for "A" and 12.923 and 13.923 hours for "B." Tables 4.9-3 and 4.9-4 present a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel for each of the air flow conditions. Plots of the pressure and steam flow (vortex meter) are shown in Figure 4.9-1. The helium was injected between 9.95 and 10.45 hours at a flow rate of 3.46×10^{-3} lb/sec.

The steam flow in test 218.1 shows a larger spread than in test 217.1 but it is a regular cycle which stays within a ±360 lb/hr range required by the test procedure.

The results of the non-condensible sampling are shown on Figure 4.9-2 at the four sampling locations (Dome-90°-63"-3", A-270°-6", E-90°-6"and F-0°-6"). The data shows that the air tends to concentrate below the operating deck level and that the helium concentration over the entire vessel reaches a well mixed condition after approximately 2 hours.

Internal velocity meters were located in five internal locations in the test vessel as indicated in Table 4.9-5. The Höntzsch anemometers (Dome-42"-165°-1.5" and A-90°-1.5") provided outputs that indicated that the velocities were generally up and toward the center in the vessel dome and down along the sidewall. Some outputs were noted from the Pacer anemometers, particularly at D-180°. No outputs were steady enough to obtain a flow direction and the high velocity outputs are most likely the result of the sensor blade being hit with condensation droplets. Table 4.9-5 contains a summary of the indicated flows for the velocity sensors for the entire test run. Plots of the behavior of the internal velocity meters is shown in Figure 4.9-3.

Water distribution around the circumference at the bottom of the baffle was taken after steady state was established before and after helium addition. Table 4.9-6 summarizes the water distribution around the circumference of the vessel during each steady state period.

a,c

TABLE 4.9-2
TEST 218.1 SUMMARY DATA
RUN RC053B AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.9-2 (cont.)
TEST 218.1 SUMMARY DATA
RUN RC053B AVERAGE TEST DATA

a,c

TABLE 4.10-7
TEST 219.1 RUN RC057, INTERNAL VELOCITY TEST DATA

LOCATION	AVERAGE (ft/sec)	MAXIMUM (ft/sec)	MINIMUM (ft/sec)	STANDARD DEVIATION (ft/sec)	NOTES

4.11 Test 220.1

The transient flow test reported herein was conducted by providing the maximum flow of steam attainable to the test section for a 20 to 30 second period of time. The flow was then reduced to approximately 0.5 lb/sec. for the remainder of the test until the vessel arrived at a constant pressure with the air cooling fan on and with water cooling to the vessel set at a predetermined level. The extent of water coverage on the vessel was measured during the steady-state periods and gas sampling was performed to determine the concentration of noncondensibles. For Test 220.1, the insulation was removed from the bottom of the vessel below the open and deadend compartment areas; insulation was left under the steam generator compartment.

Review of the steam flows from the condensate and vortex meters indicated that the vortex meter consistently performed at a 15 to 20 percent lower flow than indicated by the condensate over the steady state period. The vortex meter operates at 7.5 percent of its operational range and therefore its accuracy[1] relative to reading is a large percentage (~10 percent). It is recommended that the vortex meter outputs be used for time-dependent performance and the condensate measurement for the steady state performance characteristics (or 15 percent be added to the vortex measured steam flow rate for all times greater than 10.9 hours to compensate for this difference).

The initial transient steam flow to the test vessel is shown in Figure 4.11-1. The start of the transient is back calculated from the data contained in Appendix D to 10.7122 hours or about 10 seconds before the first transient data set.

The steady state results for Test 220.1 are tabulated in Table 4.11-1; the steam state time is defined as from 11.9814 hours to 12.9997 hours. A plot of the vessel pressure, steam flow (vortex meter), and steam flow (condensate) is shown in Figure 4.11-2. The indicated pressures are corrected for an offset of 0.12 psi at the start of the test to adjust the ambient pressure within the vessel to equal the recorded pressure from the transducer.

The results of the noncondensible sampling are shown in Figure 4.11-3 at the four sampling locations (Dome-90°-63"-3", A-270°-6", E-90°-6"and F-0°-6"); note that the pressure axis is displayed in "psia" rather than the "psig" used in Figure 4.11-1. The data show that the air tends to concentrate below the operating deck level).

Internal velocity meters were located in five locations in the test vessel as indicated in Table 4.11-2. The Höntzsch anemometer A-90°-1.5" provided output that indicated that the velocity along the wall was down along the sidewall throughout the test. The Höntzsch anemometer at Dome-42"-165°-1.5" did not provide any useable output. The Pacer anemometers at E-30° -1" provided outputs in excess of their minimum sensitivity over the first 6 minutes of the test and then read below their detection

[1] The meter accuracy is quoted as 1 percent of full scale with the range extending from 5.9 to .45 lb/sec. at the meter's test operating conditions.

limits. The Pacer located at Dome-42"-345° -1" provided outputs over the majority of the test with some high velocities noted (9, 12, 25, etc) on a sporadic basis; the majority of outputs were on the order of the average value shown in Table 4.11-2. Figure 4.11-3 contains a summary of the indicated flows for the velocity sensors for the entire test run.

Condensation collection during the steady state portion was switched to different collection tanks to determine the distribution of condensate within the vessel. Table 4.11-3 documents the condensate flows for the dome and sidewall during the steady state period. Review of the data indicates that only 3 to 4 percent of the condensate collects as rainfall and bottom collection (steam generator compartment and remainder of bottom). The remainder of the condensate is almost equally divided between the side wall and dome.

Water distribution around the circumference at the bottom of the baffle was taken after completion of the transient and after steady state was established. Table 4.11-4 summarizes the water distribution around the circumference of the vessel at each of the steady state conditions.

Figures 4.11-4 and 4.11-5 provide an indication of the average temperature distribution as a function of level for the inside vessel wall and the fluid temperature approximately 1 in. inside the vessel.

a,c

Figure 4.11-1 Initial Steam Flow Test 220.1, Run RC062

a,c

Figure 4.11-2 Vessel Pressure and Steam Flow History Test 220.1, Run RC062

a,c

Figure 4.11-3 Noncondensible Concentrations Test 220.1, Run RC062

a,c

Figure 4.11-4 Internal Velocity Measurements, Test 220.1, Run RC062

a,c

Figure 4.11-5 Inside Vessel Wall Temperatures, Test 220.1, Run RC062

a,c

Figure 4.11-6 Internal Fluid Temperatures, Test 220.1, Run RC062

a,c

TABLE 4.11.1
TEST 220.1 SUMMARY DATA
RUN RC062 AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.11.1 (cont.) TEST 220.1 SUMMARY DATA RUN RC062 AVERAGE TEST DATA					
	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

Table 4.11-2
TEST 220.1 RUN RC062, INTERNAL VELOCITY TEST DATA

LOCATION	AVERAGE (ft./sec.)	MAXIMUM (ft./sec.)	MINIMUM (ft./sec.)	STANDARD DEVIATION (ft./sec.)	NOTES

a,c

TABLE 4.11-3
TEST 220.1, RUN RC062, DISTRIBUTION OF CONDENSATE

TIME PERIOD 11.5 TO 11.85 HR			TIME PERIOD 12.0 TO 12.5 HR			TIME PERIOD 12.57 TO 13.0 HR		
LOCATION	FLOW RATE	TEMPERATURE	LOCATION	FLOW RATE	TEMPERATURE	LOCATION	FLOW RATE	TEMPERATURE
	(lb/sec.)	(°F)		(lb/sec.)	(°F)		(lb/sec.)	(°F)

a,c

TABLE 4.11-4
TEST 220.1, RUN RC062, DISTRIBUTION OF DRY STRIPS

TEST CONDITION	WET (%)	AVERAGE DRY WIDTH (in.)

a,c

a,c

TABLE 4.11-5
VESSEL TEMPERATURE DISTRIBUTION FOR TEST 220.1

	AVERAGE WALL TEMPERATURE			MAXIMUM WALL TEMPERATURE			MINIMUM WALL TEMPERATURE		
LOCATION	INSIDE	OUTSIDE	DELTA	INSIDE	OUTSIDE	DELTA	INSIDE	OUTSIDE	DELTA
	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)

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4.12 Test 221.1

The transient flow test reported herein was conducted by introducing an initial high steam flow (2 lbm/sec) for approximately 40 seconds followed by a reduced steam flow of approximately 1 lbm/sec for 5 minutes with a flow reduction to 0.1 lbm/sec for the remainder of the test. Helium is added to the system through the steam line after steady state is reached at 0.1 lbm/sec steam flow. The water cooling is shut off after steady state is reached. The test is continued until the pressure stabilizes. A constant air flow is maintained through the test by maintaining the air cooling fan at a constant speed. The insulation was removed from the bottom of the test vessel below the open and deadend compartment areas; insulation was left under the steam generator compartment.

Review of the steam flows from the condensate, vortex and Gilflo meters indicates that the Gilflo meter has consistently been performing at a 15 to 20 percent lower flow than indicated by the condensate and the vortex meter during steady state flows. The initial flow transient recorded by the vortex meter is about half of the flow recorded by the Gilflo meter during the initial transient. Review of the strip charts which continuously give an indication of the steam flow shows that the initial flow was held for approximately 48 seconds at 2.00 ± 0.11 lb/sec followed by 5.2 minutes where the average flow was 1.01 ± 0.07 lb/sec as monitored by the "Gilflo" flow meter. The vortex meter produced outputs that were beyond its calibration range for the initial flow transient. The second portion of the transient is within output range of the vortex meter and indicates a steam flow rate of 1.18 ± 0.06 lb/sec. It is recommended that the Gilflo output be used for the initial flow transient and the vortex meter outputs be used for time dependent performance after the initial transient and either the condensate measurement or the vortex meter for steady state performance characteristics.

The steady state results for Test 221.1 are tabulated in Tables 4.12-1 through 4.12-6 and are representative of approximately one hour of test operation. The tables are identified by the test run number "RC056" followed by an alpha suffix "A," "B" or "C" to indicate the steady state conditions of wet, wet with helium present, and steady state dry, respectively. The steady state times are defined as: 8.516 to 9.516 hours for "A," 12.411 to 13.245 hours for "B," and 17.5389 to 18.538 hours for "C." Tables 4.12-4 through 4.12-6 present a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel for each of the air flow conditions. Plots of the pressure and steam flow are shown in Figure 4.12-1; the steam flow is a result of the combination of Gilflo and vortex meter outputs as recommended above. The helium was injected between 9.53 and 10.28 hours at a flow rate of 0.00385 lb/sec (75°F, 70 psig). Although higher than the required flow rate, this flow is sufficient to accomplish the test purpose of addressing the effects of helium mixing on the long term cooling during post accident conditions.

The gas sampling apparatus was used during each of the steady state periods of the test. The results of the non-condensible sampling are shown on Figure 4.12-2 at the four sampling locations (Dome-90°-63"-3", A-270°-6", E-90°-6" and F-0°-6"). The data shows that the air tends to concentrate below the operating deck level. The plot also shows the helium concentration at each sample location and time. The helium concentration is shown to become uniformly distributed in the test vessel during the water cooling portion of the test after about three hours. The helium concentration difference between the volumes above and below the operating deck increased after stoppage of water flow to approximately 5 percent. Two helium concentration data points shown are incon[illegible] with the trends shown for the remainder of the test and it is recommended that they be ignored.

Internal velocity meters were located in five internal locations in the test vessel as indicated in Table 4.12-7. The Höntzsch anemometer located at A-90°-1.5" indicated a generally downward flow along the sidewall while at steady state. The Höntzsch anemometer located at Dome-42"-165°-1.5" showed little change in output from before the test was started to the end and is assumed to have failed. The Pacer anemometer at Dome-42"-345°-1.5" showed activity during the helium addition and during the dry portion of the test with few indications at other times. The Pacer anemometer at E-30° showed limited outputs which were concentrated during the dry portion of the test. The Pacer anemometers at D-180° showed very few indications higher than a nominal 0.4 ft/sec and is assumed to be nonfunctional. Table 4.12-7 contains a summary of the indicated flows for the velocity sensors for the entire test run. Plots of the behavior of the internal velocity meters is shown in Figure 4.12-3.

Condensation collection during the steady state portion of the test was performed with the condensate collection to tank 1 from the heel (open and closed areas) of the test vessel and the remainder to condensate collection tank 2.

Water distribution around the circumference at the bottom of the baffle was taken after steady state water coverage was established. Table 4.12-8 summarizes the water distribution around the circumference of the vessel at each of the steady state conditions.

Figures 4.12-4 and 4.12-5 provide an indication of the average temperature distribution as a function of level for the inside vessel wall and the fluid temperature approximately 1 inch inside the vessel.

4.13 Test 222.1

The transient flow test reported herein was conducted by providing the maximum flow of steam attainable to the test section for a 15 second period of time. The flow was then reduced to approximately 3 lbm/sec for 30 seconds and then reduced to 0.5 lbm/sec for the remainder of the test until the vessel arrived at a constant pressure with the air cooling fan on and with water cooling to the vessel set at a predetermined level. The extent of water coverage on the vessel was measured during the steady state periods and gas sampling was performed to determine the concentration of noncondensibles. For test 222.1 the insulation was removed from the bottom of the vessel below the open and deadend compartment areas; insulation was left in place under the steam generator compartment.

Review of the steam flows from the condensate and vortex meters indicates that the vortex meter consistently performs at a 8 to 12 percent lower flow than indicated by the condensate over the steady state period. It is recommended that the vortex meter outputs be used for time dependent performance and the condensate measurement for the steady state performance characteristics (or 8 percent be added to the steam flow rate for all times greater that 11.05 hours to compensate for this difference).

The initial transient steam flow to the test vessel is displayed in Figure 4.13-1. The start of the transient is back calculated from the data contained in Appendix D to 11.0302 hours or about 6 seconds before the first transient data set.

The steady state results for Test 222.1 (Run RC061) are tabulated in Table 4.13-1 and 4.13-2 prior to the first pressure upset shown in Figure 4.13-2 and are representative of approximately one hour of test operation. The steady state time is defined as from 12.434 to 13.432 hours. Table 4.13-2 presents a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel for each of the air flow conditions. Plots of the vessel pressure and steam flow (vortex meter) are shown in Figure 4.13-2. The pressure upsets shown around 13.5 and 14.1 hours were due to a direct discharge of condensate that had backed up into the test vessel. The vessel pressure transducer is closely coupled with the vessel sight gage line and is reacting to the localized decrease in pressure. The comparison of the condensate and vortex steam flow measurements are also illustrated in Figure 4.13-2. The vortex flow meter is operating at the lower end of its operational range during the third flow rate period (0.5 lbm/sec) and therefore the discrepancy noted is about 1.3 percent of full scale (6.7 lbm/sec) or about 8 to 12 percent lower than the condensate flow rate.[2] The meter has a rated accuracy of ±1 percent of full scale.

The results of the non-condensible sampling are shown on Figure 4.13-3 at the four sampling locations (Dome-90°-63"-3", A-270°-6", E-90°-6"and F-0°-6"). The data shows that the air tends to concentrate below the operating deck level).

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[2] The meter accuracy is quoted as 1% of full scale with the range extending from 5.9 to .45 lb/sec at the meter's test operating conditions.

Internal velocity meters were located in five locations in the test vessel as indicated in Table 4.13-3. The Höntzsch anemometer A-90°-1.5" provided output that indicated that the velocity was down along the sidewall throughout the test. The Höntzsch anemometer at Dome-42"-165°-1.5" did not provide any useable output. The Pacer anemometers at E-30° -1" and Dome-345°-1" provided outputs in excess of their minimum sensitivity over the first 10 minutes of the test and then read below their detection limits for the remainder of the test. The Pacer anemometer located at D-180°-1" provided outputs sporadically over the first hour of the test. The majority of outputs were on the order of the average value shown in Table 4.13-3. Table 4.13-3 contains a summary of the indicated flows for the velocity sensors for the entire test run. Plots of the behavior of the internal velocity meters is shown in Figure 4.13-4.

Condensation collection during the steady state portion was switched to different collection tanks to determine the distribution of condensate within the vessel. Table 4.13-4 documents the condensate flows for the dome and sidewall during the steady state period. Review of the data indicates that only 3 to 4 percent of the condensate collects as rainfall and bottom collection (steam generator compartment and remainder of bottom). The remainder of the condensate is almost equally divided between the side wall and dome.

Water distribution around the circumference at the bottom of the baffle was taken after completion of the transient and after steady state was established. Table 4.13-5 summarizes the water distribution around the circumference of the vessel at each of the steady state conditions.

Figures 4.13-5 and 4.13-6 provide an indication of the average temperature distribution as a function of level for the inside vessel wall and the fluid temperature approximately 1 inch inside the vessel.

a,c

Figure 4.13-1 Initial Steam Flow Test 222.1, Run RC061

a,c

Figure 4.13-2 Vessel Pressure and Steam Flow History Test 222.1, Run 2RC061

a,c

TABLE 4.13-1
TEST 222.1 SUMMARY DATA
RUN RC061 AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.13-1 TEST 222.1 SUMMARY DATA RUN RC061 AVERAGE TEST DATA	

4.14 Test 222.2

The transient flow test reported herein were conducted by providing the maximum flow of steam attainable to the test section for a 15 second period of time. The flow was then reduced to approximately 3 lbm/sec for 30 seconds and then reduced to 0.5 lbm/sec for the remainder of the test until the vessel arrived at a constant pressure with the air cooling fan on and with water cooling to the vessel set at a predetermined level. The pressure is then increased to approximately 30 psig and the vessel is allowed to come to steady state. The extent of water coverage on the vessel was measured during the steady state periods and gas sampling was performed to determine the concentration of noncondensibles. The bottom of the vessel below the open and deadened compartment areas remained uninsulated with the insulation left in place under the steam generator compartment.

The initial transient flow to the test vessel with the steam diffuser raised to a level 5.8 ft. above the operating deck is displayed in Figure 4.14-1. The start of the transient is calculated from the data contained in Appendix D to the data set taken at 9.9936 hours. The mass flow transient was calculated from the vortex meter output together with the steam temperature and pressure at the flow meter. The line pressure at the steam meter was estimated from the data available in the DAS output and the pressure history of similar transients. The steam temperature was estimated from a linear regression of the DAS monitored steam temperature. The nominal values of pressure and temperature are indicated on Figure 4.14-1.

The results for the low (RC065A) and high (RC065B) steam flow rate, steady state periods of Test 222.2 are tabulated in Tables 4.14-1 and 4.14-2. The steady state data was taken from the time periods 12.06 through 13.04 hours and 15.32 through 16.32 hours, respectively. Tables 4.14-3 and 4.14-4 show a summary of the vessel average, minimum, and maximum temperatures on the inside and outside reactor walls at each set of test conditions. Also included are the maximum, minimum, and average differential temperatures across the wall. The data presented is representative of approximately one hour of test operation; plots of the vessel pressure and steam flow (vortex meter) are shown in Figure 4.14-2. The comparison of the condensate and vortex steam flow measurements are also illustrated in Figure 4.14-2. The steam flow as recorded by the vortex meter maintains a steady flow over both of the steady state periods. The condensate flow settles into a steady flow rate approximately 5 percent higher than the steam flow rate. Condensation collection during the steady state portion was switched to different collection tanks to determine the distribution of condensate within the vessel. Table 4.14-5 documents the condensate flows during the steady state period. The initial two collection periods seem to indicate that condensate was held up for a time and later discharged during the second period and the early part of the third. Review of the data indicates that approximately 61 percent of the condensate is generated on the vessel dome during the final collection period.

The results of the non-condensible sampling are shown on Figure 4.14-3 at the four sampling locations (Dome-90°-63"-3", A-270°-6", E-90°-6"and F-0°-6"). The data shows that the air tends to concentrate below the steam injection point, since the air partial pressure at both the "F" and "E" levels are close to the pressure of the vessel.

The internal velocity meter located at A-90°-1.5" provided output that indicated that the velocity was down along the sidewall throughout the test. The majority of readings were on the order of the average value shown in Table 4.14-6 with the peak velocity occurring during the initial steam transient. The remainder of the internal velocity meters did not function throughout the test and are considered to have failed. Figure 4.14-4 shows the behavior of the internal velocity meters throughout one test.

Water distribution around the circumference at the bottom of the baffle was taken after completion of the transient and after steady state was established. Table 4.14-7 summarizes the water distribution around the circumference of the vessel at each of the steady state conditions.

Performance of the velocity meter (Channel 295) below the fan assembly is no longer providing reliable data. Use fan calibration data located in Section 2.2.7, equation 13 for an estimate of the outlet velocity based on the fan RPM.

Figures 4.14-5 and 4.14-6 provide an indication of the average temperature distribution as a function of level for the inside vessel wall and the fluid temperature approximately 1 inch inside the vessel.

a,c

TABLE 4.14-2
TES[illegible]22.2 SUMMARY DATA
RUN RC[illegible]65B AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.14-2 (cont.)
TEST 222.2 SUMMARY DATA
RUN RC065B AVERAGE TEST DATA

a,c

TABLE 4.14-3
VESSEL TEMPERATURE DISTRIBUTION FOR TEST 222.2, RC065

LOCATION	AVERAGE WALL TEMPERATURE			MAXIMUM WALL TEMPERATURE			MINIMUM WALL TEMPERATURE		
	INSIDE (°F)	OUTSIDE (°F)	DELTA (°F)	INSIDE (°F)	OUTSIDE (°F)	DELTA (°F)	INSIDE (°F)	OUTSIDE (°F)	DELTA (°F)

a,c

TABLE 4.14-4
VESSEL TEMPERATURE DISTRIBUTION FOR TEST 222.2, RC065B

LOCATION	AVERAGE WALL TEMPERATURE			MAXIMUM WALL TEMPERATURE			MINIMUM WALL TEMPERATURE		
	INSIDE (°F)	OUTSIDE (°F)	DELTA (°F)	INSIDE (°F)	OUTSIDE (°F)	DELTA (°F)	INSIDE (°F)	OUTSIDE (°F)	DELTA (°F)

4.16 Test 222.4

The initial transient steam flow to the test vessel with the discharge directed upward through a 3 in. diameter nozzle is displayed in Figure 4.16-1. The start of the transient is back calculated from the data contained in Appendix D to 10.8975 hours or about 1 second before the first transient data set. The mass flow transient was calculated from the vortex meter output together with the steam temperature and pressure at the flow meter. The steam line pressure at the flow meter was calculated from the data available in the DAS output and the pressure history of the transient. The steam temperature was estimated from a linear regression of the DAS monitored steam temperature. The nominal values of pressure and temperature are indicated on Figure 4.16-1.

The results for the low (RC066A) and high (RC066B) steam flow rate, steady state periods of Test 222.4 are tabulated in Tables 4.16-1 through 4.16-4. The steady state data was taken from the time periods 12.25 through 13.25 hours and 15.75 through 16.77 hours, respectively. The data presented is representative of approximately one hour of test operation. Tables 4.16-3 and 4.16-4 present a comparison of the average, minimum and maximum temperatures on the inside and outside vessel walls at each cross section of the vessel for each of the air flow conditions. Plots of the vessel pressure and steam flow (vortex meter) are shown in Figure 4.16-2. The comparison of the condensate and vortex steam flow measurements are also illustrated in Figure 4.16-2. The total condensate flow settles into a steady flow rate approximately 4 percent higher than the vortex steam flow rate during the first period and approximately 3 percent higher during the second.

Condensation collection during the steady state portion was switched to different collection tanks to determine the distribution of condensate within the vessel. Table 4.16-6 documents the distributed condensate flows during the steady state period. The condensate backed up into the test vessel during the third period and appears to have overflowed into the other condensate system as evidenced by the low condensate collection rate in the early portion of the third condensate collection period flowed by an increased collection period. Review of the distributed condensate data indicates an inconsistency in the condensate distribution. Although the total condensate collection agrees well with the steam flow, the specific distribution to the dome and side wall during the first two collection periods do not produce consistent results, i.e., total to 118 percent. It is recommend that this condensate distribution data be used with caution.

The results of the non-condensible sampling are shown on Figure 4.16-3 at the four sampling locations (Dome-90°-63"-3", A-270°-6", E-90°-6"and F-0°-6"). The data shows that the dome tends to have a smaller concentration of air than the remainder of the vessel. All the pressure transducers of the sampling system were in agreement with the vessel and each other within ±0.3 psi.

The internal velocity meter located at A-90°-1.5" provided output that indicated that the velocity was down along the sidewall throughout the test. The majority of outputs were on the order of the average value shown in Table 4.16-5 with the peak velocity occurring during the initial steam transient with the nozzle pointed directly upward. The remainder of the internal velocity meters did not function throughout the test and are considered to have failed. Figure 4.16-4 presents a plot of the behavior of the internal velocity meters.

Water distribution around the circumference at the bottom of the baffle was taken after completion of the transient and after steady state was established. Table 4.16-7 summarizes the water distribution around the circumference of the vessel at each of the steady state conditions.

Performance of the velocity meter (Channel 295) below the fan assembly is no longer providing reliable data. Use fan calibration data located in Section 2.2.7, equation 13 for an estimate of the outlet velocity based on the fan RPM. The velocity noted in Tables 4.16-1 and 4.16-2 reflect these values.

Figures 4.16-5 and 4.16-6 provide an indication of the average temperature distribution as a function of level for the inside vessel wall and the fluid temperature approximately 1 inch inside the vessel.

a,c

TABLE 4.16-1 TEST 222.4 SUMMARY DATA RUN RC066A AVERAGE TEST DATA					
	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.16-1 (cont.)
TEST 222.4 SUMMARY DATA
RUN RC066A AVERAGE TEST DATA

a,c

TABLE 4.16-2
TEST 222.4 SUMMARY DATA
RUN RC066B AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.16-2 (cont.)
TEST 222.4 SUMMARY DATA
RUN RC066B AVERAGE TEST DATA

a,c

TABLE 4.16-5 TEST 222.4 RUN RC066, INTERNAL VELOCITY TEST DATA					
LOCATION	AVERAGE (ft/sec)	MAXIMUM (ft/sec)	MINIMUM (ft/sec)	STANDARD DEVIATION (ft/sec)	NOTES

TABLE 4.16-6
TEST 222.4, RUN RC066, DISTRIBUTION OF CONDENSATE VERSUS STEAM FLOW

TIME PERIOD 11.25 TO 12.42 HR			TIME PERIOD 12.42 TO 13.25 HR			TIME PERIOD 13.97 TO 14.55 HR			TIME PERIOD 14.75 TO 15.67 HR			TIME PERIOD 14.58 TO 17.8 HR		
LOCATION	FLOW RATE (lb/sec)	TEMP (°F)	LOCATION	FLOW RATE (lb/sec)	TEMP (°F)	LOCATION	FLOW RATE (lb/sec)	TEMP. (°F)	LOCATION	FLOW RATE (lb/sec)	TEMP (°F)	LOCATION	FLOW RATE (lb/sec)	TEMP (°F)

a,c

Figure 4.17-1 Vessel Pressure and Steam Flow History Test 223.1, Run RC069

a,c

Figure 4.17-2 Noncondensible Concentrations Test 223.1, Run RC069

a,c

TABLE 4.17-1
TEST 223.1 SUMMARY DATA
RUN RC069 AVERAGE TEST DATA

	WALL TEMPERATURES		TEMPERATURES		
	INSIDE (°F)	OUTSIDE (°F)	INTERNAL FLUID (°F)	WALL ΔT (°F)	INSIDE BAFFLE (°F)

a,c

TABLE 4.17-1 (cont.)
TEST 223.1 SUMMARY DATA
RUN RC069 AVERAGE TEST DATA

4.19 Test Results 224.2

The flow tests reported herein were conducted by providing a constant flow of steam to a vessel initially pressurized with 2 atmospheres of air. Test 224.2 was conducted with a steam flow of 0.5 lb/sec until the vessel arrived at a constant pressure with the air cooling fan on and with water cooling to the vessel set at a predetermined level. The extent of water coverage on the vessel was measured during the steady state periods and gas sampling was performed to determine the concentration of noncondensibles. The insulation was removed from the bottom of the vessel below the open and deadend compartment areas; insulation was left in place under the steam generator compartment.

The results for the steady state period of Test 224.2 (RC068) are tabulated in Table 4.19-1. The steady state data was taken from the time periods 13.39 through 14.39 hours. Table 4.19-2 provides a comparison of the average, maximum and minimum temperatures on the inside and outside vessel walls. Also included are the maximum, minimum and average differential temperatures for the same locations. The data presented is representative of approximately one hour of test operation; plots of the vessel pressure and steam flow (vortex, Gilflo and condensate) are shown in Figure 4.19-1. Review of the vortex meter data indicates that its outputs are approximately 0.1 percent higher than the average condensate flow. The average condensate flow is approximately 16 percent higher than the average Gilflo steam flow rate over the majority of the test.

The indicated vessel pressures were determined to be an average of 0.4 psi higher than the manual data recorded during extraction of the noncondensible samples at approximately 56 psia; no pressure corrections were performed on the conversion of the vessel pressure.

The results of the non-condensible sampling are shown on Figure 4.19-2 at the four sampling locations (Dome-90°-63"-3", A-270°-6", E-90°-6"and F-0°-6"). The data shows that the air tends to concentrate below the steam injection point in the heel of the vessel.

No internal velocity meters were active during this test. The annulus velocity meter is considered to have failed. The fan calibration correlation located in Section 2.2.2 (equation 13) should be used to estimate of the outlet velocity based on the fan RPM. The velocity reported in Table 4.19-1 reflects this value.

Water distribution around the circumference at the bottom of the baffle was maintained at close to 100 percent coverage level throughout the test (Table 4.19-3). After 265 minutes two strips approximately 1.5 in. wide and approximately 6 ft. long were observed on the test vessel around the 210° location.

Figure 4.19-3 and 4.19-4 provide an indication of the average temperature distribution as a function of level for the inside vessel wall and the fluid temperature approximately 1 inch inside the vessel.

a,c

Figure 4.19-1 Vessel Pressure and Steam Flow History Test 224.2, Run RC068

APPENDIX C

DATA HANDLING

Enclosure 2