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PWR Blowdown Heat Transfer Separate-Effects Program— Thermal-Hydraulic Test Facility Experimental Data Report for Test 157

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Prepared for the U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Under Interagency Agreements DOE 40-551-75 and 40-552-75

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PWR BLOWDOWN HEAT TRANSFER SEPARATE-EFFECTS PROGRAM — THERMAL-HYDRAULIC TEST FACILITY EXPERIMENTAL DATA REPORT FOR TEST 157

G. S. Massengill R. A. Hedrick M. D. White

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PWR BLOWDOWN HEAT TRANSFER SEPARATE-EFFECTS PROGRAM —
THERMAL-HYDRAULIC TEST FACILITY EXPERIMENTAL
DATA REPORT FOR TEST 157

G. S. Massengill R. A. Hedrick M. D. White

ABSTRACT

Reduced instrument responses are presented for Thermal-Hydraulic Test Facility (THTF) test 157, which is part of the ORNL Pressurized-Water Reactor (PWR) Blowdown Heat Transfer Separate-Effects Program. The objective of the program is to investigate the thermal-hydraulic phenomenon governing the energy transfer and transport processes that occur during a loss-of-coolant accident in a PWR system.

Test 157 was conducted to obtain thermal-hydraulic and CHF information in the THTF bundle 1 operating at nominal power with significant outlet subcooling and containing four unpowered rods.

The primary purpose of this report is to make the reduced instrument responses during test 157 available. The responses are presented in graphical form in engineering units and have been analyzed only to the extent necessary to assure reasonableness and consistency.

I. INTRODUCTION

The Oak Ridge National Laboratory Pressurized-Water Reactor (ORNL-PWR) Blowdown Heat Transfer Program is a separate-effects study of the relations among the principal variables that can alter the rate of blowdown, the presence of flow reversal and rereversal, time delay to critical heat flux (CHF), the rate at which dryout progresses, and similar time- and space-related functions that are important in loss-of-coolant accident (LOCA) analyses. Primary test results are obtained from the Thermal-Hydraulic Test Facility (THTF), a large nonnuclear pressurized-water loop incorporating a 49-rod electrically heated bundle in a 7 × 7 geometry.

THTF test 157 (conducted March 24, 1977) was the 14th test conducted in the facility with bundle 1 in place. This test was performed to obtain thermal-hydraulic and CHF information in a bundle operating at nominal power with significant outlet subcooling and containing four unpowered rods.

The purpose of this report is to provide the reduced instrument responses during test 157 in a readily usable form to the nuclear community in advance of detailed analyses and interpretations. These data are presented on microfiche attached to the back cover of the report. Final analyses and interpretations are scheduled for publication six months after the completion of the test series. The program and the experimental facilities are described in Ref. 1.

II. SYSTEM, PROCEDURES, CONDITIONS, AND EVENTS FOR TEST 157

1. System Configuration and Test Procedure

The Thermal-Hydraulic Test Facility (THTF), shown in Fig. 1, consists of a test section with a 49-rod, 3.66-m-long (12-ft) electrically heated core; a circulation loop comprised of three parallel heat exchangers with bypass, a pressurizer, a pump with bypass, and associated control valves; two rupture assemblies; and a pressure-suppression system. For test 157 the break configuration was a 40% inlet—60% outlet break with a total break area of 12.54 cm^2 (0.0135 ft^2). The THTF experimental system is described further in Ref. 1.

The electric core was taken to the preblowdown power (100 kW/rod) in ∿20-kW/rod steps to provide steady-state calibration information. The main heat exchangers were operated to match the core power input. The primary coolant pump was tripped coincident with break initiation, but the electric core was operated at the preblowdown power for ∿2 sec into the transient. The power was then decayed with a time constant of ∿0.45 sec. Rods 19, 24, 39, and 47 were unpowered. Closure of the secondary side main heat exchanger valves was initiated at the trip from 100 kW/rod.

In preparation for the test, the loop was filled with demineralized water and the system pressure checked. Instrumentation and data acquisition checks were performed. During the warmup, data were taken for use in flow and pressure calibrations.

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1. *Project Description: ORNL-PWR Blowdown Heat Transfer Separate-Effects Program — Thermal-Hydraulic Test Facility (THTF)*, ORNL/NUREG/TM-2 (February 1976).

ORNL-DWG 77-5586R

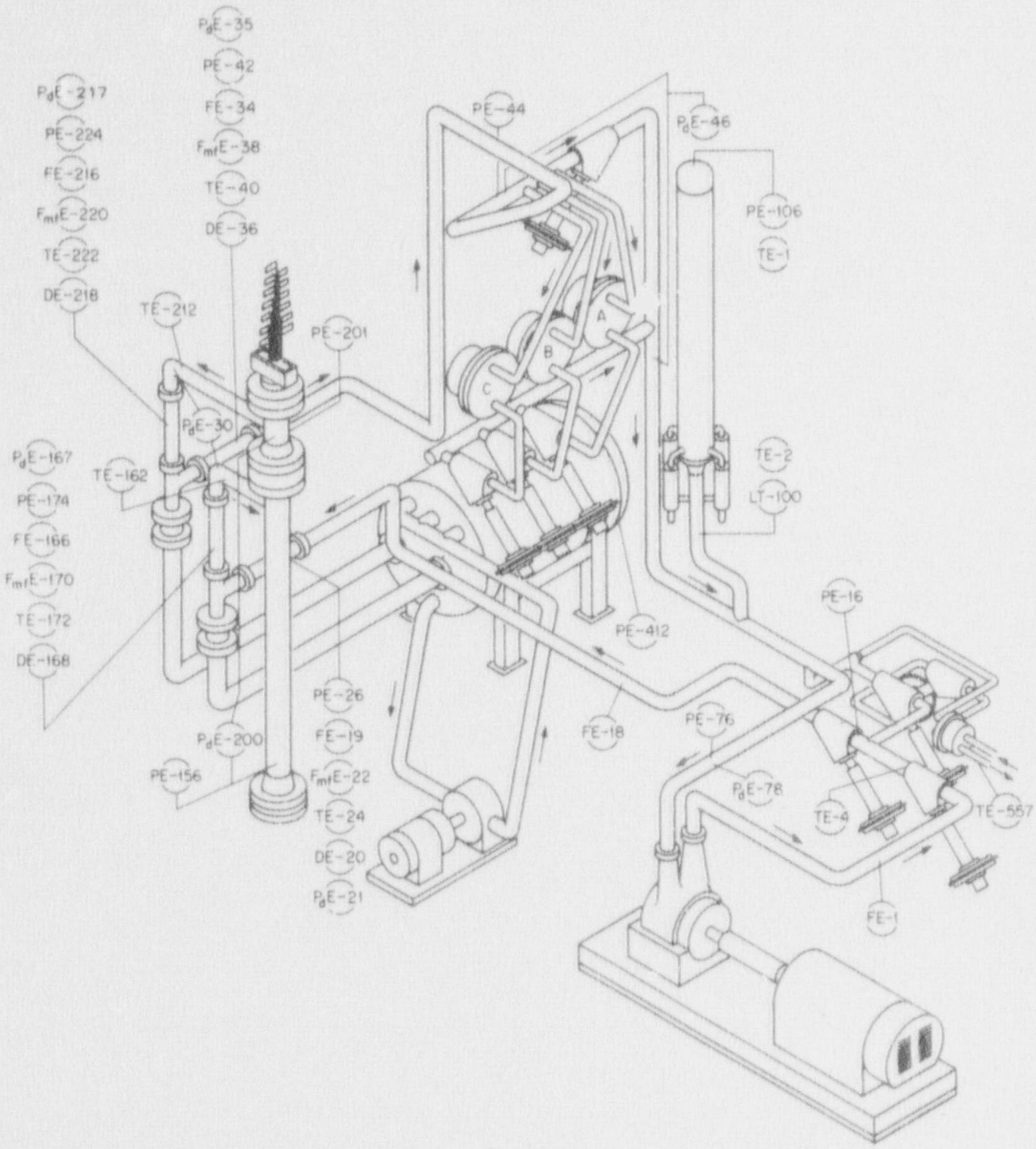


Fig. 1. Thermal-Hydraulic Test Facility (THTF).

During the test, the THTF was successfully subjected to a double-ended pipe break through the rupture assemblies containing the orifice plates. The effluent from the primary system was injected into the pressure-suppression system, which was maintained at atmospheric pressure.

2. Initial Test Conditions and Sequence of Events

The THTF conditions immediately preceding rupture are given in Tables 1 and 2. The sequence of events relative to the rupture is given in Table 3.

Table 1. Desired vs actual prerupture conditions

Parameters	Instrument	Desired[a]	Actual[b]
System pressure	PE-201		
MN/m^2		15.858	16.061
psig		2300	2329
Core power	EIE-9, EIE-10, EIE-11, EIE-12		
MW	EEE-9, EEE-10, EEE-11, EEE-12	4.500	4.493
Number of unpowered rods		4	4
Core volumetric flow rate	FE-19		
m^3/s		0.0331	0.0335
gpm		525	531
Test section inlet temperature	TE-162		
K		558.2	557.3
°F		545	544
Test section outlet temperature	TE-212		
K		588.7	587.9
°F		600	599
Pressurizer pressure	PE-106		
MN/m^2		15.444	15.499
psig		2240	2248
Mass liquid water			
kg		54.88	78.42
lb_m		121	173
Coolant pump speed	SE-72		
rps		60.33	60.04
rpm		3620	3602
Pressure differential	P_dE-78		
MN/m^2		4.509	4.573
psid		654	663
Pressure between HCV-2 and FCV-18	PE-16		
MN/m^2		16.761	17.679
psig		2431	2564
Pressure differential across main heat exchangers	P_dE-46		
MN/m^2		0.331	0.340
psid		48	49.3

[a]Desired prerupture conditions are based on programmatic requirements.

[b]Actual prerupture conditions are based on instrument signals recorded within 10 sec of primary system rupture.

Table 2. Prerupture primary-coolant temperature and pressure distribution[a] test 157

Location	Instrument	Temperature [K (°F)]	Pressure [MN/m² (psig)]
Vertical inlet spool piece	TE-172	557.3 (544)	
Vertical inlet spool piece	PE-174		16.396 (2378)
Test section inlet	TE-162	557.3 (544)	
Lower plenum	TE-150	558.3 (545)	
Lower plenum	PE-156		16.344 (2371)
Upper plenum	PE-201		16.061 (2329)
Test section outlet	TE-212	587.9 (599)	
Vertical outlet spool piece	TE-222	587.9 (599)	
Vertical outlet spool piece	PE-224		15.924 (2310)
Heat exchanger inlet header	PE-44		15.759 (2286)
Mixed mean temperature downstream heat exchangers	TE-28B	564.4 (556)	
Pressurizer surge line	TE-2	599.2 (619)	
Pressurizer	PE-106		15.499 (2248)
Primary pump suction	PE-76		15.381 (2231)
Between main control valves HCV-2, FCV-18	TE-4B	555.4 (540)	
Between main control valves HCV-2, FCV-18	PE-16		17.679 (2564)

[a]Prerupture distribution is based on instrument signals recorded within 10 sec of primary system rupture.

Table 3. Sequence of events during test 157

Event	Time relative to rupture (sec)
Core power level established	−3195
Core temperature rise established	−3015
Analog tapes and CCDAS fast scan started	−15
Blowdown initiated	0
Pump power tripped	0
Heat exchanger secondary valves closure initiated	+2
Core power tripped to decay	+2
Core power tripped	+3.5

III. DATA PRESENTATION

The recorded instrument responses for THTF test 157 have been processed only to the extent necessary to obtain appropriate engineering units and to ensure reasonableness and consistency. In converting the instrument responses to engineering units, a homogeneous fluid has been assumed. Therefore, interpretation or analysis of the data must account for the fact that the instruments may have been subjected to nonhomogeneous fluid conditions during the transient.

The reduced instrument responses presented in this report were recorded by a computer-controlled digital data acquisition system (CCDAS). Further information on this system may be found in Ref. 1.

Figures 2 through 4 provide supportive information for the instrument responses and indicate the relative locations of the detectors in the THTF.

ORNL-DWG 76-19894

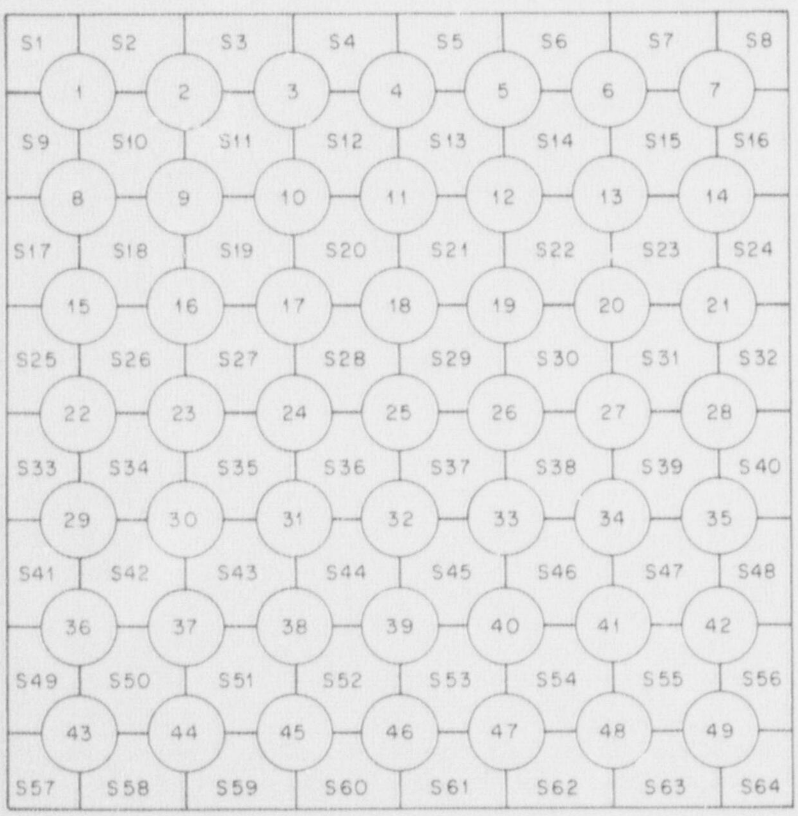


Fig. 2. Identification of THTF heater rod and subchannel locations in bundles 1 and 2.

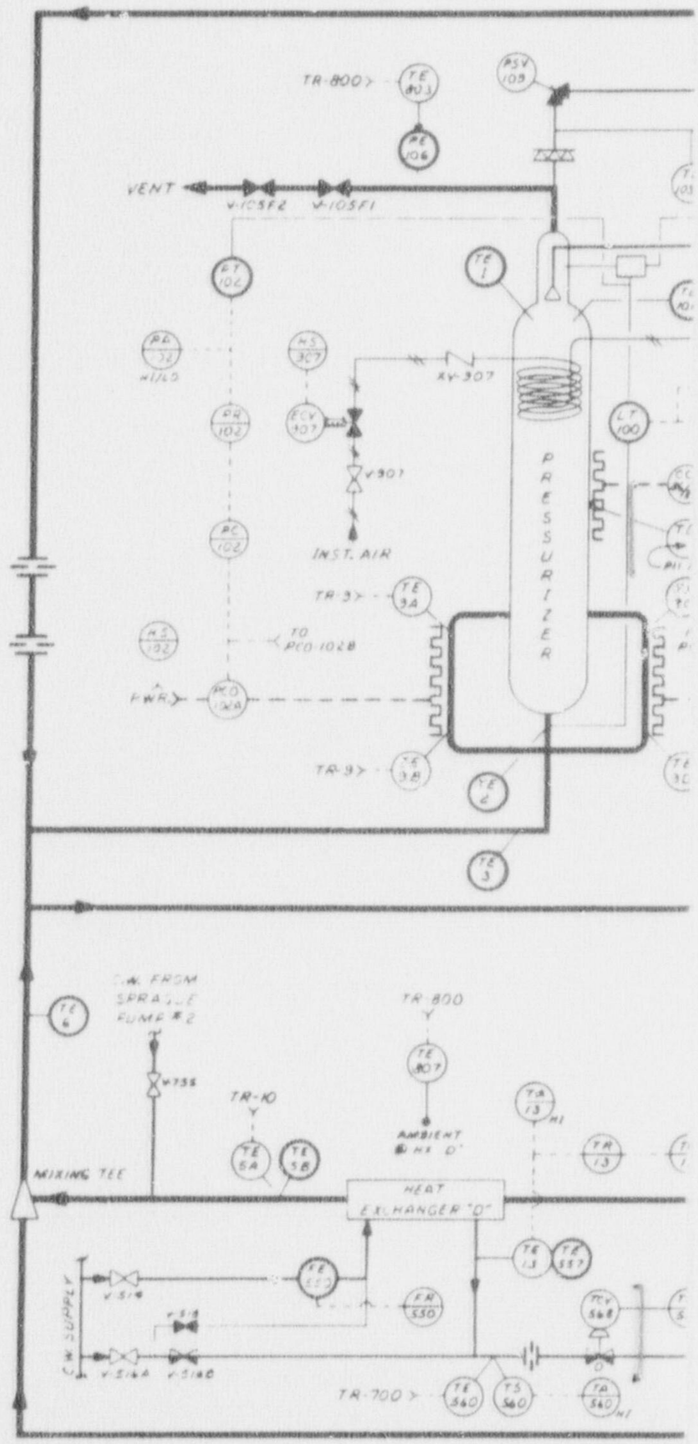
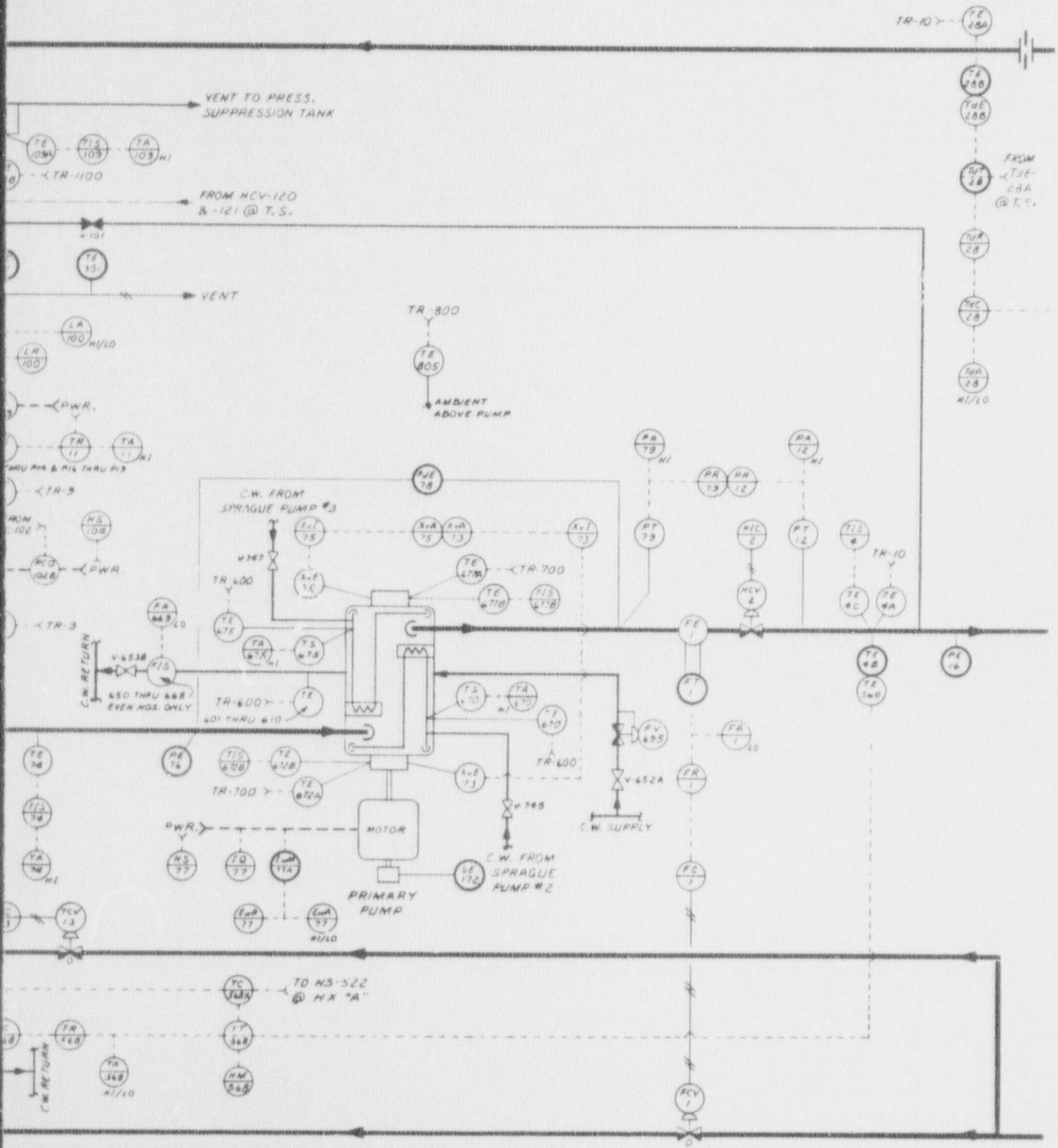

VENT
V-105F2
V-105F1
TR-800
TE 803
PE 106
PSV 109
FT 102
PR 102
PC 102
HS 307
RV-307
V-307
INST. AIR
PRESSURIZER
TE 1
TE 2
TE 3
LT 100
TR-3
TE 3A
TE 3B
HS 102
TO PCO-102B
PWR
PCO 102A
TE 6
C.W. FROM SPRAGUE PUMP #2
MIXING TEE
TR-10
TE 5A
TE 5B
TR-800
TE 807
AMBIENT @ HX 'D'
TA 13
TR 13
HEAT EXCHANGER "D"
TE 13
C.W. SUPPLY
FR 550
TR-700
TE 560
TS 560
TA 560
TCV 568

Fig.



4. THTF instrument identification and location.

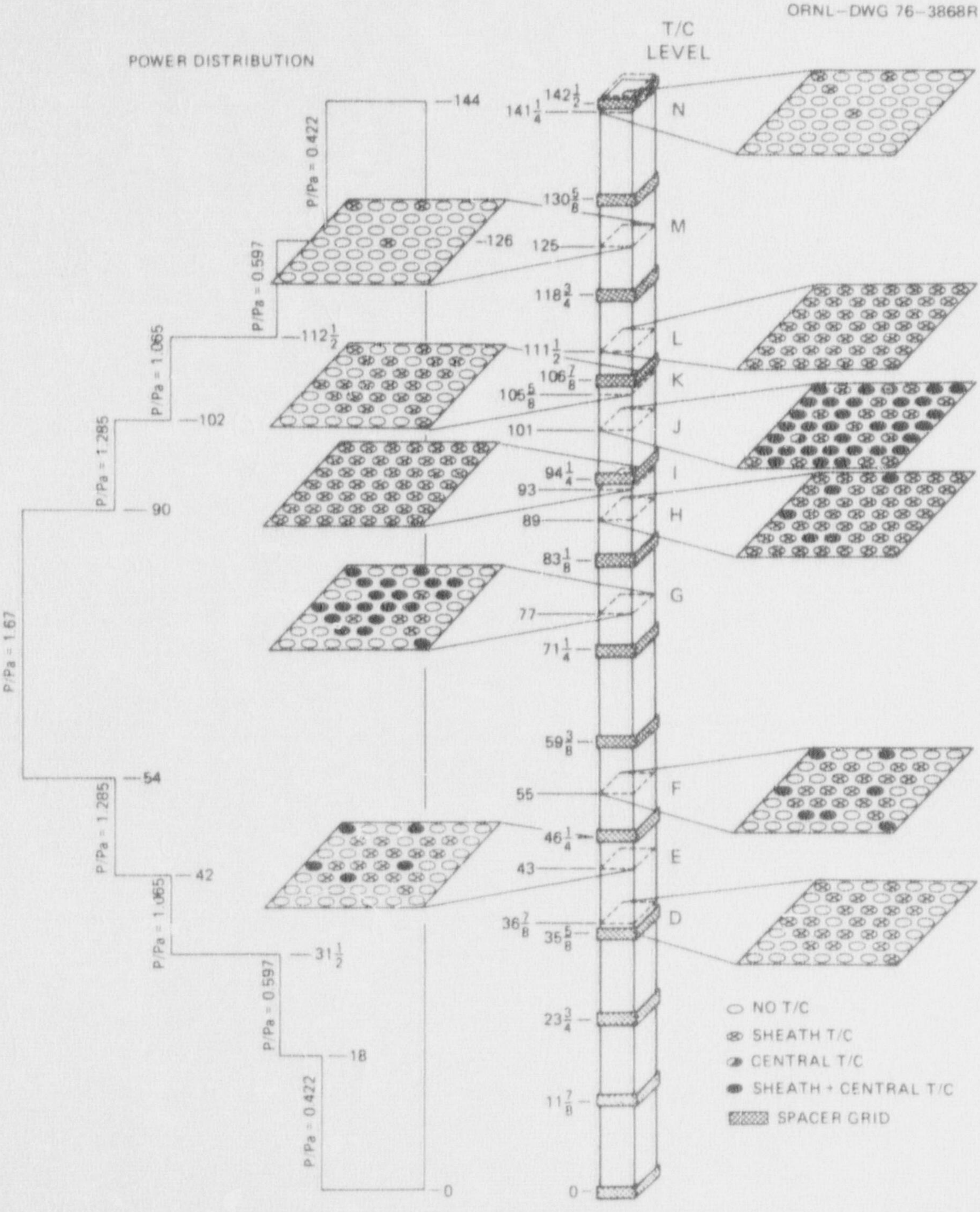


Fig. 3. Location of thermocouples in THTF bundle 1.

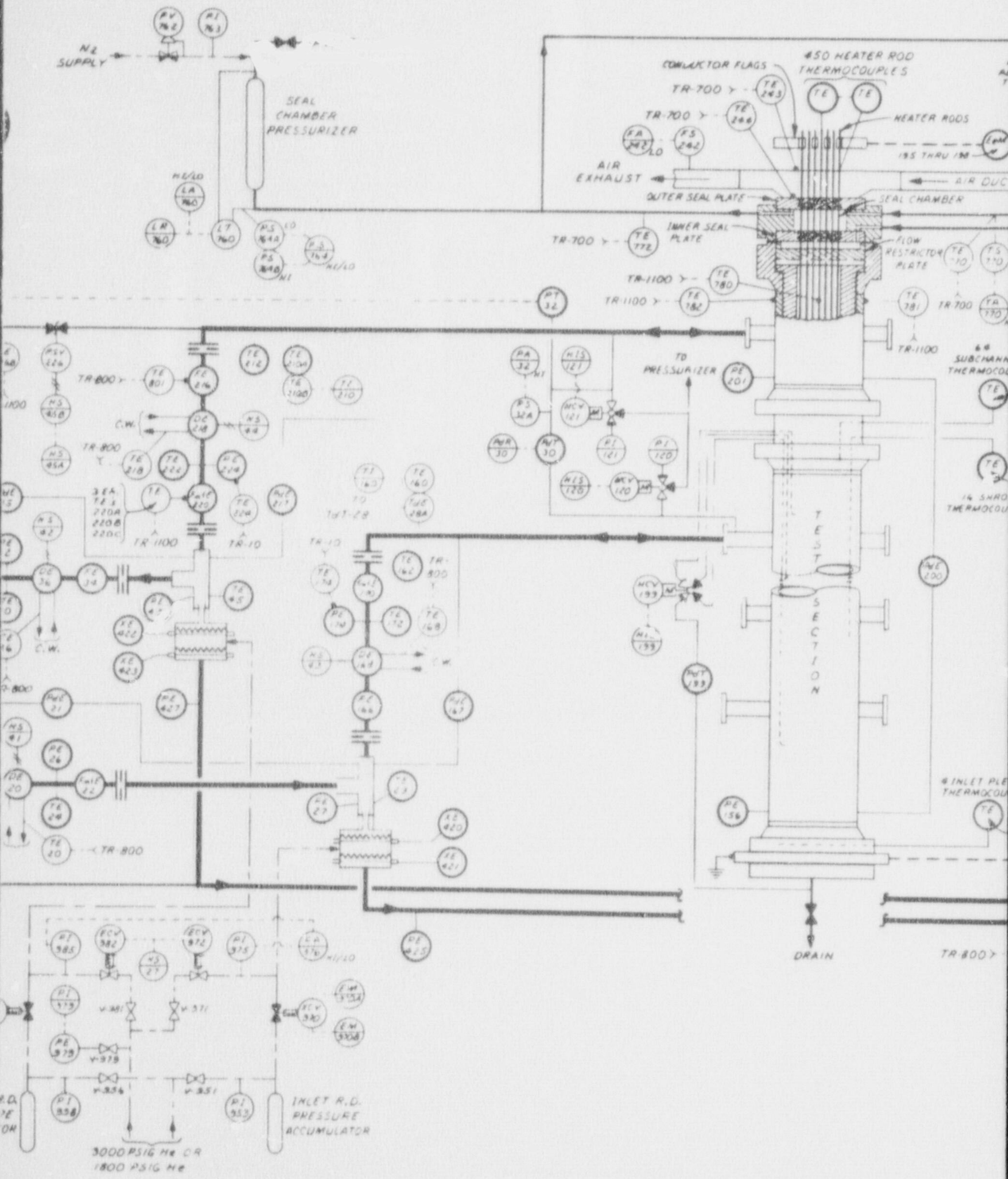


Fig. 4 (continued)

ORNL-DWG 77-12968

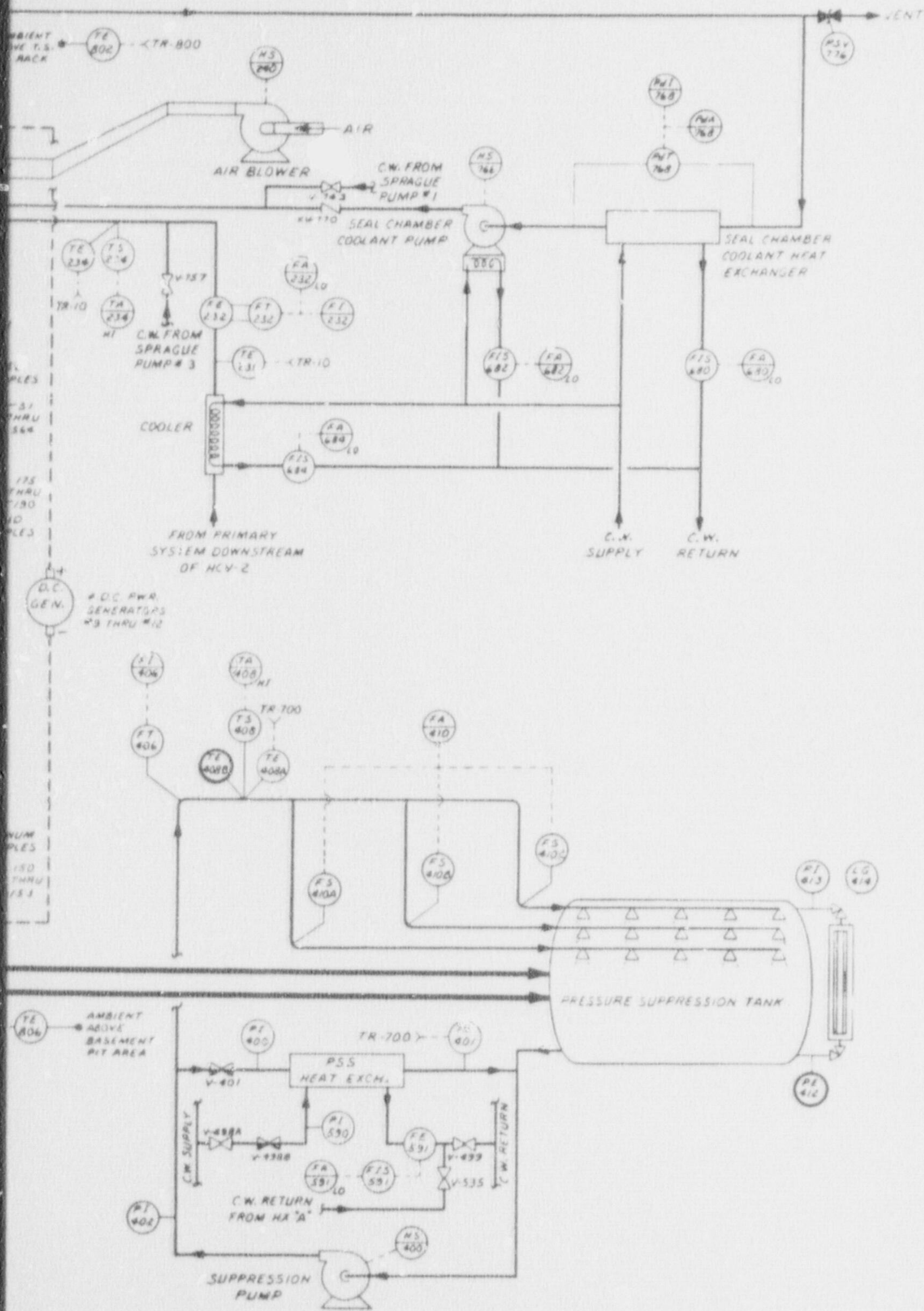


Table 4 gives the precision of the recorded instrument responses, and Table 5 groups the measurements by location and provides brief comments regarding the detectors and the recorded responses. Time zero on all graphs is the time of break initiation.

Table 4. Precision of experimental measurements for test 157

System	Standard deviation
Pressure measurement, MN/m^2 (psig)	
CCDAS	0.185 (26.8)
Analog tape system	0.197 (28.5)
Pressure difference measurement, MN/m^2 (psid)	
CCDAS	
6.89-MN/m^2 (1000-psid) span	0.025 (3.6)
1.38-MN/m^2 (200-psid) span	0.005 (0.72)
0.34-MN/m^2 (50-psid) span	0.001 (0.18)
Analog tape system	
6.89-MN/m^2 (1000-psid) span	0.033 (4.8)
1.38-MN/m^2 (200-psid) span	0.007 (0.95)
0.34-MN/m^2 (50-psid) span	0.002 (0.24)
Temperature measurement, K (°F)	2.4 (4.3)
Electric core power measurement	
Rod current, A	0.877
Rod voltage, V	0.304
Flow measurement, m^3/sec (gpm)	
FE-19	
Forward	+0.0009 −0.0002 (+13.97) (−2.90)
Reverse	+0.0011 −0.0004 (+16.77) (−5.70)
FE-166	
Forward	+0.0011 −0.0004 (+17.49) (−6.43)
Reverse	+0.0009 −0.0002 (+14.14) (−3.07)
FE-216	
Forward	+0.0008 −0.0001 (+12.88) (−1.81)
Reverse	+0.0009 −0.0002 (+14.46) (−3.39)
FE-34	
Forward	+0.0019 −0.0005 (+30.71) (−8.58)
Reverse	+0.0019 −0.0005 (+29.54) (−7.41)
Momentum flux measurement, kg/m-sec^2 (lb_m/ft-sec^2)	
CCDAS	2264 (1522)
Analog tape system	2554 (1716)
Density measurement @ 961 kg/m^3 (60 lb_m/ft^3), kg/m^3 (lb_m/ft^3)	12.9 (0.81)

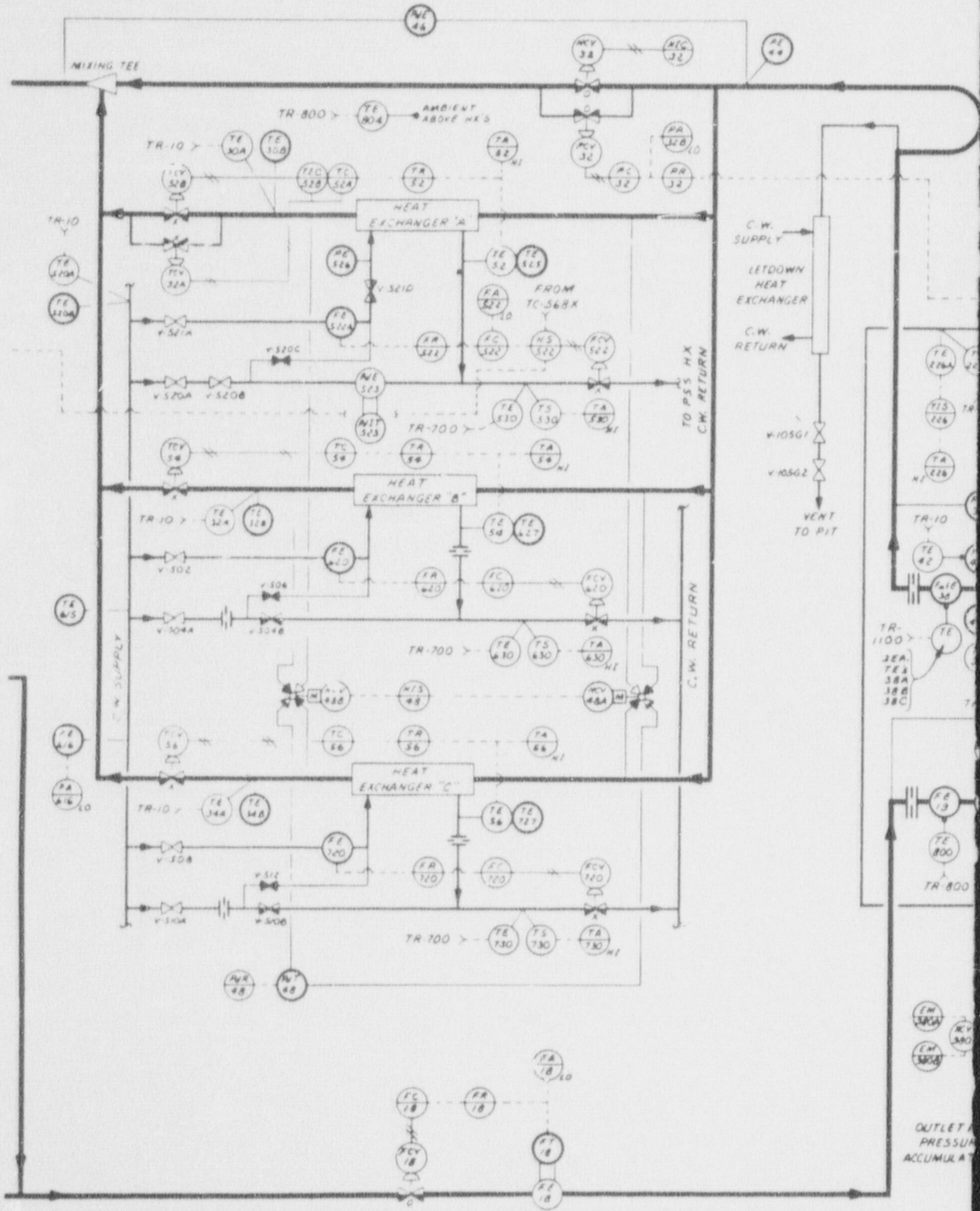

MIXING TEE
HEAT EXCHANGER "A"
HEAT EXCHANGER "B"
HEAT EXCHANGER "C"
AMBIENT ABOVE HX'S
FROM TC-568X
TO PSS HX C.W. RETURN
C.W. SUPPLY
C.W. RETURN
LETDOWN HEAT EXCHANGER
VENT TO PIT

Table 5. Data presentation for test 157

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE	Chromel-Alumel thermocouples	+32 to +1897°F (all)	-0.0027 to +0.0[illegible]00 V (all)		
Heater Rod Sheath					
	LEVEL D				
TE-301AD	Rod 1			5	Erratic prior to BD
TE-304AD	Rod 4			6	
TE-309AD	Rod 9			7	
TE-310AD	Rod 10			8	Small spike
TE-312AD	Rod 12			9	
TE-313AD	Rod 13			10	
TE-317AD	Rod 17			11	
TE-318AD	Rod 18			12	
TE-320AD	Rod 20			13	
TE-322AD	Rod 22			14	
TE-323AD	Rod 23			15	
TE-325AD	Rod 25			16	
TE-326AD	Rod 26			17	
TE-331AD	Rod 31			18	
TE-338AD	Rod 38			19	
TE-339AD	Rod 39			20	Unpowered rod
TE-341AD	Rod 41			21	Noisy
TE-349AD	Rod 49			22	
	LEVEL E				
TE-301AE	Rod 1			23	Instrument failed
TE-304AE	Rod 4			24	
TE-309AE	Rod 9			25	
TE-312AE	Rod 12			26	
TE-313AE	Rod 13			27	
TE-317AE	Rod 17			28	
TE-318AE	Rod 18			29	
TE-320AE	Rod 20			30	
TE-322AE	Rod 22			31	
TE-323AE	Rod 23			32	
TE-324AE	Rod [illegible]4			33	Unpowered rod
TE-325AE	Rod 25			34	
TE-326AE	Rod 26			35	
TE-331AE	Rod 31			36	
TE-333AE	Rod 33			37	
TE-338AE	Rod 38			38	
TE-339AE	Rod 39			39	Unpowered rod
TE-341AE	Rod 41			40	
TE-349AE	Rod 49			41	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL F				
TE-301BF	Rod 1			42	
TE-304BF	Rod 4			43	
TE-309BF	Rod 9			44	
TE-310BF	Rod 10			45	
TE-312BF	Rod 12			46	
TE-313BF	Rod 13			47	
TE-317BF	Rod 17			48	
TE-320BF	Rod 20			49	
TE-322BF	Rod 22			50	Spike
TE-323BF	Rod 23			51	
TE-324BF	Rod 24			52	Unpowered rod
TE-325BF	Rod 25			53	Spike
TE-326BF	Rod 26			54	
TE-331BF	Rod 31			55	
TE-333BF	Rod 33			56	Spike
TE-338BF	Rod 38			57	Spikes
TE-341BF	Rod 41			58	Spike
TE-349BF	Rod 49			59	Spike
	LEVEL G				
TE-301BG	Rod 1			60	Instrument failed
TE-304BG	Rod 4			61	
TE-309BG	Rod 9			62	
TE-310BG	Rod 10			63	Small spike
TE-312BG	Rod 12			64	
TE-313BG	Rod 13			65	
TE-317BG	Rod 17			66	
TE-318BG	Rod 18			67	
TE-320BG	Rod 20			68	
TE-322BG	Rod 22			69	Noisy
TE-323BG	Rod 23			70	
TE-325BG	Rod 25			71	
TE-326BG	Rod 26			72	
TE-331BG	Rod 31			73	
TE-333BG	Rod 33			74	Spike
TE-338BG	Rod 38			75	Spike
TE-339BG	Rod 39			76	Unpowered rod, spike
TE-341BG	Rod 41			77	
TE-349BG	Rod 49			78	Instrument failed

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
BUNDLE TEMPERATURE (continued)					
	LEVEL H				
TE-301CH	Rod 1			79	Spike
TE-302AH	Rod 2			80	
TE-303AH	Rod 3			81	Spike
TE-304CH	Rod 4			82	
TE-305AH	Rod 5			83	
TE-306AH	Rod 6			84	
TE-307AH	Rod 7			85	
TE-308AH	Rod 8			86	
TE-309CH	Rod 9			87	
TE-310CH	Rod 10			88	
TE-311AH	Rod 11			89	
TE-312CH	Rod 12			90	
TE-313CH	Rod 13			91	
TE-314AH	Rod 14			92	
TE-315AH	Rod 15			53	Instrument failed
TE-316AH	Rod 16			94	
TE-317CH	Rod 17			95	
TE-318CH	Rod 18			96	
TE-320CH	Rod 20			97	
TE-321AH	Rod 21			98	
TE-322CH	Rod 22			99	
TE-323CH	Rod 23			100	
TE-324CH	Rod 24			101	Unpowered rod
TE-325CH	Rod 25			102	
TE-326CH	Rod 26			103	
TE-327AH	Rod 27			104	
TE-331CH	Rod 31			105	
TE-333CH	Rod 33			106	
TE-336AH	Rod 36			107	
TE-337AH	Rod 37			108	
TE-338CH	Rod 38			109	
TE-339CH	Rod 39			110	Unpowered rod
TE-341CH	Rod 41			111	
TE-342AH	Rod 42			112	
TE-343AH	Rod 43			113	
TE-344AH	Rod 44			114	
TE-345AH	Rod 45			115	
TE-346AH	Rod 46			116	
TE-348AH	Rod 48			117	
TE-349CH	Rod 49			118	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL I				
TE-301CI	Rod 1			119	
TE-302AI	Rod 2			120	
TE-303AI	Rod 3			121	
TE-304CI	Rod 4			122	
TE-305AI	Rod 5			123	
TE-306AI	Rod 6			124	
TE-307AI	Rod 7			125	
TE-308AI	Rod 8			126	Spike
TE-309CI	Rod 9			127	
TE-310CI	Rod 10			128	Small spike
TE-311AI	Rod 11			129	
TE-312CI	Rod 12			130	
TE-313CI	Rod 13			131	
TE-314AI	Rod 14			132	Small spike
TE-315AI	Rod 15			133	Spike
TE-316AI	Rod 16			134	Spike
TE-317CI	Rod 17			135	
TE-318CI	Rod 18			136	
TE-320CI	Rod 20			137	
TE-321AI	Rod 21			138	
TE-322CI	Rod 22			139	
TE-323CI	Rod 23			140	
TE-324CI	Rod 24			141	Unpowered rod
TE-325CI	Rod 25			142	
TE-326CI	Rod 26			143	
TE-327AI	Rod 27			144	
TE-328AI	Rod 28			145	
TE-331CI	Rod 31			146	
TE-333CI	Rod 33			147	Small spikes
TE-336AI	Rod 36			148	
TE-337AI	Rod 37			149	
TE-338CI	Rod 38			150	
TE-339CI	Rod 39			151	Unpowered rod
TE-341CI	Rod 41			152	
TE-342AI	Rod 42			153	
TE-343AI	Rod 43			154	
TE-344AI	Rod 44			155	Small spike
TE-345AI	Rod 45			156	Small spikes
TE-346AI	Rod 46			157	Small spike
TE-348AI	Rod 48			158	
TE-349CI	Rod 49			159	Small spikes

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL J				
TE-301DJ	Rod 1			160	Small spikes
TE-302CJ	Rod 2			161	
TE-304DJ	Rod 4			162	
TE-305CJ	Rod 5			163	
TE-306CJ	Rod 6			164	
TE-307CJ	Rod 7			165	
TE-308CJ	Rod 8			166	
TE-309DJ	Rod 9			167	
TE-310DJ	Rod 10			168	
TE-312DJ	Rod 12			169	
TE-313DJ	Rod 13			170	
TE-314[illegible]J	Rod 14			171	
TE-316CJ	Rod 16			172	
TE-317DJ	Rod 17			173	
TE-318DJ	Rod 18			174	
TE-320DJ	Rod 20			175	
TE-321CJ	Rod 21			176	
TE-322DJ	Rod 22			177	
TE-323DJ	Rod 23			178	
TE-324DJ	Rod 24			179	Unpowered rod
TE-325DJ	Rod 25			180	
TE-326DJ	Rod 26			181	
TE-327CJ	Rod 27			182	
TE-328CJ	Rod 28			183	
TE-331DJ	Rod 31			184	
TE-333DJ	Rod 33			185	
TE-336CJ	Rod 36			186	
TE-337CJ	Rod 37			187	
TE-338DJ	Rod 38			188	
TE-339DJ	Rod 39			189	Unpowered rod
TE-340CJ	Rod 40			190	
TE-341DJ	Rod 41			191	
TE-342CJ	Rod 42			192	
TE-343CJ	Rod 43			193	
TE-344CJ	Rod 44			194	
TE-345CJ	Rod 45			195	
TE-346CJ	Rod 46			196	
TE-349DJ	Rod 49			197	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL K				
TE-301DK	Rod 1			198	
TE-304DK	Rod 4			199	
TE-309DK	Rod 9			200	
TE-310DK	Rod 10			201	Slightly noisy
TE-312DK	Rod 12			202	
TE-313DK	Rod 13			203	
TE-317DK	Rod 17			204	
TE-318DK	Rod 18			205	
TE-320DK	Rod 20			206	
TE-322DK	Rod 22			207	
TE-323DK	Rod 23			208	
TE-324DK	Rod 24			209	Unpowered rod
TE-325DK	Rod 25			210	
TE-326DK	Rod 26			211	
TE-331DK	Rod 31			212	
TE-333DK	Rod 33			213	
TE-338DK	Rod 38			214	
TE-339DK	Rod 39			215	Unpowered rod
TE-341DK	Rod 41			216	
TE-349DK	Rod 49			217	
	LEVEL L				
TE-301EL	Rod 1			218	
TE-302CL	Rod 2			219	
TE-303CL	Rod 3			220	
TE-304EL	Rod 4			221	
TE-305CL	Rod 5			222	
TE-306CL	Rod 6			223	
TE-307CL	Rod 7			224	Instrument failed
TE-308CL	Rod 8			225	
TE-309EL	Rod 9			226	Reads low
TE-310EL	Rod 10			227	
TE-311CL	Rod 11			228	
TE-312EL	Rod 12			229	
TE-313EL	Rod 13			230	
TE-316[illegible]L	Rod 16			231	
TE-317EL	Rod 17			232	
TE-318EL	Rod 18			233	
TE-320EL	Rod 20			234	
TE-321CL	Rod 21			235	
TE-322EL	Rod 22			236	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL L (continued)				
TE-323EL	Rod 23			237	
TE-324EL	Rod 24			238	Unpowered rod
TE-325EL	Rod 25			239	
TE-326EL	Rod 26			240	
TE-327CL	Rod 27			241	
TE-328CL	Rod 28			242	
TE-331EL	Rod 31			243	
TE-333EL	Rod 33			244	
TE-336CL	Rod 36			245	
TE-337CL	Rod 37			246	
TE-338EL	Rod 38			247	
TE-339EL	Rod 39			248	Unpowered rod
TE-341EL	Rod 41			249	
TE-342CL	Rod 42			250	
TE-343CL	Rod 43			251	
TE-344CL	Rod 44			252	
TE-345CL	Rod 45			253	Small spike
TE-346CL	Rod 46			254	
TE-348CL	Rod 48			255	
TE-349EL	Rod 49			256	
	LEVEL M				
TE-301EM	Rod 1			257	
TE-304EM	Rod 4			258	
TE-309EM	Rod 9			259	
TE-325EM	Rod 25			260	
	LEVEL N				
TE-301FN	Rod 1			261	
TE-304FN	Rod 4			262	
TE-325FN	Rod 25			263	
	LEVEL O				
TE-301FO	Rod 1			264	
TE-304FO	Rod 4			265	
TE-309FO	Rod 9			266	
TE-310EO	Rod 10			267	
TE-312EO	Rod 12			268	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL O (continued)				
TE-317EO	Rod 17			269	Noisy
TE-318EO	Rod 18			270	
TE-320EO	Rod 20			271	
TE-322EO	Rod 22			272	
TE-323EO	Rod 23			273	
TE-324EO	Rod 24			274	Unpowered rod
TE-325FO	Rod 25			275	
TE-326EO	Rod 26			276	
TE-331EO	Rod 31			277	Noisy
TE-333EO	Rod 33			278	
TE-338EO	Rod 38			279	
TE-339EO	Rod 39			280	Unpowered rod
TE-341EO	Rod 41			281	
TE-349EO	Rod 49			282	
Heater Rod Center					
	LEVEL E				
TE-301ME	Rod 1			283	
TE-304ME	Rod 4			284	Small spike
TE-318ME	Rod 18			285	Spike
TE-322ME	Rod 22			286	Small spike
TE-326ME	Rod 26			287	Small spike
TE-331ME	Rod 31			288	Instrument failed
TE-338ME	Rod 33			289	
TE-349ME	Rod 49			290	
	LEVEL F				
TE-301MF	Rod 1			291	
TE-304MF	Rod 4			292	
TE-322MF	Rod 22			293	
TE-326MF	Rod 26			294	
TE-338MF	Rod 38			295	
TE-349MF	Rod 49			296	
	LEVEL G				
TE-301MG	Rod 1			297	Small spike
TE-310MG	Rod 10			298	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
Heater Rod Center (continued)					
	LEVEL G (continued)				
TE-313MG	Rod 13			299	
TE-317MG	Rod 17			300	
TE-318MG	Rod 18			301	
TE-322MG	Rod 22			302	
TE-323MG	Rod 23			303	
TE-325MG	Rod 25			304	
TE-326MG	Rod 26			305	
TE-338MG	Rod 38			306	
TE-349MG	Rod 49			307	
	LEVEL H				
TE-304MH	Rod 4			308	
TE-309MH	Rod 9			309	
TE-318MH	Rod 18			310	
TE-322MH	Rod 22			311	
TE-338MH	Rod 38			312	
	LEVEL J				
TE-301MJ	Rod 1			313	
TE-310MJ	Rod 10			314	
TE-317MJ	Rod 17			315	
TE-323MJ	Rod 23			316	
TE-324MJ	Rod 24			317	Unpowered rod
TE-326MJ	Rod 26			318	
TE-338MJ	Rod 38			319	
SPOOL PIECE INSTRUMENTS					
Temperature	Chromel-Alumel thermocouples	+32 to +1897°F	-0.0027 to +0.0400 V		
TE-24	Horizontal inlet			360	
TE-172	Vertical inlet			366	
TE-222	Vertical outlet			372	
TE-40	Horizontal outlet			378	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
SPOOL PIECE INSTRUMENTS (continued)					
<u>Pressure</u>		0 to +3000 psig	0.0 to +5.0 V		
PE-26	Horizontal inlet			357	
PE-174	Vertical inlet			363	
PE-224	Vertical outlet			369	
PE-42	Horizontal outlet			375	
<u>Pressure Drop</u>		-200 to +200 psid	-5.0 to +5.0 V		
PDE-21	Horizontal inlet			359	
PDE-167	Vertical inlet			365	
PDE-217	Vertical outlet			371	
PDE-35	Horizontal outlet			377	
<u>Flow</u>					
FE-19	Horizontal inlet	-2000 to +2000 gpm	-5.0 to +5.0 V	355	Erroneous flow direction, spike at blowdown
FE-166	Vertical inlet	-2000 to +2000 gpm	-5.0 to +5.0 V	361	
FE-216	Vertical outlet	-2000 to +2000 gpm	-5.0 to +5.0 V	367	Signal loss at approx. 7 sec
FE-34	Horizontal outlet	-4000 to +4000 gpm	-5.0 to +5.0 V	373	
<u>Momentum Flux</u>		-250,000 to +250,000 $lb_m/ft\text{-}sec^2$	-5.0 to +5.0 V		
FMFE-22	Horizontal inlet			358	Erratic
FMFE-170	Vertical inlet			364	Zero shifted, erratic
FMFE-220	Vertical outlet			370	Erratic
FMFE-38	Horizontal outlet			376	Somewhat erratic
<u>Fluid Density</u>		0 to +62.4 lb_m/ft^3	0.0 to +10.0 V		
DE-20	Horizontal inlet			356	Erroneous cal[illegible] tion caused signal loss
DE-168	Vertical inlet			362	Somewhat err[illegible]
DE-218	Vertical outlet			368	Somewhat er[illegible]
DE-36	Horizontal outlet			374	Erroneous [illegible] tion caused by signal loss

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
TEST SECTION TEMPERATURE	Chromel-Alumel thermocouples	+32 to +1897°F	-0.0027 to +0.0400 V		
Bundle Shroud					
TE-175	0.142L/LMAX			325	Instrument failed
TE-176	0.142L/LMAX			326	Instrument failed
TE-177	0.142L/LMAX			327	Instrument failed
TE-178	0.142L/LMAX			328	
TE-179	0.388L/LMAX			329	
TE-180	0.388L/LMAX			330	Large spike at power trip, erratic prior to blowdown
TE-181	0.388L/LMAX			331	Erratic
TE-182	0.388L/LMAX			332	
TE-183	0.633L/LMAX			333	Erratic
TE-184	0.633L/LMAX			334	Erratic
TE-185	0.633L/LMAX			335	Erratic
TE-186	0.633L/LMAX			336	Erratic
TE-187	0.875L/LMAX			337	Erratic
TE-189	0.875L/LMAX			338	
TE-190	0.875L/LMAX			339	Erratic
Bundle Subchannel					
TE-S1	Subchannel 1			477	
TE-S2	Subchannel 2			478	
TE-S3	Subchannel 3			479	
TE-S5	Subchannel 5			480	Instrument failed
TE-S9	Subchannel 9			481	
TE-S10	Subchannel 10			482	
TE-S11	Subchannel 11			483	
TE-S14	Subchannel 14			484	Instrument failed
TE-S16	Subchannel 16			485	
TE-S33	Subchannel 33			486	Instrument failed

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
TEST SECTION TEMPERATURE (continued)					
Bundle Subchannel (continued)					
TE-S34	Subchannel 34			487	Instrument failed
TE-S36	Subchannel 36			488	Instrument failed
TE-S38	Subchannel 38			489	Questionable
TE-S39	Subchannel 39			490	
TE-S40	Subchannel 40			491	Noisy
TE-S41	Subchannel 41			492	Instrument failed
TE-S42	Subchannel 42			493	Instrument failed
TE-S44	Subchannel 44			494	Instrument failed
TE-S45	Subchannel 45			495	
TE-S49	Subchannel 49			496	
TE-S50	Subchannel 50			497	Noisy
TE-S51	Subchannel 51			498	Noisy
TE-S54	Subchannel 54			499	
TE-S55	Subchannel 55			500	
TE-S57	Subchannel 57			501	
TE-S59	Subchannel 59			502	Spikes, noisy
TE-S63	Subchannel 63			503	Questionable
TE-S64	Subchannel 64			504	Questionable
Test Section					
TE-162	Inlet line T/C			320	
TE-150	Bottom flange T/C			321	
TE-151	Bottom flange T/C			322	
TE-152	Bottom flange T/C			323	
TE-153	Bottom flange T/C			324	
TE-212	Outlet line T/C			340	
TE-210A	Outlet line RTD (steady state)	+32 to +800°F	+0.2 to +0.52 V	410	
TEST SECTION PRESSURE					
PE-156	Inlet plenum	0 to +3000 psig	0.0 to +5.0 V	379	
PE-201	Outlet plenum	0 to +3000 psig	0.0 to +5.0 V	380	
PE-27	Inlet plenum bottom	0 to +3000 psig	0.0 to +5.0 V	399	
PE-43	Outlet plenum bottom	0 to +3000 psig	0.0 to +5.0 V	400	
PT-32	Outlet steady state	+500 to +2500 psig	+1.0 to +5.0 V	402	Zero shifted

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
TEST SECTION PRESSURE DROP					
PDT-199	Shroud box steady-state differential pressure	0 to +50 psid	+1.0 to +5.0 V	387	
PDE-200	Bundle transient differential pressure	-200 to +200 psid	-5.0 to +5.0 V	388	
PDT-30	Test section steady-state differential pressure	0 to +50 psid	+1.0 to +5.0 V	401	
PRESSURIZER INSTRUMENTS					
Temperature					
TE-1	Tank top T/C	+32 to +1897°F	-0.0027 to +0.0400 V	346	
TE-2	Tank exit T/C	+32 to +1897°F	-0.0027 to +0.0400 V	347	
Pressure					
PT-102	Steady-state pressure	+500 to +2500 psig	+1.0 to +5.0 V	383	Zero shifted
PE-106	Vapor transient pressure	0 to +3000 psig	0 to +5.0 V	384	
Level					
LT-100	Steady-state liquid level	0 to +150 in.	+1.0 to +5.0 V	406	
HEATER ROD POWER					
Heater Current		0 to +800 A	0.0 to +5.0 V		
EIE-11S6	Rod 1			412	
EIE-12S6	Rod 2			413	
EIE-11S7	Rod 3			414	
EIE-12S7	Rod 4			415	
EIE-9S6	Rod 5			416	
EIE-9S8	Rod 6			417	
EIE-9S5	Rod 7			418	
EIE-11S5	Rod 8			419	
EIE-11S8	Rod 9			420	
EIE-12S8	Rod 10			421	
EIE-9S7	Rod 11			422	
EIE-9S4	Rod 12			423	
EIE-9S3	Rod 13			424	
EIE-9S11	Rod 14			425	
EIE-11S4	Rod 15			426	

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
HEATER ROD POWER (continued)					
Heater Current (continued)					
EIE-11S9	Rod 16			427	
EIE-12S5	Rod 17			428	
EIE-9S9	Rod 18			429	
EIE-9S10	Rod 19			430	Unpowered rod
EIE-9S2	Rod 20			431	
EIE-9S12	Rod 21			432	
EIE-11S11	Rod 22			433	
EIE-11S10	Rod 23			434	
EIE-11S3	Rod 24			435	Unpowered rod
EIE-9S13	Rod 25			436	
EIE-10S6	Rod 26			437	
EIE-9S1	Rod 27			438	
EIE-10S7	Rod 28			439	
EIE-11S2	Rod 29			440	
EIE-11S12	Rod 30			441	
EIE-12S2	Rod 31			442	
EIE-12S1	Rod 32			443	
EIE-10S12	Rod 33			444	
EIE-10S5	Rod 34			445	
EIE-10S8	Rod 35			446	
EIE-11S1	Rod 36			447	
EIE-12S4	Rod 37			448	
EIE-12S3	Rod 38			449	
EIE-12S12	Rod 39			450	Unpowered rod
EIE-10S11	Rod 40			451	
EIE-10S10	Rod 41			452	
EIE-10S9	Rod 42			453	
EIE-12S9	Rod 43			454	
EIE-12S10	Rod 44			455	
EIE-12S11	Rod 45			456	
EIE-10S1	Rod 46			457	
EIE-10S2	Rod 47			458	Unpowered rod
EIE-10S3	Rod 48			459	
EIE-10S4	Rod 49			460	
GENERATOR POWER					
Generator Current		0 to +10,000 A	0.0 to +2.5 V		
EIE-9	Generator 9 current			461	
EIE-10	Generator 10 current			462	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
GENERATOR POWER (continued)					
Generator Current (continued)					
EIE-11	Generator 11 current			463	
EIE-12	Generator 12 current			464	
Generator Voltage		0 to +285 V	0.0 to +10.0 V		
EEE-9	Generator 9 voltage			465	
EEE-10	Generator 10 voltage			466	
EEE-11	Generator 11 voltage			467	
EEE-12	Generator 12 voltage			468	
HEAT EXCHANGER INSTRUMENTS					
Primary Side	Outlet Line Thermocouples	+32 to +1897°F	-0.0027 to +0.0400 V		
TE-308	Heat exchanger A			341	
TE-328	Heat exchanger B			342	
TE-348	Heat exchanger C			343	
TE-58	Heat exchanger D			345	
TE-288	Main HX mixing tee steady-state temp., RTD	+32 to +500°F	+0.032 to +0.800 V	395	
Secondary Side	Secondary discharge steady-state temp., RTD	+32 to +500°F	+0.2 to +0.4 V		
TE-525	Heat exchanger A			409	Noisy
TE-627	Heat exchanger B			389	
TE-727	Heat exchanger C			394	
TE-557	Heat exchanger D			408	Noisy
Heat Exchanger Secondary Flow					
FE-522	Heat exchanger A	0 to +150 gpm	+0.2 to +1.0 V	407	HX A valved off
FE-620	Heat exchanger B	0 to +150 gpm	+0.2 to +1.0 V	351	Flow surge
FE-720	Heat exchanger C	0 to +150 gpm	+0.2 to +1.0 V	352	
FE-550	Heat exchanger D	0 to +50 gpm	+0.2 to +1.0 V	353	
Heat Exchanger Pressure					
PE-44	Upstream main HX transient pressure	0 to +3000 psig	0.0 to +5.0 V	381	
PE-526	HX A secondary inlet pressure	0 to +350 psig	0.0 to +5.0 V	397	Spike

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
HEAT EXCHANGER INSTRUMENTS (continued)					
Pressure Drop					
PDT-48	Main HX steady-state pressure drop	0 to +24 psid	+1.0 to +5.0 V	390	Flow surge at approx. 23 sec
PDE-46	Main HX bypass transient pressure drop	-200 to +200 psid	-5.0 to +5.0 V	396	
PRIMARY PUMP INSTRUMENTS					
FE-1A	Primary side pump flow	0 to +800 gpm	+1.0 to +5.0 V	354	
PE-76	Pump suction transient pressure	0 to +3000 psig	0 to +5.0 V	382	
PDE-78	Primary pump transient pressure drop	-1000 to +1000 psid	-5.0 to +5.0 V	391	
SE-72	Primary pump speed	+100 to +5400 rpm	0 to +5.0 V	403	
TE-48	Base primary steady-state temp., RTD	+32 to +800°F	+0.2 to +0.52 V	350	
PE-16	Downstream HCV-2 transient pressure	0.0 to +3000 psig	0.0 to +5.0 V	398	
PRESSURE SUPPRESSION SYSTEM INSTRUMENTS					
PE-412	Pressure suppression receiver transient pressure	0 to +200 psig	0 to +5.0 V	385	
PE-425	PSS inlet blowdown line transient pressure	0 to +3000 psig	0 to +5.0 V	392	
PE-427	PSS outlet blowdown line transient pressure	0 to +3000 psig	0 to +5.0 V	393	Instrument failed
TE-29	Inlet blowdown plenum T/C	+32 to +1897°F	-0.0027 to +0.0400 V	348	
TE-45	Outlet blowdown plenum T/C	+32 to +1897°F	-0.0027 to +0.0400 V	349	
DEMINERALIZED WATER SYSTEM					
TE-520B	RBT 4-in. demineralized water header T/C	+32 to +1897°F	-0.0027 to +0.0400 V	344	
TE-615	Demineralized water 6-in. header steady-state temp., RTD	+32°F to +500°F	+0.2 to +0.4 V	386	Spikes
GENERAL INSTRUMENTATION (ELECTRICAL)					
Breakwire Detectors					
XM-4000I	Inlet bre[illegible]	0.0 to +5.0 V	0.0 to +5.0 V	404	
XM-4000O	Outlet	0.0 to +5.0 V	0.0 to +5.0 V	405	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
GENERAL INSTRUMENTATION (ELECTRICAL) (continued)					
RTD Power					
EIM-10018	RTD power supply current	2.0 mA	0.400 V	411	
Data Acquisition Calibration Signals					
Zero cal. input	Channels 0–127	0.0 mV	0.0 mV	469	
Zero cal. input	Channels 128–255	0.0 mV	0.0 mV	470	
Zero cal. input	Channels 256–383	0.0 mV	0.0 mV	471	
Zero cal. input	Channels 384–511	0.0 mV	0.0 mV	472	
Full-scale cal. input	Channels 0–127	35.00 mV	35.00 mV	473	
Full-scale cal. input	Channels 128–255	35.00 mV	35.00 mV	474	
Full-scale cal. input	Channels 256–383	35.00 mV	35.00 mV	475	
Full-scale cal. input	Channels 384–511	35.00 mV	35.00 mV	476	

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