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PWR Blowdown He: ransfer Separate-Effects Program—Thermal-Hydraulic Test Facility Experimental Data Report for Test 153

D. M. Leon
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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 153

D. M. Leon 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 153

D. M. Leon   R. A. Hedrick   M. D. White

ABSTRACT

Reduced instrument responses are presented for Thermal-Hydraulic Test Facility (THTF) test 153, 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 153 was conducted to obtain thermal-hydraulic and critical heat flux information in THTF bundle 1 operating at a low power and containing four unpowered rods.

The primary purpose of this report is to make the reduced instrument responses during test 153 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 153 (conducted December 8, 1976) was the ninth 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 low power and containing four unpowered rods.

The purpose of this report is to provide the reduced instrument responses during test 153 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 153

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. The break configuration for test 153 was 40% inlet–60% outlet with a total 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 (80 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 and then the power was 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 80 kW/rod.

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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

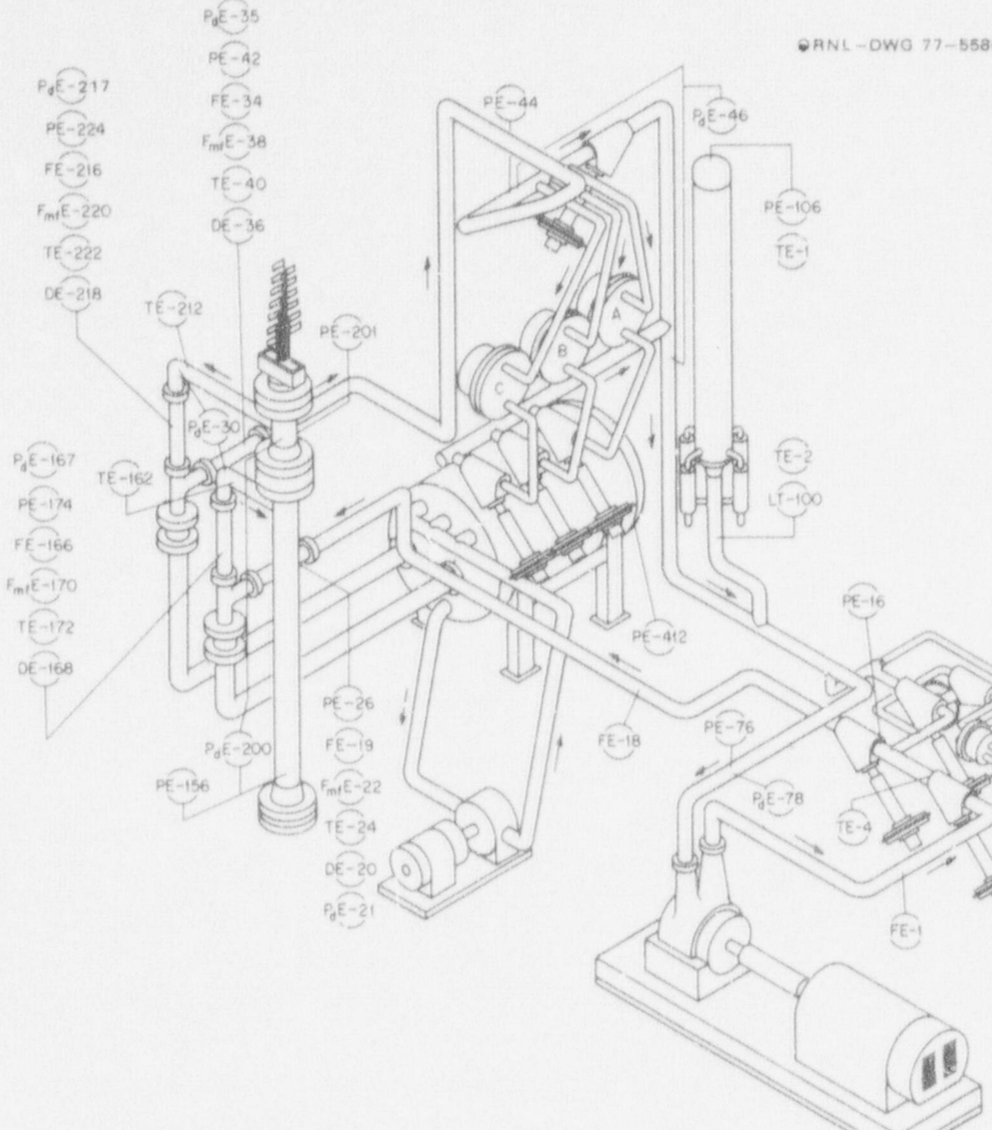

Fig. 1. Thermal-Hydraulic Test Facility (THTF).

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.

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 prerupture steady-state primary and secondary energy balances are shown in Figs. 2 through 4. 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		15.720	15.782
psig		2280	2289
Core power MW	EIE-9, EIE-10, EIE-11, EIE-12, EEE-9, EEE-10, EEE-11, EEE-12	3.600	3.591
Number of unpowered rods		4	4
Core volumetric flow rate	FE-19		
m^3/s		0.0196	0.0200
gpm		310	317
Test section inlet temperature	TE-162		
K		558.2	557.0
°F		545	543
Test section outlet temperature	TE-212		
K		598.2	597.6
°F		617	616
Pressurizer pressure	PE-106		
MN/m^2		15.224	15.430
psig		2208	2238
Mass liquid water			
kg		54.88	53.52
lb_m		121	118
Coolant pump speed	SE-72		
rps		60.52	59.52
rpm		3631	3571
Pressure differential	P_dE-78		
MN/m^2		4.661	4.516
psid		676	655
Pressure between HCV-2 and FCV-18	PE-16		
MN/m^2		17.706	16.706
psig		2568	2423
Pressure differential across main heat exchangers	P_dE-46		
MN/m^2		0.320	0.334
psid		46.4	48.4

[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] for test 153

Location	Instrument	Temperature [K (°F)]	Pressure [MN/m² (psig)]
Vertical inlet spool piece	TE-172	557.6 (544)	
Vertical inlet spool piece	PE-174		15.844 (2298)
Test section inlet	TE-162	557.0 (543)	
Lower plenum	TE-150	559.8 (548)	
Lower plenum	PE-156		15.865 (2301)
Upper plenum	PE-201		15.782 (2289)
Test section outlet	TE-212	597.6 (616)	
Vertical outlet spool piece	TE-222	597.6 (616)	
Vertical outlet spool piece	PE-224		15.658 (2271)
Heat exchanger inlet header	PE-44		15.672 (2273)
Mixed mean temperature downstream heat exchangers	TE-28B	559.8 (548)	
Pressurizer surge line	TE-2	593.2 (608)	
Pressurizer	PE-106		15.4[illegible]0 (2238)
Primary pump suction	PE-76		15.348 (2226)
Between main control valves HCV-2, FCV-18	TE-4B	555.4 (540)	
Between main control valves HCV-2, FCV-18	PE-16		16.706 (2423)

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

Table 3. Sequence of events during test 153

Event	Time relative to rupture (sec)
Core power level established	−6135
Core temperature rise established	−1155
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	+3.4

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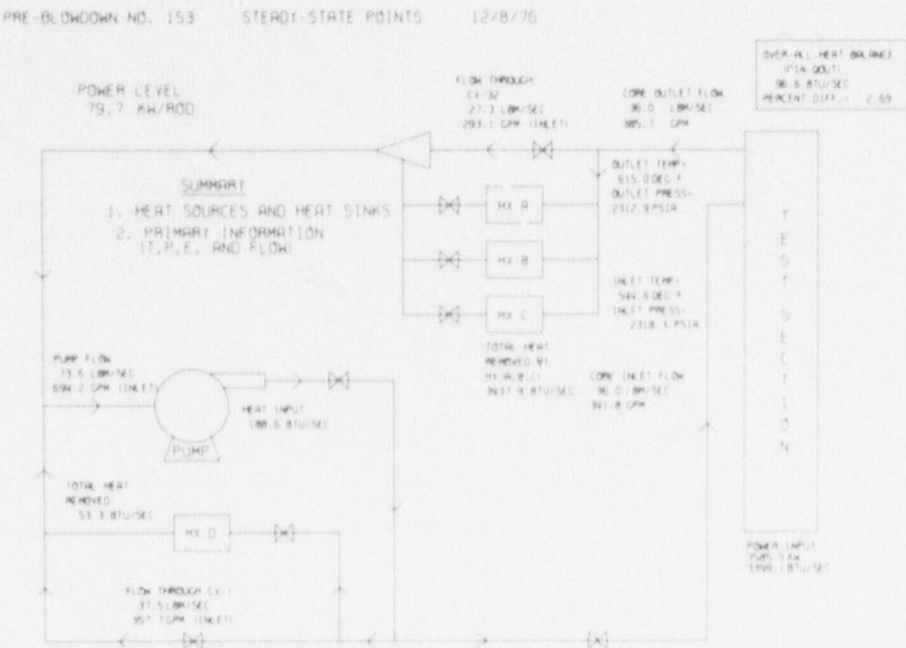

Fig. 2. Prerupture loop energy balance.

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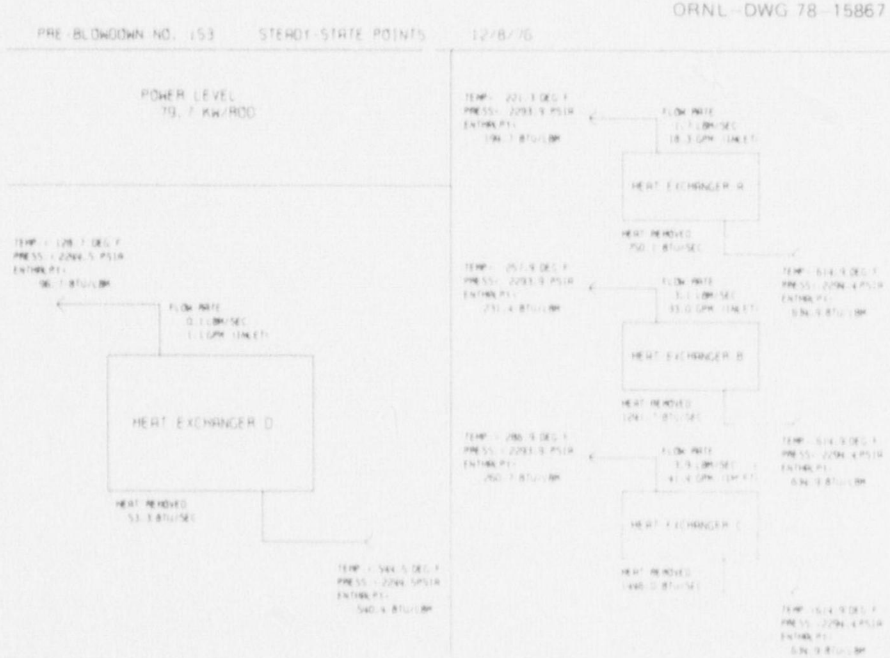

Fig. 3. Prerupture primary side heat exchanger summary.

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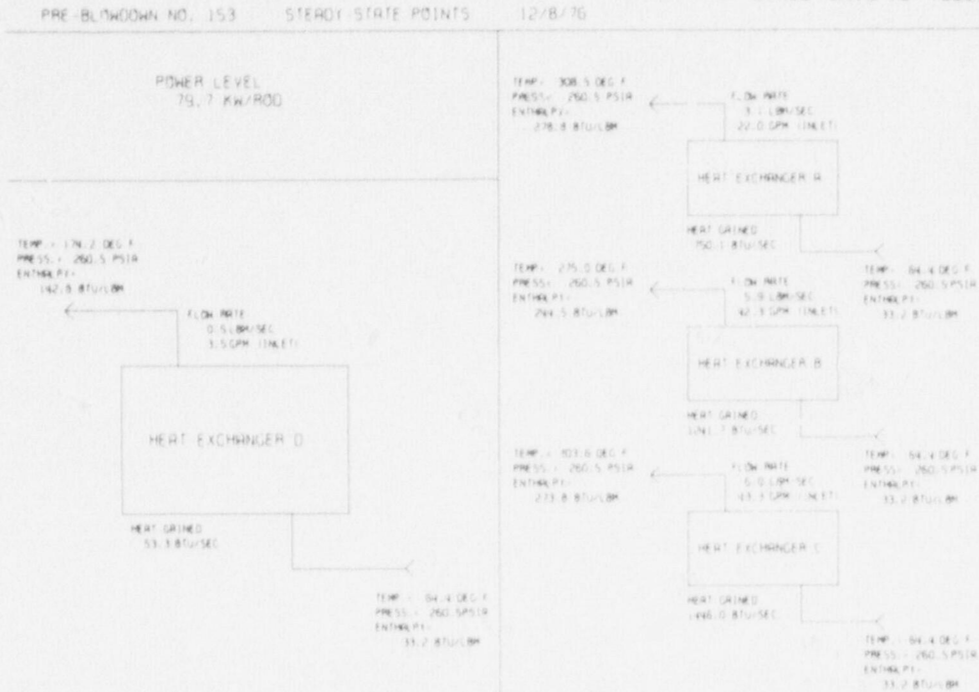


Fig. 4. Prerupture secondary side heat exchanger summary.

III. DATA PRESENTATION

The recorded instrument responses for THTF test 153 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 5 through 7 provide supportive information for the instrument responses and indicate the relative locations of the detectors in the THTF. 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.

ORNL-DWG 76-19894

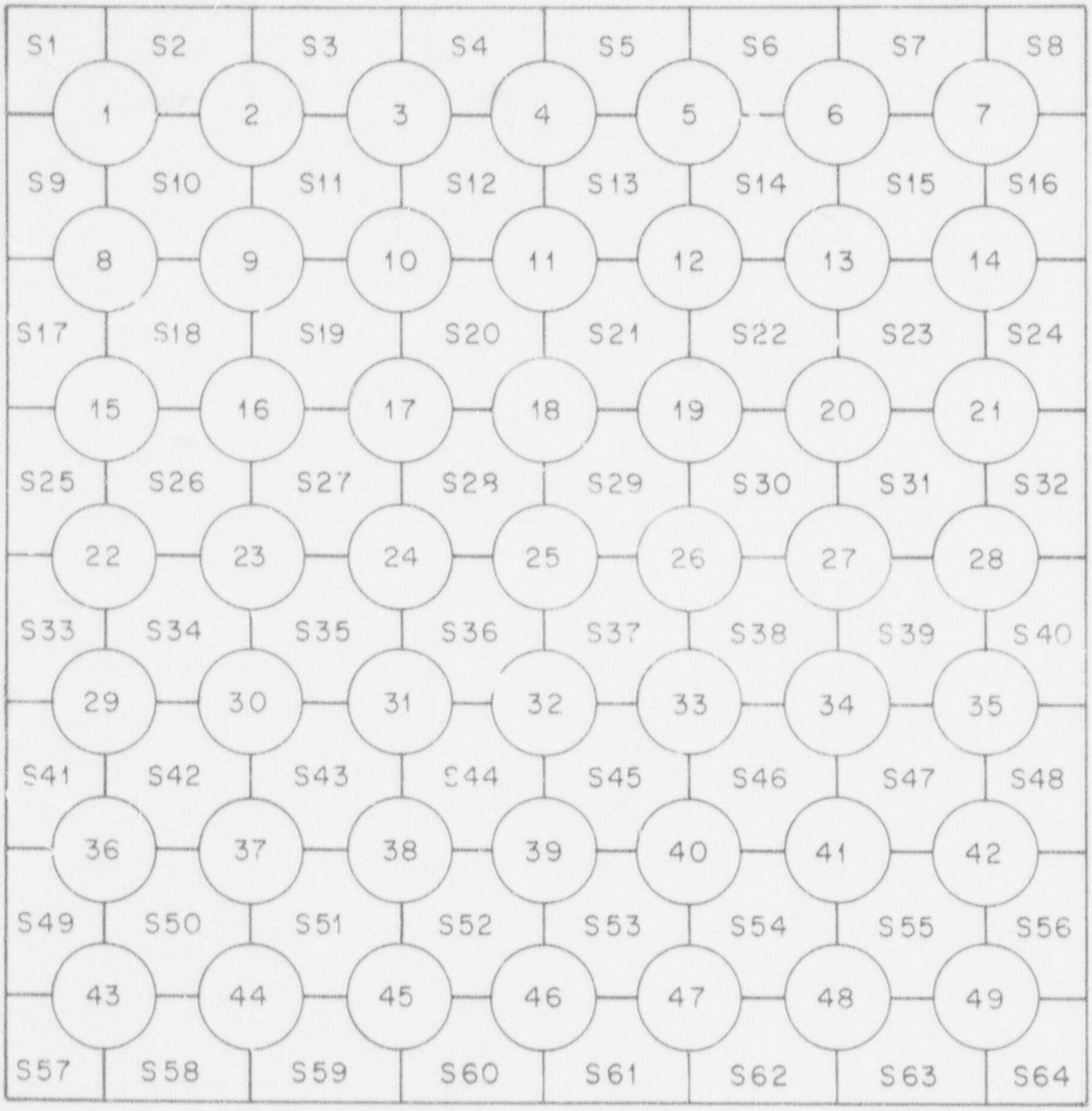


Fig. 5. Identification of THTF heater rod and subchannel locations in bundles 1 and 2.

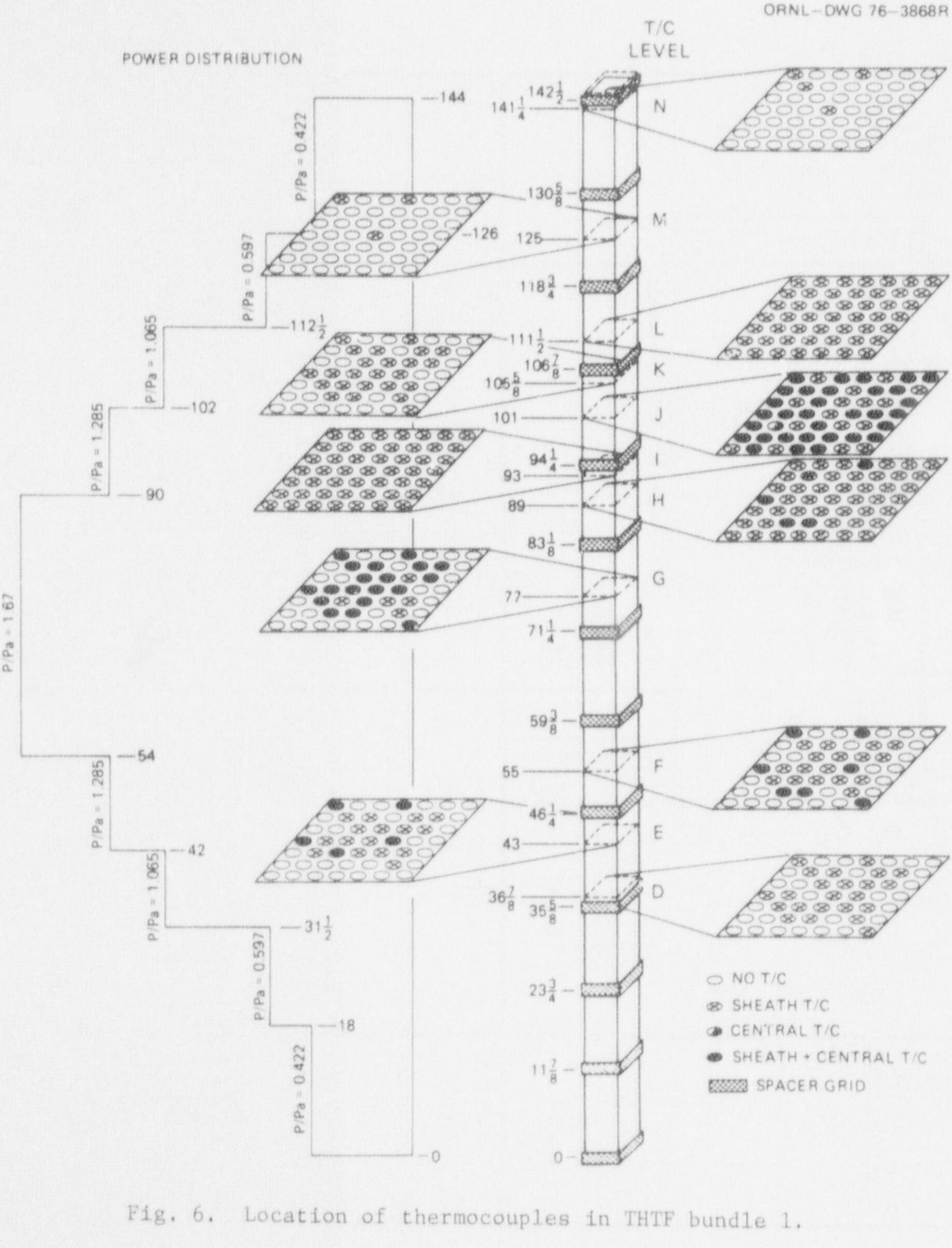


Fig. 6. Location of thermocouples in THTF bundle 1.

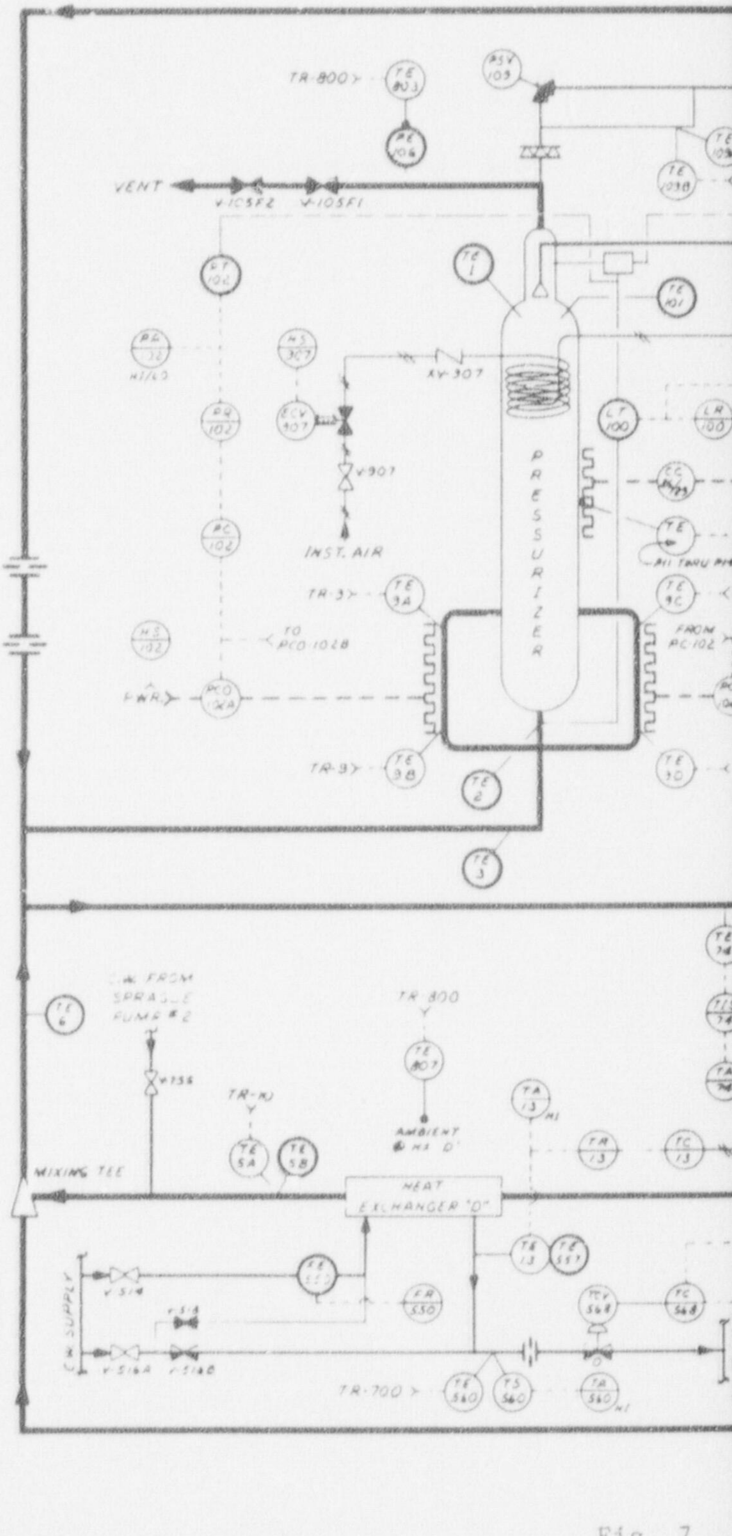
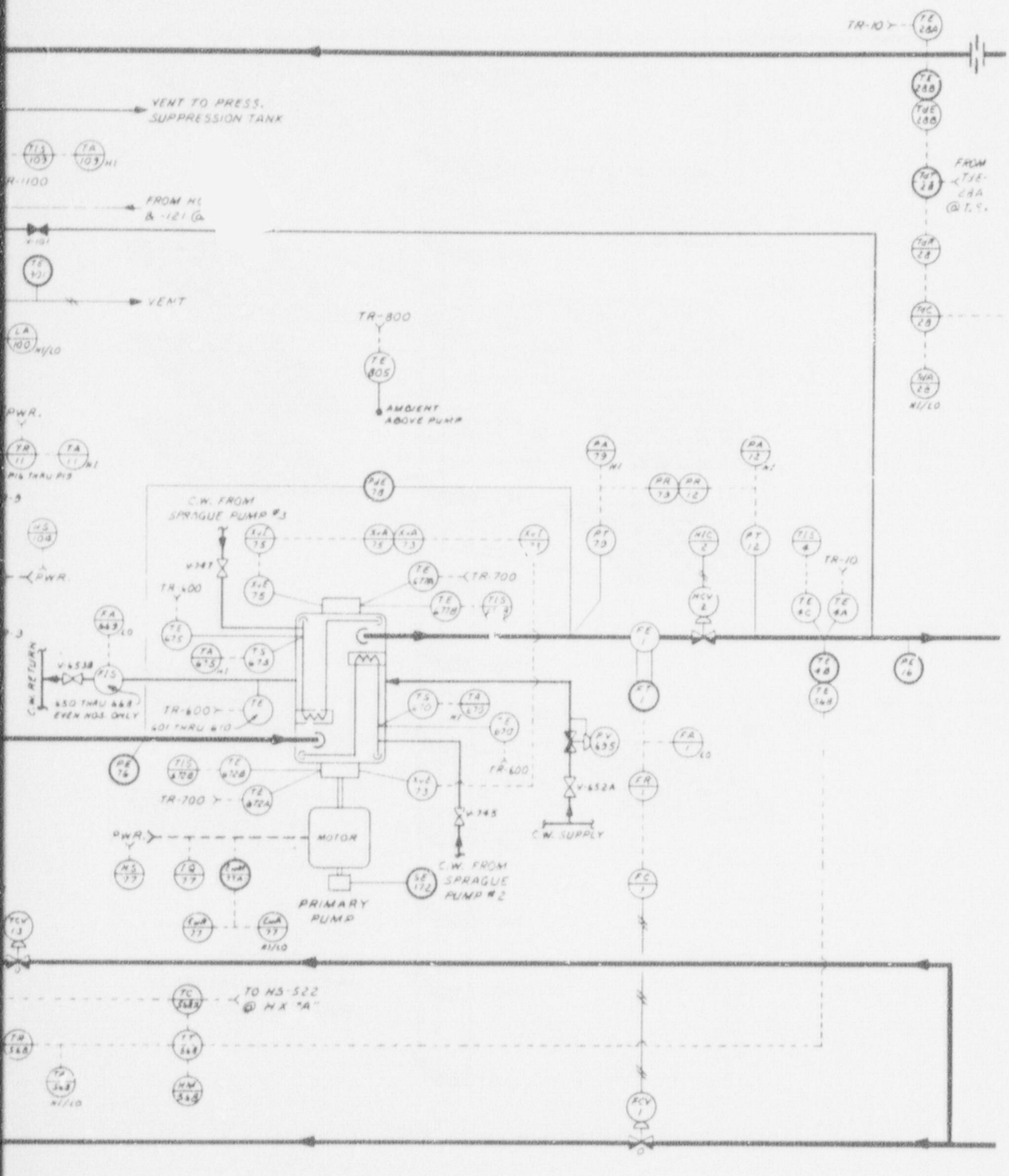
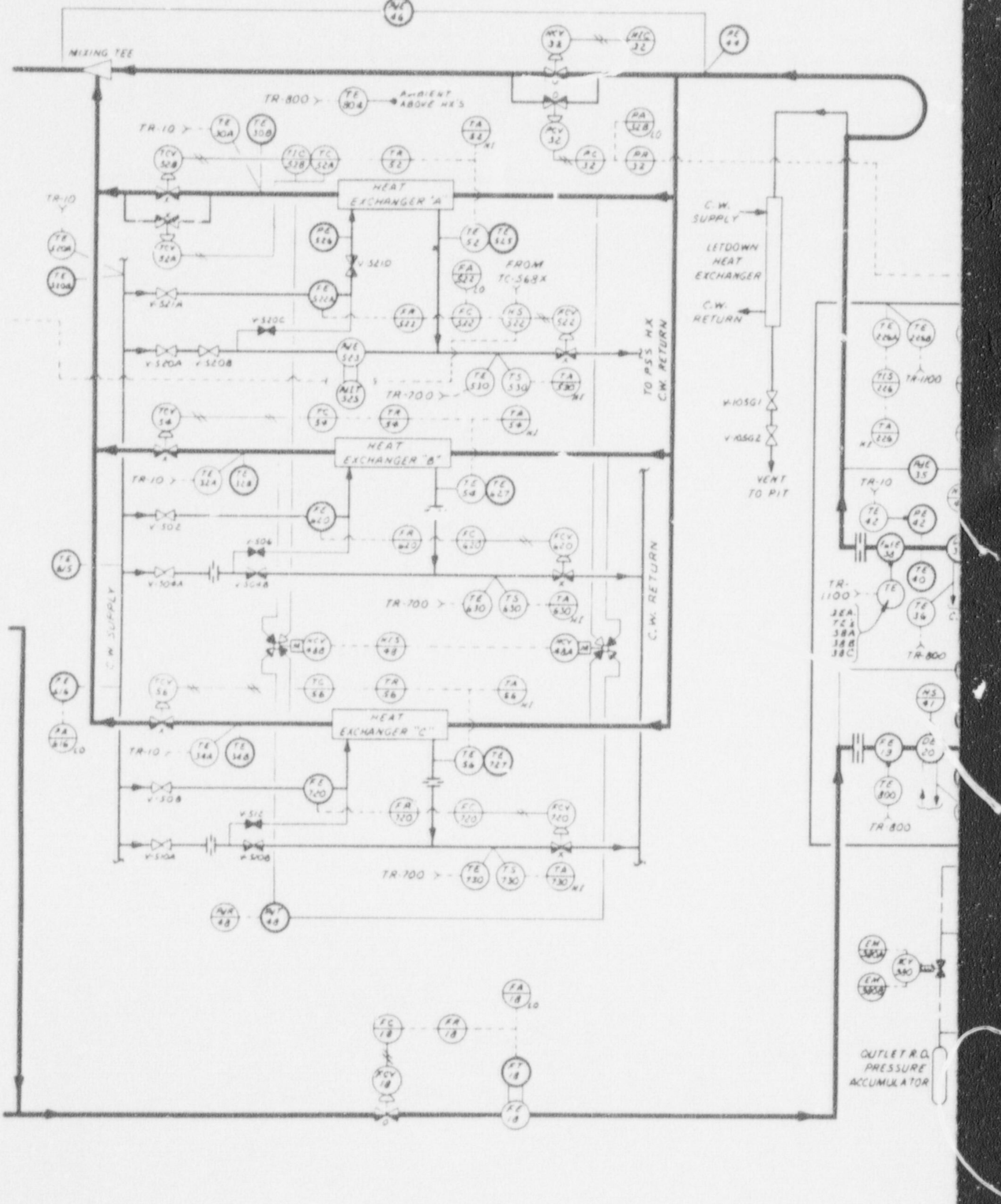

VENT
INST. AIR
P R E S S U R I Z E R
MIXING TEE
HEAT EXCHANGER "D"
C.W. FROM SPRAGUE PUMP #2
C.W. SUPPLY

Fig. 7.



HTF instrument identification and location.


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
OUTLET R.O. PRESSURE ACCUMULATOR

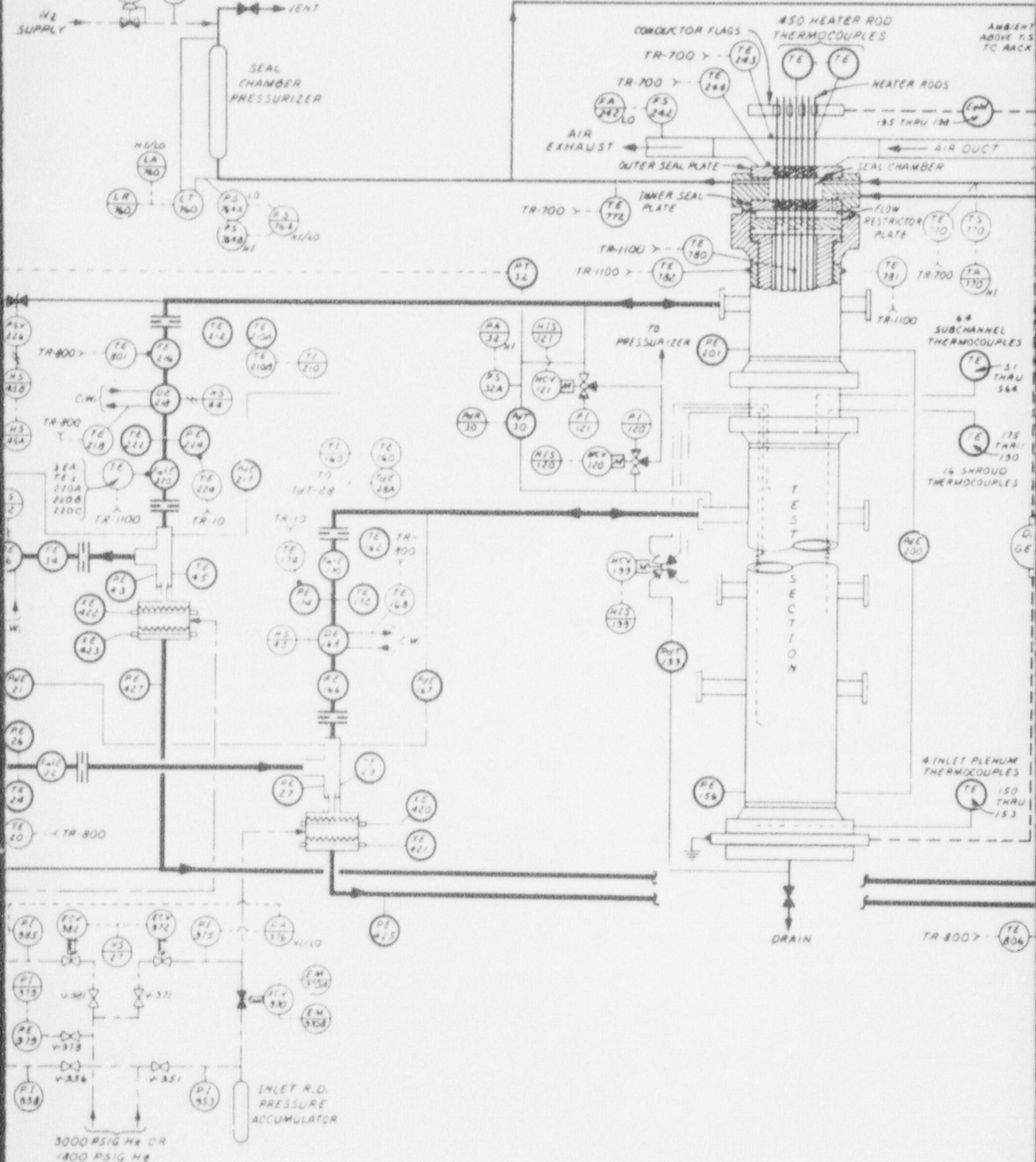


Fig. 7 (continued)

ORNL-DWG 77-12968

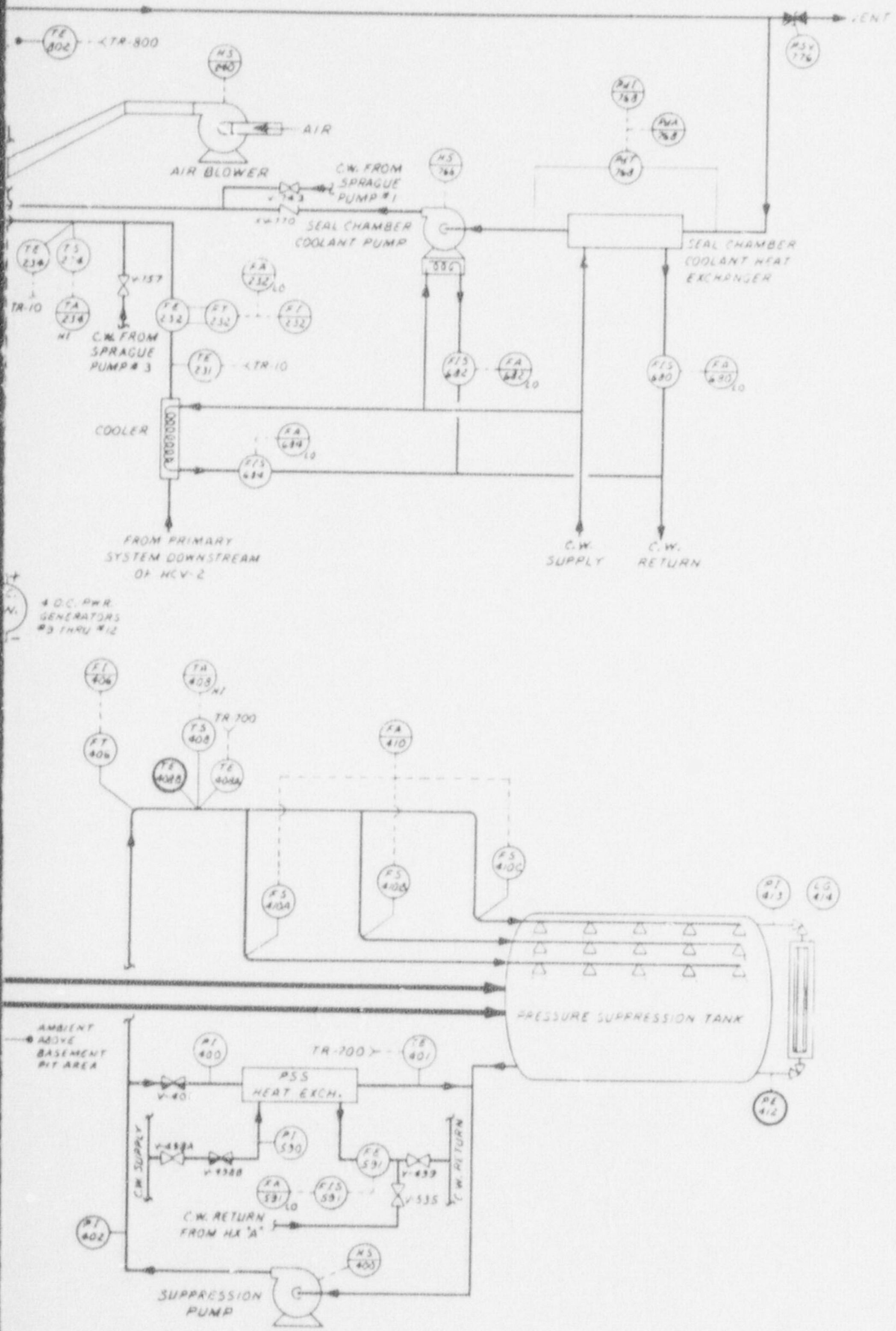


Table 4. Precision of experimental measurements for test 153

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, $kg/m\text{-}sec^2$ ($lb_m/ft\text{-}sec^2$)	
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)

Table 5. Data presentation for test 153

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
BUNDLE TEMPERATURE	Chromel-Alumel thermocouples	+32 to +1897°F (all)	−0.0027 to +0.0400 V (all)		
Heater Rod Sheath					
	LEVEL D				
TE-301AD	Rod 1			8	
TE-304AD	Rod 4			9	
TE-309AD	Rod 9			10	
TE-310AD	Rod 10			11	
TE-312AD	Rod 12			12	
TE-313AD	Rod 13			13	
TE-317AD	Rod 17			14	
TE-318AD	Rod 18			15	
TE-320AD	Rod 20			16	
TE-322AD	Rod 22			17	
TE-323AD	Rod 23			18	
TE-325AD	Rod 25			19	
TE-326AD	Rod 26			20	
TE-331AD	Rod 31			21	
TE-338AD	Rod 38			22	
TE-339AD	Rod 39			23	Unpowered rod
TE-341AD	Rod 41			24	
TE-349AD	Rod 49			25	
	LEVEL E				
TE-301AE	Rod 1			26	Instrument failed
TE-304AE	Rod 4			27	
TE-309AE	Rod 9			28	
TE-312AE	Rod 12			29	
TE-313AE	Rod 13			30	
TE-317AE	Rod 17			31	
TE-318AE	Rod 18			32	
TE-320AE	Rod 20			33	
TE-322AE	Rod 22			34	
TE-323AE	Rod 23			35	
TE-324AE	Rod 24			36	Unpowered rod
TE-325AE	Rod 25			37	
TE-326AE	Rod 26			38	
TE-331AE	Rod 31			39	
TE-333AE	Rod 33			40	
TE-338AE	Rod 38			41	

Table 5 (continued)

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

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL G (continued)				
TE-326BG	Rod 26			75	
TE-331BG	Rod 31			76	
TE-333BG	Rod 33			77	
TE-338BG	Rod 38			78	
TE-339BG	Rod 39			79	Unpowered rod
TE-341BG	Rod 41			80	
TE-349BG	Rod 49			81	Instrument reading bad in early part of transient
	LEVEL H				
TE-301CH	Rod 1			87	
TE-302AH	Rod 2			83	
TE-303AH	Rod 3			84	
TE-304CH	Rod 4			85	
TE-305AH	Rod 5			86	
TE-306AH	Rod 6			87	
TE-307AH	Rod 7			88	
TE-308AH	Rod 8			89	
TE-309CH	Rod 9			90	
TE-310CH	Rod 10			91	
TE-311AH	Rod 11			92	
TE-312CH	Rod 12			93	
TE-313CH	Rod 13			94	
TE-314AH	Rod 14			95	
TE-315AH	Rod 15			96	
TE-316AH	Rod 16			97	
TE-317CH	Rod 17			98	
TE-318CH	Rod 18			99	
TE-320CH	Rod 20			100	
TE-321AH	Rod 21			101	
TE-322CH	Rod 22			102	
TE-323CH	Rod 23			103	
TE-324CH	Rod 24			104	Unpowered rod
TE-325CH	Rod 25			105	
TE-326CH	Rod 26			106	
TE-327AH	Rod 27			107	
TE-331CH	Rod 31			108	
TE-333CH	Rod 33			109	
TE-336AH	Rod 36			110	
TE-337AH	Rod 37			111	
TE-338CH	Rod 38			112	Spike

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL H (continued)				
TE-339CH	Rod 39			113	Unpowered rod and spike
TE-341CH	Rod 41			114	
TE-342AH	Rod 42			115	
TE-343AH	Rod 43			116	
TE-344AH	Rod 44			117	
TE-345AH	Rod 45			118	
TE-346AH	Rod 46			119	
TE-348AH	Rod 48			120	
TE-349CH	Rod 49			121	
	LEVEL I				
TE-301CI	Rod 1			122	
TE-302AI	Rod 2			123	
TE-303AI	Rod 3			124	
TE-304CI	Rod 4			125	
TE-305AI	Rod 5			126	
TE-306AI	Rod 6			127	
TE-307AI	Rod 7			128	
TE-308AI	Rod 8			129	
TE-309CI	Rod 9			130	
TE-310CI	Rod 10			131	
TE-311AI	Rod 11			132	
TE-312CI	Rod 12			133	
TE-313CI	Rod 13			134	
TE-314AI	Rod 14			135	
TE-315AI	Rod 15			136	
TE-316AI	Rod 16			137	
TE-317CI	Rod 17			138	
TE-318CI	Rod 18			139	
TE-320CI	Rod 20			140	
TE-321AI	Rod 21			141	
TE-322CI	Rod 22			142	
TE-323CI	Rod 23			143	
TE-324CI	Rod 24			144	Unpowered rod
TE-325CI	Rod 25			145	
TE-326CI	Rod 26			146	
TE-327AI	Rod 27			147	
TE-328AI	Rod 28			148	
TE-331CI	Rod 31			149	
TE-333CI	Rod 33			150	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL I (continued)				
TE-336AI	Rod 36			151	
TE-337AI	Rod 37			152	
TE-338CI	Rod 38			153	
TE-339CI	Rod 39			154	Unpowered rod
TE-341CI	Rod 41			155	
TE-342AI	Rod 42			156	
TE-343AI	Rod 43			157	
TE-344AI	Rod 44			158	
TE-345AI	Rod 45			159	
TE-346AI	Rod 46			160	
TE-348AI	Rod 48			161	
TE-349CI	Rod 49			162	
	LEVEL J				
TE-301DJ	Rod 1			163	
TE-302CJ	Rod 2			164	
TE-304DJ	Rod 4			165	
TE-305CJ	Rod 5			166	
TE-306CJ	Rod 6			167	
TE-307CJ	Rod 7			168	
TE-308CJ	Rod 8			169	
TE-309DJ	Rod 9			170	
TE-310DJ	Rod 10			171	
TE-312DJ	Rod 12			172	
TE-313DJ	Rod 13			173	
TE-314CJ	Rod 14			174	
TE-316CJ	Rod 16			175	
TE-317DJ	Rod 17			176	
TE-318DJ	Rod 18			177	
TE-320DJ	Rod 20			178	
TE-321CJ	Rod 21			179	
TE-322DJ	Rod 22			180	
TE-323DJ	Rod 23			181	
TE-324DJ	Rod 24			182	Unpowered rod
TE-325DJ	Rod 25			183	
TE-326DJ	Rod 26			184	
TE-327CJ	Rod 27			185	
TE-328CJ	Rod 28			186	
TE-331DJ	Rod 31			187	
TE-333DJ	Rod 33			188	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL J (continued)				
TE-336CJ	Rod 36			189	
TE-337CJ	Rod 37			190	
TE-338DJ	Rod 38			191	
TE-339DJ	Rod 39			192	Unpowered rod
TE-340CJ	Rod 40			193	
TE-341DJ	Rod 41			194	
TE-342CJ	Rod 42			195	
TE-343CJ	Rod 43			196	
TE-344CJ	Rod 44			197	
TE-345CJ	Rod 45			198	
TE-346CJ	Rod 46			199	
TE-349DJ	Rod 49			200	
	LEVEL K				
TE-301DK	Rod 1			201	
TE-304DK	Rod 4			202	
TE-309DK	Rod 9			203	
TE-310DK	Rod 10			204	
TE-312DK	Rod 12			205	
TE-313DK	Rod 13			206	
TE-317DK	Rod 17			207	
TE-318DK	Rod 18			208	
TE-320DK	Rod 20			209	
TE-322DK	Rod 22			210	Small spike
TE-323DK	Rod 23			211	
TE-324DK	Rod 24			212	Unpowered rod
TE-325DK	Rod 25			213	
TE-326DK	Rod 26			214	
TE-331DK	Rod 31			215	
TE-333DK	Rod 33			216	Spike
TE-338DK	Rod 38			217	Spike
TE-339DK	Rod 39			218	Unpowered rod
TE-341DK	Rod 41			219	Spike
TE-349DK	Rod 49			220	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL L				
TE-301EL	Rod 1			221	Small spike
TE-302CL	Rod 2			222	
TE-303CL	Rod 3			223	
TE-304EL	Rod 4			224	
TE-305CL	Rod 5			225	
TE-306CL	Rod 6			226	
TE-307CL	Rod 7			227	Instrument failed
TE-308CL	Rod 8			228	
TE-309EL	Rod 9			229	
TE-310EL	Rod 10			230	
TE-311CL	Rod 11			231	
TE-312EL	Rod 12			232	
TE-313EL	Rod 13			233	
TE-316CL	Rod 16			234	
TE-317EL	Rod 17			235	
TE-318EL	Rod 18			236	
TE-320EL	Rod 20			237	
TE-321CL	Rod 21			238	
TE-322EL	Rod 22			239	
TE-323EL	Rod 23			240	
TE-324EL	Rod 24			241	Unpowered rod
TE-325EL	Rod 25			242	
TE-326EL	Rod 26			243	
TE-327CL	Rod 27			244	
TE-328CL	Rod 28			245	
TE-331EL	Rod 31			246	
TE-333EL	Rod 33			247	
TE-336CL	Rod 36			248	
TE-337CL	Rod 37			249	
TE-338EL	Rod 38			250	
TE-339EL	Rod 39			251	Unpowered rod
TE-341EL	Rod 41			252	
TE-342CL	Rod 42			253	
TE-343CL	Rod 43			254	
TE-344CL	Rod 44			255	
TE-345CL	Rod 45			256	
TE-346CL	Rod 46			257	
TE-348CL	Rod 48			258	
TE-349EL	Rod 49			259	

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
BUNDLE TEMPERATURE (continued)					
	LEVEL M				
TE-301EM	Rod 1			260	
TE-304EM	Rod 4			261	
TE-309EM	Rod 9			262	
TE-325EM	Rod 25			263	
	LEVEL N				
TE-301FN	Rod 1			264	
TE-304FN	Rod 4			265	
TE-325FN	Rod 25			266	
	LEVEL O				
TE-301FO	Rod 1			267	
TE-304FO	Rod 4			268	
TE-309FO	Rod 9			269	
TE-310EO	Rod 10			270	
TE-312EO	Rod 12			271	
TE-317EO	Rod 17			272	Noisy
TE-318EO	Rod 18			273	
TE-320EO	Rod 20			274	
TE-322EO	Rod 22			275	
TE-323EO	Rod 23			276	
TE-324EO	Rod 24			277	Unpowered rod
TE-325FO	Rod 25			278	
TE-326EO	Rod 26			279	
TE-331EO	Rod 31			280	Noisy
TE-333EO	Rod 33			281	
TE-338EO	Rod 38			282	
TE-339EO	Rod 39			283	Unpowered rod
TE-341EO	Rod 41			284	
TE-349EO	Rod 49			285	
Heater Rod Center					
	LEVEL E				
TE-301ME	Rod 1			286	
TE-304ME	Rod 4			287	
TE-318ME	Rod 18			288	
TE-322ME	Rod 22			289	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
Heater Rod Center (continued)					
	LEVEL E (continued)				
TE-326ME	Rod 26			290	
TE-331ME	Rod 31			291	Spike (small)
TE-338ME	Rod 38			292	
TE-349ME	Rod 49			293	Instrument failed
	LEVEL F				
TE-301MF	Rod 1			294	
TE-304MF	Rod 4			295	
TE-322MF	Rod 22			296	
TE-326MF	Rod 26			297	
TE-338MF	Rod 38			298	
TE-349MF	Rod 49			299	
	LEVEL G				
TE-301MG	Rod 1			300	
TE-310MG	Rod 10			301	
TE-313MG	Rod 13			302	
TE-317MG	Rod 17			303	
TE-318MG	Rod 18			304	
TE-322MG	Rod 22			305	
TE-323MG	Rod 23			306	
TE-325MG	Rod 25			307	Large spike
TE-326MG	Rod 26			308	
TE-338MG	Rod 38			309	
TE-349MG	Rod 49			310	
	LEVEL H				
TE-304MH	Rod 4			311	Small spikes
TE-309MH	Rod 9			312	Small spikes
TE-318MH	Rod 18			313	
TE-322MH	Rod 22			314	
TE-338MH	Rod 38			315	Large spike

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
BUNDLE TEMPERATURE (continued)					
	LEVEL J				
TE-301MJ	Rod 1			31[illegible]	Spikes
TE-310MJ	Rod 10			317	Large spike
TE-317MJ	Rod 17			318	Large spike
TE-323MJ	Rod 23			319	Spikes
TE-324MJ	Rod 24			320	Unpowered rod, spikes
TE-326MJ	Rod 26			321	Spikes
TE-338MJ	Rod 38			322	Small spikes
SPOOL PIECE INSTRUMENTS					
Temperature	Chromel-Alumel thermocouples	+32 to +1897°F	−0.0027 to +0.0400 V		
TE-24	Horizontal inlet			323	Slightly noisy
TE-172	Vertical inlet			324	
TE-222	Vertical outlet			325	
TE-40	Horizontal outlet			326	
Pressure		0 to +3000 psig	0.0 to +5.0 V		
PE-26	Horizontal inlet			366	
PE-174	Vertical inlet			367	
PE-224	Vertical outlet			370	
PE-42	Horizontal outlet			371	
Pressure Drop		−200 to +200 psid	−5.0 to +5.0 V		
PDE-21	Horizontal inlet			396	
PDE-167	Vertical inlet			377	
PDE-217	Vertical outlet			382	
PDE-35	Horizontal outlet			381	
Flow					
FE-19	Horizontal inlet	−2000 to +2000 gpm	−5.0 to +5.0 V	362	
FE-166	Vertical inlet	−2000 to +2000 gpm	−5.0 to +5.0 V	363	
FE-216	Vertical outlet	−2000 to +2000 gpm	−5.0 to +5.0 V	364	
FE-34	Horizontal outlet	−4000 to +4000 gpm	−5.0 to +5.0 V	365	

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
SPOOL PIECE INSTRUMENTS (continued)					
Momentum Flux		-250,000 to +250,000 $lb_m/ft\text{-}sec^2$	-5.0 to +5.0 V		
FMFE-22	Horizontal inlet			391	
FMFE-170	Vertical inlet			392	Zero shifted
FMFE-220	Vertical outlet			393	
FMFE-38	Horizontal outlet			394	Erratic
Fluid Density		0 to +62.4 lb_m/ft^3	0.0 to +10.0 V		
DE-20	Horizontal inlet			468	
DE-168	Vertical inlet			469	
DE-218	Vertical outlet			470	
DE-36	Horizontal outlet			471	
TEST SECTION TEMPERATURE	Chromel-Alumel thermocouples	+32 to +1897°F	-0.0027 to +0.0400 V		
Bundle Shroud					
TE-175	0.142L/LMAX			332	Instrument failed
TE-176	0.142L/LMAX			333	Instrument failed
TE-177	0.142L/LMAX			334	Instrument failed
TE-178	0.142L/LMAX			335	Spike
TE-179	0.388L/LMAX			336	Large spike at power trip
TE-180	0.388L/LMAX			337	Large spike at power trip
TE-181	0.388L/LMAX			338	Large spike at power trip
TE-182	0.388L/LMAX			339	Large spike at power trip
TE-183	0.633L/LMAX			340	Erratic
TE-184	0.633L/LMAX			341	Large spike at power trip, erratic
TE-185	0.633L/LMAX			342	Large spike at power trip, erratic
TE-186	0.633L/LMAX			343	Erratic prior to BD
TE-187	0.875L/LMAX			344	Large spike at power trip, reads high
TE-189	0.875L/LMAX			345	Large spike at power trip
TE-190	0.875L/LMAX			346	Large spike at power trip

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
TEST SECTION TEMPERATURE (continued)					
<u>Bundle Subchannel</u>					
TE-S1	Subchannel 1			480	
TE-S2	Subchannel 2			481	
TE-S3	Subchannel 3			482	
TE-S5	Subchannel 5			483	Instrument failed
TE-S9	Subchannel 9			484	Small spike
TE-S10	Subchannel 10			485	
TE-S11	Subchannel 11			486	
TE-S14	Subchannel 14			487	Instrument failed
TE-S16	Subchannel 16			488	
TE-S33	Subchannel 33			489	
TE-S34	Subchannel 34			490	Instrument failed
TE-S36	Subchannel 36			491	Slightly noisy
TE-S38	Subchannel 38			492	Instrument failed
TE-S39	Subchannel 39			493	
TE-S40	Subchannel 40			494	Noisy
TE-S41	Subchannel 41			495	Noisy
TE-S42	Subchannel 42			496	
TE-S44	Subchannel 44			497	
TE-S45	Subchannel 45			498	
TE-S49	Subchannel 49			499	
TE-S50	Subchannel 50			500	Noisy
TE-S51	Subchannel 51			501	
TE-S54	Subchannel 54			502	
TE-S55	Subchannel 55			503	
TE-S57	Subchannel 57			504	
TE-S59	Subchannel 59			505	
TE-S63	Subchannel 63			506	
TE-S64	Subchannel 64			507	
<u>Test Section</u>					
TE-162	Inlet line T/.			327	Slightly noisy
TE-150	Bottom flange T/C			328	
TE-151	Bottom flange T/C			329	
TE-152	Bottom flange T/C			330	
TE-153	Bottom flange T/C			331	Spike (small)
TE-212	Outlet line T/C			347	
TE-210A	Outlet line RTD (steady state)	+32 to +800°F	+0.2 to +0.52V	409	Spikes

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
TEST SECTION PRESSURE					
PE-156	Inlet plenum	0 to +3000 psig	0.0 to +5.0 V	368	
PE-201	Outlet plenum	0 to +3000 psig	0.0 to +5.0 V	369	
PE-27	Inlet plenum bottom	0 to +3000 psig	0.0 to +5.0 V	398	
PE-43	Outlet plenum bottom	0 to +3000 psig	0.0 to +5.0 V	399	
PT-32	Outlet steady state	+500 to +2500 psig	+1.0 to +5.0 V	401	Zero shifted
TEST SECTION PRESSURE DROP					
PDT-199	Shroud box steady-state differential pressure	0 to +50 psid	+1.0 to +5.0 V	379	
PDE-200	Bundle transient differential pressure	-200 to +200 psid	-5.0 to +5.0 V	380	
PDT-30	Test section steady-state differential pressure	0 to +50 psid	+1.0 to +5.0 V	400	Erratic at blowdown
PRESSURIZER INSTRUMENTS					
<u>Temperature</u>					
TE-1	Tank top T/C	+32 to +1897°F	-0.0027 to +0.0400 V	353	
TE-2	Tank exit T/C	+32 to +1897°F	-0.0027 to +0.0400 V	354	
<u>Pressure</u>					
PT-102	Steady-state pressure	+500 to +2500 psig	+1.0 to +5.0 V	374	Zero shifted
PE-106	Vapor transient pressure	0 to +3000 psig	0 to +5.0 V	375	
<u>Level</u>					
LT-100	Steady-state liquid level	0 to +150 in.	+1.0 to +5.0 V	405	
HEATER ROD POWER					
<u>Heater Current</u>		0 to +800 A	0.0 to +5.0 V		
EIE-11S6	Rod 1			411	
EIE-12S6	Rod 2			412	
EIE-11S7	Rod 3			413	
EIE-12S7	Rod 4			414	
EIE-9S6	Rod 5			415	
EIE-9S8	Rod 6			416	
EIE-9S5	Rod 7			417	

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
HEATER ROD POWER (continued)					
<u>Heater Current</u> (continued)					
EIE-11S5	Rod 8			418	
EIE-11S8	Rod 9			419	
EIE-12S8	Rod 10			420	
EIE-9S7	Rod 11			421	
EIE-9S4	Rod 12			422	
EIE-9S3	Rod 13			423	
EIE-9S11	Rod 14			424	
EIE-11S4	Rod 15			425	
EIE-11S9	Rod 16			426	
EIE-12S5	Rod 17			427	
EIE-9S9	Rod 18			428	
EIE-9S10	Rod 19			429	Unpowered rod
EIE-9S2	Rod 20			430	
EIE-9S12	Rod 21			431	
EIE-11S11	Rod 22			432	
EIE-11S10	Rod 23			433	
EIE-11S3	Rod 24			434	Unpowered rod
EIE-9S13	Rod 25			435	
EIE-10S6	Rod 26			436	
EIE-9S1	Rod 27			437	
EIE-10S7	Rod 28			438	
EIE-11S2	Rod 29			439	
EIE-11S12	Rod 30			440	
EIE-12S2	Rod 31			441	
EIE-12S1	Rod 32			442	
EIE-10S12	Rod 33			443	
EIE-10S5	Rod 34			444	
EIE-10S8	Rod 35			445	
EIE-11S1	Rod 36			446	
EIE-12S4	Rod 37			447	
EIE-12S3	Rod 38			448	
EIE-12S12	Rod 39			449	Unpowered rod
EIE-10S11	Rod 40			450	
EIE-10S10	Rod 41			451	
EIE-10S9	Rod 42			452	
EIE-12S9	Rod 43			453	
EIE-12S10	Rod 44			454	
EIE-12S11	Rod 45			455	
EIE-10S1	Rod 46			456	
EIE-10S2	Rod 47			457	Unpowered rod
EIE-10S3	Rod 48			458	
EIE-10S4	Rod 49			459	

Table 5 (continued)

Measurement	Location and comments	Range: Detector	Range: Data acquisition system	Figure	Measurement comments
GENERATOR POWER					
Generator Current		0 to +10,000 A	0.0 to +5.0 V		
EIE-9	Generator 9 current			460	
EIE-10	Generator 10 current			461	
EIE-11	Generator 11 current			462	
EIE-12	Generator 12 current			463	
Generator Voltage		0 to +285 V	0.0 to +10.0 V		
EEE-9	Generator 9 voltage			464	
EEE-10	Generator 10 voltage			465	
EEE-11	Generator 11 voltage			466	
EEE-12	Generator 12 voltage			467	
HEAT EXCHANGER INSTRUMENTS					
Primary Side	Outlet Line Thermocouples	+32 to +1897°F	-0.0027 to +0.0400 V		
TE-30B	Heat exchanger A			348	
TE-32B	Heat exchanger B			349	Slightly noisy
TE-34B	Heat exchanger C			350	
TE-5B	Heat exchanger D			352	
TE-28B	Main HX mixing tee steady-state temp., RTD	+32 to +800°F	+0.2 to +0.52 V	389	Small spikes
Secondary Side	Secondary discharge steady-state temp., RTD	+32 to +500°F	+0.2 to +0.4 V		
TE-525	Heat exchanger A			408	Slightly noisy
TE-627	Heat exchanger B			383	Small spikes
TE-727	Heat exchanger C			388	Small spikes
TE-557	Heat exchanger D			407	Slightly noisy
Heat Exchanger Secondary Flow					
FE-522	Heat exchanger A	0 to +150 gpm	+0.2 to +1.0 V	406	
FE-620	Heat exchanger B	0 to +150 gpm	+0.2 to +1.0 V	358	
FE-720	Heat exchanger C	0 to +150 gpm	+0.2 to +1.0 V	359	
FE-550	Heat exchanger D	0 to +50 gpm	+0.2 to +1.0 V	360	
Heat Exchanger Pressure					
PE-44	Upstream main HX transient pressure	0 to +3000 psig	0.0 to +5.0 V	372	
PE-526	HX A secondary inlet pressure	0 to +350 psig	0.0 to +5.0 V	395	

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	384	
PDE-46	Main HX bypass transient pressure drop	-200 to +200 psid	-5.0 to +5.0 V	390	
PRIMARY PUMP INSTRUMENTS					
FE-1A	Primary side pump flow	0 to +800 gpm	+1.0 to +5.0 V	361	
PE-76	Pump suction transient pressure	0 to +3000 psig	0 to +5.0 V	373	
PDE-78	Primary pump transient pressure drop	-1000 to +1000 psid	-5.0 to +5.0 V	385	
SE-72	Primary pump speed	+100 to +5400 rpm	0 to +5.0 V	402	
TE-4B	Base primary steady-state temp., RTD	+32 to +800°F	+0.2 to +0.52 V	357	Small spike
PE-16	Downstream HCV-2 transient pressure	0.0 to +3000 psig	0.0 to +5.0 V	397	
PRESSURE SUPPRESSION SYSTEM INSTRUMENTS					
PE-412	Pressure suppression receiver transient pressure	0 to +200 psig	0 to +5.0 V	376	
PE-425	PSS inlet blowdown line transient pressure	0 to +3000 psig	0 to +5.0 V	386	
PE-427	PSS outlet blowdown line transient pressure	0 to +3000 psig	0 to +5.0 V	387	
TE-29	Inlet blowdown plenum T/C	+32 to +1897°F	-0.0027 to +0.0400 V	355	
TE-45	Outlet blowdown plenum T/C	+32 to +1897°F	-0.0027 to +0.0400 V	356	Slightly noisy
DEMINERALIZED WATER SYSTEM					
TE-520B	RBT 4-in. demineralized water header T/C	+32 to +1897°F	-0.0027 to +0.0400 V	351	
TE-615	Demineralized water 6-in. header steady-state temp., RTD	+32°F to +500°F	+0.2 to +0.4 V	378	Spikes
GENERAL INSTRUMENTATION (ELECTRICAL)					
Breakwire Detectors					
XM-4000I	Inlet break	0.0 to +5.0 V	0.0 to +5.0 V	403	
XM-4000O	Outlet break	0.0 to +5.0 V	0.0 to +5.0 V	404	

Table 5 (continued)

Measurement	Location and comments	Range		Figure	Measurement comments
		Detector	Data acquisition system		
GENERAL INSTRUMENTATION (ELECTRICAL) (continued)					
RTD Power					
EIM-1001B	RTD power supply current	2.0 mA	0.400 V	410	Small spikes
Data Acquisition Calibration Signals					
Zero cal. input	Channels 0–127	0.0 mV	0.0 mV	472	
Zero cal. input	Channels 128–255	0.0 mV	0.0 mV	473	
Zero cal. input	Channels 256–383	0.0 mV	0.0 mV	474	
Zero cal. input	Channels 384–511	0.0 mV	0.0 mV	475	
Full-scale cal. input	Channels 0–127	35.00 mV	35.00 mV	476	
Full-scale cal. input	Channels 128–255	35.00 mV	35.00 mV	477	
Full-scale cal. input	Channels 256–383	35.00 mV	35.00 mV	478	
Full-scale cal. input	Channels 384–511	35.00 mV	35.00 mV	479	

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