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APPLICATION OF GAS TRACER TECHNIQUES
TO THE DEFINITION OF REACTOR LEAKAGE FLOW LINES
(Title Unclassified)

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TO THE DEFINITION OF REACTOR LEAKAGE FLOW LINES
(Title Unclassified)

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MASTER

Classification cancelled (or changed to)

by authority of

by

107. C

TIC, date

SEP 11 1975

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ABSTRACT

Feasibility of the gas tracer technique in defining flow directions through a complicated medium such as a reactor is demonstrated and test parameters are defined. Results of nineteen flow tests are presented in which, under steady-state hydrogen flow through the reactor at 300 psia, methane was injected through various interelement probes and sampled downstream of the injectors through other probes. Plots of methane concentrations from these samples versus reactor location are presented. They indicate a generally well-defined radial location of the tracer gas stream centerline at each axial core station. These centerline positions when plotted against axial station show flow directions along the core at the four radii at which injection probes were available. The resulting flowlines are reported and show a generally axial direction at the centerline and 13.5-inch radius but show a multiplicity of flow paths at the 7.5-inch radius. Inflow is indicated by flow lines near the core periphery. Initial efforts to correlate flow line maps with pressure maps are reported with an indication of general agreement between the two.

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I. INTRODUCTION

A. Background

The Phase I Plugged Core Flow Tests (FFL-9) were conducted from March 1964 through August 1964 and successfully completed the test plan set forth in WANL-TNR-095.¹ A report on these tests was published in August 1964.² The first series of the tests were steady-state tests in which reactor inlet pressures were varied over the range of 55 to 700 psia and core pressure drops were varied over the range of 30 to 130 psi to explore the pressure envelope which might be encountered in NRX-A1, A2 and subsequent reactors.³ The second series of tests were conducted at core inlet pressures of 300, 500, and 700 psia and core pressure drops of 50, 90, and 130 psi with induced seal perturbations (vented seal chambers) in successive groups of four seals from the aft end of the core toward the dome end. This seal perturbation series was performed to define the possible areas of aeromechanical instability which might be encountered in the event of seal failure in the lateral support system during full power and reduced power tests of NRX-A reactors. In both of these series, only lateral support leakage, core interelement leakage, and end seal leakage flows were permitted since all main flow passages and coolant channels were plugged. Thus the lateral support and core pressure profiles were established to simulate NRX-A reactor profiles while hydrogen flow consisted of leakage flows only.

The steady-state series provided a consistent set of data for normal, unperturbed reactor operation which mapped the NRX-A fluid flow and mechanical characteristics for the ambient temperature case over a series of twenty-one pressure levels up to a pressure of 700 psia and total leakage flow rates of 0.6 lbm/sec of hydrogen. Tabulated data included pressure profiles in the core and lateral support

system, axial displacement of the core, mechanical stresses in the tie rods and inner reflector, displacement of the lateral support plunger pins, and total leakage flow rates. The seal perturbation series mapped a similar set of data over conditions favoring reduced stability in which bundling pressures on the core were reduced by externally controlling the seal pressure distribution. Additional data included high-speed motion picture coverage of the core support blocks and acceleration of the core support blocks and core support plate. No sustained vibrations were measured during even the most severe of the perturbation tests.

Several more or less tentative conclusions were drawn from the pressure data compiled in the Phase I Plugged Core Tests in the quest for a more thorough understanding of the leakage flow paths in and between the core and lateral support system.² From the close agreement in interelement pressures measured at 45° , 165° , and 285° azimuths all along the length of the core, it was inferred that the core exhibited azimuthal symmetry. Pressure measured just inside the filler strips indicated very little pressure drop between the seal chambers and the outer periphery of the core. The generally concave-upwards shape of the pressure versus radius profiles in the upper and central areas of the core with core pressures lower than seal pressures at a given level showed a high degree of inward pressure bundling and what might be characterized as a condition favorable to inflow from the seals. The profiles in the aft area of the core exhibited a downward concave shape with core pressures higher than corresponding seal pressures indicating some tendency to broom outward and a condition favorable to outflow from the core and the seals. Finally, there was some indication of radial communication between interelement channels throughout the core.

Both the mechanical and pressure data obtained in the steady-state series correlated well with theoretical predictions of reactor behavior especially in the lateral support system.² It was found that reasonable agreement could be obtained

between experimental data and theoretical predictions of interelement pressures if the following theoretical model were assumed:² continuously tapered interelement gap (0.5 mils at dome end to 1.5 mils at nozzle end), radial communication, and hydrogen diffusion. Although it was not possible to separate and measure the various leakage flow rates independently, the measured total leakage rate could be predicted to within 20% by the theoretical model.

B. Definition of Problem

The fluid flow analyses and experimental conclusions noted above were based on the pressure data obtained experimentally from probes between elements and in the seal chambers. As noted, only total leakage flow was measured in each test so that component leakage flows could only be estimated from other tests or from theoretical models. Much of the justification for the analytical predictions as well as for the conclusions derived from experimental data were based on important assumptions regarding the basic nature of the flow through the core. The analytical program for interelement pressure distribution assumed azimuthal symmetry in the core and assumed a pre-determined distribution of interelement gap sizes. Experimental conclusions were based on the assumption that the core can be considered to exhibit sufficient radial and azimuthal communication between interelement channels so that the overall flow characteristics are those of a more or less homogeneous medium. This characteristic would be in contrast to the opposite case in which each channel behaves as an independent flow channel with little or no inter-channel flow. The real case is probably a combination of the two extremes. The problem is, basically, the determination of which extreme more nearly approximates actual reactor behavior.

If the core can be considered to be homogeneous as to transport properties, then it should be possible to use the pressure profiles to map the isobars or lines of constant pressure at a given core cross section (taken along a given azimuth). Then

from a fluid flow analysis, flow lines or streamlines might be considered to be perpendicular to the isobars. Such maps were drawn for more or less typical runs in an attempt to define flow lines. Although some consistency was obtained which appeared to provide reasonable clues as to the flow directions, other observations were less easily understood theoretically. For example, the shape of the isobars near the core periphery indicated, again, a condition favorable to inflow from the seals. However, some of the runs showed "islands" or enclosed areas of constant pressure which would indicate a flow "sink" at that location. Flow from the sink would then have to take place in a third dimension (say, diffusion into an element flow hole) away from the given azimuthal cross section to provide continuity of flow. This is, of course, quite possible but difficult to describe based on the sparsity of pressure probes available.

The description of streamlines was, therefore, left to a more positive experimental observation and the tracer gas technique was chosen as the tool.

C. Objective

Based on the above noted uncertainties, the Plugged Core Tracer Gas Tests were designed with the following major objectives:

- 1) to develop gas tracer techniques which might be used in a general way to solve complicated flow problems, and
- 2) to employ these techniques to describe or "map" the leakage flow paths throughout the plugged core reactor (ND 20702).

D. Status of Test

The experimental techniques required for controlled, measured injection of tracer gas and consistent acquisition of samples have been established. Injection and sampling rates, sample times, and other parameters have been optimized. The low pressure core mapping series is nearly complete. This report includes a review of all tests performed prior to May 14, 1965. Additional tests at 300 psia to

corroborate the results obtained in these tests, a limited series of 700 psia core mapping tests, and a final analysis of the results will be presented in a final report to follow the completion of the test program.

II. EXPERIMENTAL

A. Test Model

The test model employed in the tracer gas test series is the ND 20701, or Plugged Core Reactor modified to permit the injection and sampling of a tracer gas at various points in the core, above the core, at the core outlet, and in the seal chambers. The reactor, as modified, is designated as ND 20702. It is housed in a pressure vessel fabricated in accordance with the Pennsylvania Code for Unfired Vessels⁴ and the assembly is located in Test Cell A at the Westinghouse Astronuclear Hydrogen Experimental Facility (WANHEF) facility as shown in Figures 1 and 2.

The ND 20702 is generally typical, mechanically speaking, of NRX-A reactor designs through NRX-A2 (ND 10201).^{5,6,7} It consists of a full core sub-assembly of Oak Ridge Y-12 uncoated, unfueled, graphite elements; an inner reflector fabricated from H4LM graphite and reimpregnated with a silica dispersion after final machining; a core support plate; perforated core support ring; dome end leaf seal; nozzle end "W" seal; aluminum barrel; lateral support system of plunger pins, leaf springs, and seal segments; filler strips and pyrotile; core band; interlocking core support blocks; tie rods; and related hardware. Figures 3, 4, and 5 show the components included in the core subassembly.

The ND 20702 includes several modifications to the basic NRX-A design typical of ND 10101 and ND 10201 for one or more of the following reasons:

Figure 1

Plugged Core Reactor and Pressure Vessel

Figure 2

Test Model and Experimental Hardware

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Figure 3
Core Assembly

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Figure 4

Inner Reflector Assembly

Figure 5

Core Subassembly

- 1) to reduce hydrogen flow requirements of the tests and thereby to permit testing within the capabilities of the WANHEF flow system,
- 2) to permit a more precise study of leakage flows and their effect on reactor pressure profiles, mechanical stability, and other operating characteristics,
- 3) to reduce overall cost by eliminating components of the complete reactor which are not essential to the accomplishment of test goals, and
- 4) to permit injection and sampling of a tracer gas at points throughout the core and lateral support system.

Aside from the injector and sampling probe installation, the design modifications in the ND 20701 and ND 20702 pertinent to the Plugged Core Tracer Gas Tests may be summarized by the following:

- 1) Substitution of a stainless steel support assembly for the complete outer-reflector control drum assembly.
- 2) Plugging of all main propellant flow channels in the elements and inner reflector and around the tie rods.⁸
- 3) Substitution of an aluminum dome and external flow control loop to simulate the upper aluminum shield and screen.
- 4) Installation of additional pressurizer probes in the inner reflector to permit remote control of seal pressures.
- 5) Installation of 37 interelement pressure probes in the core as well as accelerometers and other special instrumentation necessary for the test series.

The internal instrumentation in the ND 20702 consists of the sensors necessary to monitor 16 seal chamber pressures; core inlet and core outlet pressures; core

interelement pressures at three azimuthal, five axial, and four radial stations; mechanical strain in the core support ring, fuel elements, tie rods, and inner reflector; temperatures in the core and lateral support system; axial displacement of the core from the support plate; relative displacement of the inner reflector and lateral support plunger pins; acceleration of the core support blocks and core support plate; and sound pressure in the core inlet and outlet plenums. Figures 6, 7, 8, 9, and 10 and Table I give the tabulated sensor lists and locations in the reactor.

Several modifications were made on the ND 20701 reactor to provide the tracer gas injection and sampling capability of the ND 20702. Seven injector probes were installed along the 45° azimuth radius approximately every 2-inches from the core centerline to the core periphery. These injectors pass through the pressure vessel instrumentation ring and down through coolant holes in the core support plate to a termination about 1/2-inch above the core. At the aft end of the core seven sampling probes were installed along the same azimuth and at the same radius locations as the above core injector probes. These aft end sampling probes pass through the flange of the vessel in the outlet plenum and terminate at a point about 1/4-inch from the core support blocks. Table II gives the locations of these probes fore and aft while Figures 11 and 12 show the probes as installed in the reactor.

In addition to the core inlet and core outlet probes, interelement and seal probes were installed to permit either injection or sampling of tracer gas. The existing interelement and seal pressure probes were modified by teeing into the lines that pass down through the core support plate or ring and into the core or seals. Figure 13 schematically illustrates this modification. The lines through which tracer gas injection or sampling is accomplished pass through the vessel instrumentation ring as in the case of other in-core probes and sensor leads. This ring is shown in Figure 12. Table I lists the locations of the in-core pressure injector-sampling probes.

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Figure 6

Core Support Plate Instrumentation

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STRAIN GAGE LOCATIONS IN INNER REFLECTOR
AND CORE SUPPORT RING

GAGE NO.	θ DEGREES	R INCH	L INCH
S-401	109	18.9	-4.0
S-402	109	19.8	-2.1
S-403	109	20.0	-1.7
S-404	109	18.7	-4.0
S-405	109	19.6	-2.1
S-406	109	19.8	-1.7
S-407	109	20.4	-0.9
S-408	109	20.1	-0.9
S-421	30	19.9	6.9
S-422	30	19.9	
S-423	30	19.9	23.7
S-424	30	19.9	24.2
S-425	30	19.9	40.6
S-426	30	19.9	41.1
S-435	150 Lateral Support Springs		8.6
S-437	150 Lateral Support Springs		19.8
S-439	150 Lateral Support Springs		31.1
S-442	150 Lateral Support Springs		47.9
S-443	270 Lateral Support Springs		8.6
S-444	270 Lateral Support Springs		19.8
S-445	270 Lateral Support Springs		31.1
S-446	270 Lateral Support Springs		42.3
S-447	50 Lateral Support Springs		14.2
S-448	50 Lateral Support Springs		25.4
S-449	50 Lateral Support Springs		36.7
S-450	50 Lateral Support Springs		47.9

NOTES

R = radius to strain gage

L = location of gage measured from forward edge of inner reflector. L is positive when measured toward the aft direction.

Figure 7

Strain Gage Instrumentation on Inner Reflector Assembly

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PRESSURE PROBE LOCATIONS IN
 INNER REFLECTOR

PROBE NO.	θ DEGREES	L INCH
DP-401	163	7.2
DP-402	277	12.8
DP-403	43	18.4
DP-404	173	24.0
DP-405	293	29.6
DP-406	53	35.3
DP-407	157	40.9
DP-408	283	46.5
DP-409	73	9.47
DP-410	97	15.6
DP-411	113	21.2
DP-412	187	26.8
DP-413	217	32.5
DP-414	307	38.1
DP-415	353	43.7
DP-416	7	6.34
DP-417	67	Thru

NOTES

L = Location of probe measured from forward edge of inner reflector. "L" is positive when measured toward the aft direction.

Figure 8

Pressure Instrumentation on Inner Reflector Assembly

THERMOCOUPLE LOCATIONS IN INNER
REFLECTOR AND CORE SUPPORT RING

GAGE NO.	θ DEGREES	R INCH	L INCH
T-401	70	19.9	6.4
T-402	70	19.2	6.6
T-403	70	19.9	17.8
T-404	70	19.2	17.8
T-405	70	19.9	29.1
T-406	70	19.2	29.1
T-407	70	19.9	45.9
T-408	70	19.2	45.9
T-421	250	19.8	8.6
T-423	250	19.8	42.3
T-437	262	19.5	-2.5
T-438	262	20.4	-0.64
T-447	230	seal chamber	10.4
T-448	230	seal chamber	16.0
T-449	230	seal chamber	21.6
T-450	230	seal chamber	27.2
T-451	230	seal chamber	32.9
T-452	230	seal chamber	38.5
T-453	230	seal chamber	44.1
T-454	170	seal chamber	7.2
T-455	170	seal chamber	29.6
T-456	170	seal chamber	40.9
T-457	50	seal chamber	18.4
T-458	50	seal chamber	35.3
T-459	290	seal chamber	46.5
T-460	290	seal chamber	24.0
T-461	290	seal chamber	12.8
T-462	10	seal chamber	4.3
T-475	50	18.7	53.7
T-478	170	18.7	53.7
T-481	290	18.7	53.7

NOTES

R = radius to instrument

L = Location of instrumentation measured from forward edge of inner reflector. The positive direction of L is taken as measuring towards the aft direction.

Figure 9

Thermocouple Instrumentation on Inner Reflector Assembly

Figure 10

Core Identification Convention for NRX-A Reactors

Figure 11

Core Outlet Sample Probes

Figure 12

Core Inlet and In-Core Probes

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Figure 13

Modified In-Core and Seal Probes

Table I
 Summary of Core Instrumentation

Instrument Designation	Location of Core Instrumentation					Type of Sensor
	Cluster Assembly Element & Hole #	Face of Element	Length from Top of Fuel ¹ (inches)	Approximate Radius (inches)	Approximate Azimuth (degrees)	
DP704	0-00-D-13	C	+ 7.16	0	-	Differential Pressure
DP706	1-04-D-13	C	+ 7.16	7.5	45	Differential Pressure
DP707	3-04-D-13	C	+ 7.16	7.5	165	Differential Pressure
DP708	5-04-D-13	C	+ 7.16	7.5	285	Differential Pressure
DP709	3-J7-K-18	D	+ 7.16	17.5	165	Differential Pressure
DP710	5-J7-K-18	D	+ 7.16	17.5	285	Differential Pressure
DP741	1-07-D-13	C	+ 7.16	13.5	45	Differential Pressure
DP746	1-06-K-2	A	+ 7.16	17.5	45	Differential Pressure
DP711	1-04-D-7	P	+ 18.40	7.5	45	Differential Pressure
DP720	0-00-D-7	P	+ 18.40	0	-	Differential Pressure
DP742	3-04-D-7	P	+ 18.40	7.5	165	Differential Pressure
DP730	5-04-D-7	P	+ 18.40	7.5	285	Differential Pressure
DP742	3-J7-K-16	E	+ 18.40	17.5	165	Differential Pressure
DP762	1-07-D-7	P	+ 18.40	13.5	45	Differential Pressure
DP716	1-04-G-13	C	+ 29.65	7.5	45	Differential Pressure
DP724	3-04-G-13	C	+ 29.65	7.5	165	Differential Pressure
DP732	5-04-G-13	C	+ 29.65	7.5	285	Differential Pressure
DP740	1-J6-P-18	D	+ 29.65	17.5	45	Differential Pressure
DP743	0-00-G-13	C	+ 29.65	0	-	Differential Pressure
DP741	5-J6-P-18	D	+ 29.65	17.5	45	Differential Pressure
DP742	1-07-G-4	B	+ 29.65	13.5	45	Differential Pressure
DP718	1-04-G-7	F	+ 40.90	7.5	45	Differential Pressure
DP726	3-04-G-7	F	+ 40.90	7.5	165	Differential Pressure
DP734	5-04-G-7	F	+ 40.90	7.5	285	Differential Pressure
DP736	0-00-G-7	P	+ 40.90	0	-	Differential Pressure
DP738	1-J7-K-18	D	+ 40.90	17.5	45	Differential Pressure
DP741	3-J6-H-18	D	+ 40.90	17.5	165	Differential Pressure
DP742	5-J6-H-18	D	+ 40.90	17.5	285	Differential Pressure
DP744	1-07-G-13	C	+ 40.90	13.5	45	Differential Pressure
DP767	1-J6-H-2	A	+ 40.90	17.5	45	Differential Pressure
DP719	1-04-G-4	B	+ 46.52	7.5	45	Differential Pressure
DP727	3-04-G-4	B	+ 46.52	7.5	165	Differential Pressure
DP735	5-04-G-4	B	+ 46.52	7.5	285	Differential Pressure
DP737	1-J7-K-16	E	+ 46.52	17.5	45	Differential Pressure
DP747	0-00-G-4	B	+ 46.52	0	-	Differential Pressure
DP748	5-J7-K-16	F	+ 46.52	17.5	285	Differential Pressure
DP765	1-07-G-7	F	+ 46.52	13.5	45	Differential Pressure
T720	-	Core Inlet Plenum		14.8	0	Thermocouple
T726	-	Core Inlet Plenum		14.8	120	Thermocouple
T730	-	Core Inlet Plenum		14.8	240	Thermocouple
T732	1-E5-B-7	Core Exit	+ 54.7	8.5	45	Thermocouple
T735	3-E5-B-7	Core Exit	+ 54.7	8.5	165	Thermocouple
T739	5-E5-B-7	Core Exit	+ 54.7	8.5	285	Thermocouple

Table I (Continued)
 Summary of Core Instrumentation (Continued)

Instrument Designation	Location of Core Instrumentation					Type of Sensor
	Cluster Assembly Element & Hole #	Face of Element	Length from Top of Fuel ¹ (inches)	Approximate Radius (inches)	Approximate Azimuth (degrees)	
T710	3-J9-U-13	C	+ 14.5	17.0	180	Thermocouple
T711	5-J9-U-13	C	+ 42.0	17.5	300	Thermocouple
T712	5-EL-A- 1	A	+ 25.8	8.5	285	Thermocouple
T713	3-J9-R-18	D	+ 25.8	15.5	180	Thermocouple
T714	3-J9-W-18	C	+ 3.2	16.0	180	Thermocouple
T715	3-J9-V- 4	B	+ 50.8	16.0	180	Thermocouple
T716	4-J9-T-18	D	+ 8.6	17.5	0	Thermocouple
T717	2-J9-T-18	D	+ 19.8	17.0	120	Thermocouple
T718	4-J9-T-18	D	+ 47.9	17.0	300	Thermocouple
S709	5-EL-E-17	C	+ 26.5	8.5	285	Strain Gage
S710	5-EL-F- 1	A	+ 26.5	8.5	285	Strain Gage
S712	5-EL-C- 3	F	+ 26.5	8.5	285	Strain Gage
S715	5-EL-C-19	D	+ 26.5	8.5	285	Strain Gage
S726	5-EL-A- 9	E	+ 26.5	8.5	285	Strain Gage
S728	5-EL-F- 2	A	+ 3.9	8.5	285	Strain Gage
S732	5-EL-F-13	C	+ 3.9	8.5	285	Strain Gage
S735	5-EL-C- 7	F	+ 3.9	8.5	285	Strain Gage
S739	5-EL-C-18	D	+ 3.9	8.5	285	Strain Gage
S740	5-EL-A- 3	B	+ 26.5	8.5	285	Strain Gage
S774	5-J7-F- 2	A	+ 3.9	17.0	285	Strain Gage
S775	5-J7-F- 1	A	+ 26.5	17.0	285	Strain Gage
S776	5-J7-F-17	D	+ 3.9	17.0	285	Strain Gage
S777	5-J7-F-13	C	+ 26.5	17.0	285	Strain Gage
S757	2-B1-A	Tie Rod	- 5.0	4.0	45	Strain Gage
S758	2-B1-A	Tie Rod	- 5.0	4.0	45	Strain Gage
S760	2-G1-A	Tie Rod	- 5.0	14.5	45	Strain Gage
S760	2-G1-A	Tie Rod	- 5.0	14.5	45	Strain Gage
S761	4-B1-A	Tie Rod	- 5.0	4.0	180	Strain Gage
S762	4-B1-A	Tie Rod	- 5.0	4.0	180	Strain Gage
S763	3-JC-A	Tie Rod	- 5.0	15.5	180	Strain Gage
S764	3-JC-A	Tie Rod	- 5.0	15.5	180	Strain Gage
S765	5-B2-A	Tie Rod	- 5.0	4.0	285	Strain Gage
S766	5-B2-A	Tie Rod	- 5.0	4.0	285	Strain Gage
S767	5-G7-A	Tie Rod	- 5.0	13.0	285	Strain Gage
S768	5-G7-A	Tie Rod	- 5.0	13.0	285	Strain Gage
G707	6-H5-C-13	C	+ 53.8	14.0	330	Accelerometer
G708	0-00-F-16	E	+ 53.8	0	-	Accelerometer
G709	0-00-B-16	E	+ 53.8	0	-	Accelerometer
G710	4-G2-G- 2	A	+ 53.8	12.0	180	Accelerometer
G711	4-H5-C-13	C	+ 53.8	14.0	210	Accelerometer
G712	4-H3-G- 2	A	+ 53.8	14.0	315	Accelerometer

NOTE: 1. Positive sign indicates that measurement is from top of fuel toward aft end.
 Negative sign indicates that sensor is located above core (i.e. forward).

Table II

Location of Core Inlet and Core Outlet Probes

Probe Designation	Azimuth $\ominus$	Radius (From Centerline) R, Inches	Axial Location (From Top of Core) L, Inches
I 301	45°	- 1.75	- 0.5
I 302	45°	1.75	- 0.5
I 303	45°	4.13	- 0.5
I 304	45°	6.88	- 0.5
I 305	45°	10.13	- 0.5
I 306	45°	13.00	- 0.5
I 307	45°	15.38	- 0.5
ST 301	45°	- 1.75	54.5
ST 302	45°	1.75	54.5
ST 303	45°	4.13	54.5
ST 304	45°	6.88	54.5
ST 305	45°	10.13	54.5
ST 306	45°	13.00	54.5
ST 307	45°	15.38	54.5

B. Hydrogen Flow System

The flow loop used for supplying and controlling the flow of hydrogen gas to and from the test model was designed to provide sufficient flexibility to fulfill the requirements of present and future test plans as well as to insure maximum safety to operating personnel and to preclude damage to any part of the test reactor. With these considerations in mind, the flow system illustrated by Figure 14 was designed and fabricated in the test cell at the Waltz Mill Hydrogen Experimental Facility (WANHEF).

The flow system consists, basically, of:

- 1) high pressure gaseous hydrogen supply,
- 2) test model piping and controls,
- 3) seal pressurization piping and controls,
- 4) low pressure gaseous nitrogen supply,
- 5) system evacuation piping and controls, and
- 6) vent system.

The 2400 psig gaseous hydrogen supply system consists of either a 20,000 SCF storage sphere or one or more commercial tube trailers of 60,000 SCF to 115,000 SCF capacity. The storage sphere is used for high flow rate, short duration runs; whereas, the trailers, either individually or in parallel, are used for low and intermediate flow rate, long duration runs. Both supplies are controlled by remotely actuated valves backed up by manually-operated, positive shut-off valves.

The inlet piping to the test model consists of a parallel bank of diaphragm-actuated pressure control valves (PCV-1, PCV-1A, and PCV-1B) and related instrumentation as well as an orifice meter for flow measurement. The high-pressure diaphragm valves are of four capacities to permit a precise control of flow over a relatively wide range of conditions (0 to 2 lb/sec of gaseous hydrogen at 70°F).

Figure 14

Plugged Core Flow Test Flow Diagram

These valves regulate the vessel inlet pressure which is sensed and transmitted to a proportional-plus-reset pressure controller, the output of which actuates the valve. The orifice meter consists of a square-edged orifice, differential pressure transmitter, and a strip chart flow recorder. Pressures from the orifice taps and the vessel inlet are transmitted pneumatically to the receiver units located in the control room. The core outlet loop and dome bleed loops are essentially the same as the inlet loop insofar as control action and flow measurement are concerned. In each case, the valves (PCV-3 and PCV-2) are used as back pressure regulators to control the pressure at the core outlet and at the lateral support inlet.

The seal pressurization system, used to regulate individual seal chamber pressures, consists of a remotely actuated pressure reducing valve (PCV-5) and sixteen pressure regulating valves. These valves regulate downstream pressure by either supplying gas or venting gas from the seal chamber so as to maintain a balance between the pre-set actuator pressure and the pressure downstream of the valve. The actuator pressure is applied manually from the control room.

The nitrogen storage and supply systems provide low pressure (100 psig) gaseous nitrogen for process instrumentation and controls and for purging the test model, flow system, and vent stacks. Liquid nitrogen from a 2400 gallon dewar is vaporized in two air-heated plate heat exchangers and is controlled by remotely actuated valves.

Safety considerations dictated the use of an adequate venting system and evacuation system. The vent system consists of vent stacks located on the inlet and outlet piping. Safety relief valves and rupture discs are located at several places in the inlet piping. They are designed to vent the entire storage capacity of hydrogen without increasing the pressure more than 10 percent above a maximum operating pressure of the system of 790 psig. A vent flare on the main effluent stack is used to burn the hydrogen during a test. In order to eliminate all oxygen from the system

prior to operation with hydrogen, a 212 CFM vacuum pump is used to evacuate the test model and flow system to a pressure of 1.0 millimeter of mercury absolute. Vent stacks are continually purged with nitrogen to prevent the ignition of a hydrogen-air mixture prior to flaring.

The subsystems of the flow system are integrated through control consoles located in the test control room. Figure 15 illustrates the consoles. The inclined panel is the main control console and contains the actuator switches for all remote control valves, cameras, data acquisition equipment, flare igniters, vacuum pump, and flow controls. Each switch is part of an overall electrical interlock network designed for maximum safety to personnel and equipment. For example, hydrogen flow cannot be started until several electrical interlocks are satisfied. These verify that the system has been evacuated and purged, that cell ventilating fans are on, that all interconnecting valves to the nitrogen system are closed, and that all electrical equipment in the cell has been disconnected. When these and other interlocks are satisfied, the test can proceed through the actuation of the hydrogen supply valve switch.

Figures 16, 17, and 18 show various portions of the basic hydrogen and nitrogen flow systems.

C. Injection and Sampling System

The tracer gas injection and sampling systems were designed to provide controlled, measured injection of the methane tracer gas at various points in the reactor over a range of flow rates from 1×10^{-5} lb/sec to 0.2 lb/sec and to control the sampling rates of hydrogen-methane mixtures from reactor probes to a value approximating single channel core flow rates. Figure 19 shows the flow diagram for the injection and sampling systems.

Figure 15

Flow System Control Consoles

Figure 16

Tank Farm Area at WANHEF

Figure 17

Inlet Piping and Controls

Figure 18

Outlet Piping and Primary Control Elements

Tracer Gas Injection and Sampling Flow Diagram

Figure 19

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Methane flow from the high-purity methane manifold in the tank farm is controlled first by a pressure regulator in the manifold and finally by one of three diaphragm control valves (PCV-7, PCV-7A, or PCV-7B) depending on the flow rate required in the test. Methane flow rate is monitored on a pneumatic flow recorder which receives a signal from a differential pressure transmitter across an orifice meter. Very low injection rates are monitored by a heated thermopile mass flow meter. The flow rate is controlled by a pressure-recorder-controller which maintains a constant pressure in the injection manifold prior to entry into the reactor pressure vessel. Some of these components can be seen on Figures 20 and 21 which shows the front and rear of the injection and sampling panel.

The sampling network was designed to provide the maximum experimental flexibility commensurate with cost and installation time. Thus it provides for sampling from as many as 40 reactor probes either simultaneously or at three successive times through an electrical selector panel. Flexible tubing is used to connect a given reactor probe to one or more 300 c. c. stainless steel sample cylinders. By such a "patch-panel" arrangement, any reactor probe can be routed to any sample cylinder and sampled on demand at any of three successive times during the test.

The flow rates from the reactor probes are controlled by small sonic orifices. Three, six, and nine mil diameters are available. During a test a purge flow is established from the reactor to the sample acquisition cylinders to insure that the steady-state concentration in the reactor is also present at the sample cylinder inlet. This flow, as well as flow to the vent and to the sample cylinder vacuum manifold, is controlled by solenoid valves connected through the sample selector panel to the control console in the control room.

Samples of methane-hydrogen mixtures acquired during the tests are taken from the sample cylinders through plug-in couplings on the panel and passed through a hydrocarbon analyzer. The analyzer is a flame ionization type which burns the

Figure 20

Front View of Injection and Sampling Panel

Figure 21

Rear View of Injection and Sampling Panel

methane-hydrogen mixture and produces a millivolt signal that is proportional to the carbon content of the mixture. This signal is either read on a direct reading meter or sent to a recorder for remote monitoring.

D. Data Acquisition and Reduction

The data acquisition capability at WANHEF was designed to provide a complete multichannel record of experimental flow tests as well as a quick-look record of many of the important parameters required both for process control and for rapid post-test evaluation of the adequacy and validity of the tests. The quick-look capability includes pneumatic pressure-recorder-controllers employed in the flow control system, DC voltmeters used in the seal pressurization system, recording oscillograph, pneumatic flow recorders, and stereo tape recorders. FM/FM telemetry, FM wideband, and high-speed motion pictures are used as a more permanent record of the major portion of the test data.

The system is housed in the WANHEF control room about 150 feet from the test cell. Figure 22 shows those portions of the system not included in the main control consoles. On the right are two 14-channel Consolidated Electrodynamics Corporation tape recorders. A panel of voltage controlled oscillators (VCO) in the adjoining console provide the variable frequency input to the recorders which is proportional to the variable voltage fed into the oscillators from the DC amplifiers on the far left panel. Two racks of strain gage conditioning modules adjacent to the VCO's provide the excitation voltage as well as calibration and bridge completion resistors to the strain gages located in the test model. Other equipment includes a time code generator, charge amplifier system for the piezoelectric accelerometers, stereo tape recorder for recording test narration and acoustic level in the reactor, and two 24-channel Honeywell recording oscillographs.

Figure 22

Data Acquisition System

Expansion of the data handling capability from the 24 channels available on the two tape decks to 98 data channels is made possible through the use of FM/FM telemetry techniques. Data is recorded in multiplexed form so that each tape channel records five data channels. This is accomplished by using individual FM carriers for each of the five data channels. The five data channels are mixed with a 100 KC tape speed compensation signal and fed into the direct-record electronics of the tape recorders. The individual FM carrier frequencies selected are 22, 30, 40, 52.5, and 70 KC. Each carrier has a uniform $\pm 7\frac{1}{2}\%$ full scale deviation giving a variable intelligence bandwidth of 330 to 1050 cps. The use of these carriers and deviations corresponds to the IRIG (Inter Range Instrumentation Group) channels 14 through 18. This convention was adopted to be compatible with the NRDS FM/FM system.

The primary quick-look records used for rapid evaluation of a test and for control of test parameters are the pressure controller-recorders and flow recorders used in the flow system. These instruments give continuous time traces of pressure and flow conditions in the test model and flow system. In addition to these, the 24-channel recording oscillographs provide post-test evaluation data as well as a method of continuously monitoring dynamic displacement, pressure, strain, and acceleration measurements. The sixteen DC voltmeters can also be employed as a quick-look capability during the test. These meters give a continuous indication of the output of seal chamber pressure transducers.

The reduction of quick-look data is straight forward. Data on FM wideband channels is played back directly on the oscillograph and values are scaled off the charts. Flow recorder and pressure recorder charts can also be read directly. Voltmeter indications are read directly during the test. The reduction of FM/FM data is somewhat more involved. The variable frequency data on each channel is played back through a discriminator system which filters and separates the five

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multiplexed data channels and puts out a variable millivolt signal proportional to the frequency. The discriminator output is recorded on an oscillograph and values are scaled off the traces. Final reduction of the oscillograph readings and computing, compiling, and plotting of pressure, strain, and other data is accomplished by IBM 7094 computer using programs written for the Plugged Core Tests.

E. Test Operation

1. Experimental Technique

One of the primary objectives of these tests was to establish and optimize the experimental techniques required for meaningful use of the tracer gas in defining leakage paths in a complicated, labyrinth-like flow model. Much of the initial effort was directed toward this goal and was concerned with solving the control problems and measurement problems anticipated in the experimental design as well as several problems which unexpectedly appeared during the check-out phase of the experiments.

Controlling methane flow rate at the extremely low flows on the order of 1×10^{-4} lb/sec was the first problem encountered. When the pressure drop across the control valves approached the critical pressure ratio for sonic flow, the resulting temperature drop in the methane stream caused sporadic liquification, and control under these conditions was impossible. Control valves were subsequently re-sized to be used at lower pressure drops and a pressure regulator was installed upstream of the control valve to provide flexibility in attaining flows over a broad range.

Measurement of the low injection flow rates was initially a problem because of the lack of suitable commercial meters for the continuous remote monitoring of such flows at pressures up to 700 psia. A series of small square-edged orifices were designed and built to provide this capability. Both 20

and 25 mil diameter orifices were used in these tests with a 100-inches of water differential pressure transmitter to send a signal to the remote recorders. The orifice sections were designed for quick assembly into a 1/4-inch line.

The most unexpected and, perhaps, most critical problem encountered in establishing experimental techniques was a phenomenon observed during the analysis of methane-hydrogen mixtures from the stainless steel sample cylinders used for sample acquisition. At low methane concentrations, (and at higher concentrations, although less prominently) it was observed that when the sample was first admitted to the analyzer from the cylinders a low concentration was indicated, but as the sample continued to be fed into the analyzer the apparent concentration rose steadily. Following a complete check of the meter and analyzer with no indication of malfunctioning, a test program was initiated to determine how the sampling cylinders themselves could be influencing the concentrations obtained in the analysis.

It was hypothesized that the methane was being selectively adsorbed on the walls of the stainless steel sample cylinders at the sample acquisition pressures of about 200 psia and then slowly desorbed as the sample pressure was being reduced by the transfer of the gases from the cylinder to the analyzer. Several sample cylinders were given pre-treatments as follows:

- a) A fresh, unused cylinder was filled during an actual reactor test with an unknown methane-hydrogen mixture.
- b) A fresh, unused stainless cylinder was untreated and used as a control.
- c) A cylinder was filled with a 100 ppm methane in hydrogen mixture, allowed to stand for 12 hours, and subsequently, evacuated for two hours at 0.1 mm Hg absolute.

- d) A cylinder was filled with a 100 ppm methane in hydrogen mixture, allowed to stand for 12 hours, and subsequently purged with nitrogen and evacuated to 0.1 mm Hg for about 5 minutes.

Except for cylinder (a) above, the pretreated cylinders were filled with a gas of known composition: 11.3 ppm methane in hydrogen. Figure 23 shows the resulting concentration versus time curves obtained during the analysis of the mixtures from these cylinders. The only cylinder which gave a constant, time-independent analysis was the cylinder which was pre-conditioned with methane and not subsequently evacuated for a long period.

Although these experiments were not extensive enough to support the hypothesis of selective adsorption conclusively, the results and the hypothesis mechanism did agree. Based on the fact that adequate results were obtained with cylinders pre-treated with methane and not subsequently "re-activated" by evacuation at low pressures for long periods, the investigation was not carried further. The test procedures were then revised to include this pretreatment and eliminate the evacuation. The analyses obtained from all tests after this revision in procedures were steady-state analyses and did not exhibit the time-dependent concentration profiles noted above.

It would appear that if the selective adsorption mechanism is correct, then the pretreatment with methane coats the walls of the cylinder with a thin layer of physically adsorbed molecules which will not desorb under any but severe conditions of high vacuum for long periods. The adsorbed layer then prevents the further adsorption of methane.

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Figure 23

Effect of Sample Cylinder Pretreatment on Gas Analysis

2. Test Procedures

A typical experiment is conducted basically as follows:

- a) All flow systems are checked for proper operation and control and measurement instruments are calibrated prior to test.
- b) Reactor is evacuated and purged with nitrogen twice to remove air from the system.
- c) All data acquisition equipment is calibrated and set up for proper gain, excitation voltage, center frequency, and other pre-run operational standards.
- d) All safety devices are checked for proper functioning.
- e) All data acquisition equipment is started.
- f) Gaseous hydrogen flow from the high pressure supplies is established to the reactor. Inlet pressure and core outlet pressure are placed on automatic control and maintained at prescribed values.
- g) All hydrogen flow controls and data acquisition equipment are checked for proper functioning at the prescribed control points.
- h) Methane flow from the high pressure source is established through the control valve and the secondary shut-off solenoid valve and is placed on automatic control at the prescribed flow rate.
- i) At the attainment of steady-state operation in both the hydrogen and methane systems the following sequence is performed:
 - 1) Time is marked.

- 2) Purge flow from the reactor probes to the vent system is established through the sample vent solenoids to insure that the concentration at the sample cylinders is the same as that in the core.
- 3) Evacuation of sample cylinders is initiated through the vacuum solenoids.
- j) After a pre-determined purging time, the evacuation of sample cylinders is stopped and simultaneously the sample solenoids are opened to establish flow into the cylinders. Sample cylinder pressure is monitored remotely during sample acquisition.
- k) Upon completion of sample acquisition methane flow is stopped by closing the sample solenoid and control valve.
- l) Normal shutdown procedure is assumed following a final check on the adequacy of all control points and data acquisition:
 - 1) Hydrogen supply valves are closed.
 - 2) Reactor and flow system are vented to atmospheric pressure.
 - 3) All data acquisition equipment is turned off.
- m) System is purged, evacuated, and secured, and data acquisition system post-test calibration is recorded.
- n) Samples acquired during the test are analyzed for methane concentration using the flame ionization hydrocarbon analyzer.
- o) FM multiplex data is played back on oscillograph for data reduction.

A more detailed check list and operation procedure is included in the Appendix for reference.

III. RESULTS

A. Parameter Optimization

The variables associated with a controlled experiment such as the tracer gas tests can be predicted to some extent from theoretical calculations and prior test data. Test conditions must ultimately be optimized experimentally. This is difficult and inefficient using the one-at-a-time experimental approach in which all variables but one are held constant while the one is varied over a specified range and its effect noted. This approach generally requires a prohibitive number of tests and, more important, it fails to indicate interacting effects of two or more parameters varying simultaneously. A more precise, efficient, and far reaching approach is an experimental design in which the important parameters are varied over pre-selected levels. By examining the dependent variables of interest, the main and secondary interaction effects of the independent variables can be ascertained by an analysis of variance technique.⁹

The above approach was employed in optimizing test parameters according to the following logic:

- 1) All the variables which could be assumed to have any effect on the outcome of the tests were listed.
- 2) Based on assumed physical and theoretical models and on past experience with the Plugged Core Reactor, the effect of each variable was described to the degree possible from existing knowledge.

- 3) Variables which were to be held constant for the entire series and which were known to have an insignificant effect on reactor flow profiles were eliminated.
- 4) The variables which were considered critical to the outcome of the test were assigned ranges of values calculated from knowledge of reactor flows.
- 5) An experimental design was written to include the critical parameters.
- 6) Optimum levels for parameters were selected on the basis of measurement of the dependent variable in the designed experiments and on the basis of other factors observed during these experiments.

The independent variables selected as "critical" parameters were methane injection rate, sampling rate (sonic orifice size), core inlet pressure, time of sample acquisition (i. e. purge time from reactor probe to vent prior to sampling) measured from attainment of steady-state flow in the core, and radial and axial location of injector and sampling probes. The dependent variable was the location of the centerline of the tracer gas streamline at each axial location in the core at the 45° azimuth. This variable was, in fact, calculated graphically from plots of methane concentration versus sample probe location. Variables which were assumed to be constant were core inlet temperature, core outlet temperature, and core pressure drop.

The experiment to optimize these variables for the remaining core mapping test series was designed according to Table III which also lists the test numbers for each set of conditions tested. R_o in the table is the radial centerline location of the tracer gas stream. The given design applies to each of the six axial core stations, L , at which R_o was measured. Underlying the design was the assumption that all of the probes were equivalent from the point of view of injection and its effect on the

Table III

Experimental Design for Parameter Optimization

		Injection Rate r_1 , lb/sec 1.5×10^{-4}	Injection Rate r_2 , lb/sec 3.0×10^{-4}	Injection Rate r_3 , lb/sec 6.0×10^{-4}
Sampling Orifice O_1 .003"	Sample Time, t_{s1} 60 sec.	$R_o(111)$ FFL-17-6	$R_o(211)$ FFL-17-5	$R_o(311)$ -----
	Sample Time, t_{s2} 120 sec.	$R_o(112)$ FFL-17-6	$R_o(212)$ FFL-17-5	$R_o(312)$ -----
	Sample Time, t_{s1} 60 sec.	$R_o(121)$ FFL-17-9	$R_o(221)$ FFL-17-11	$R_o(321)$ FFL-17-7
	Sample Time, t_{s2} 120 sec.	$R_o(122)$ FFL-17-9	$R_o(222)$ FFL-17-11	$R_o(322)$ FFL-17-7

Table IV
Results of Experimental Design Tests

			r_1 1.5×10^{-4} lb/sec	r_2 3.0×10^{-4} lb/sec	r_3 6.0×10^{-4} lb/sec
L_3 18.4"	O_1 .003"	$t_{s_1} = 60 \text{ sec.}$	13.5	13.5	----
		$t_{s_2} = 120 \text{ sec.}$	13.5	13.5	----
	O_2 .009"	$t_{s_1} = 60 \text{ sec.}$	13.5	13.5	13.5
		$t_{s_2} = 120 \text{ sec.}$	13.5	13.5	13.5
L_4 29.7"	O_1 .003"	$t_{s_1} = 60 \text{ sec.}$	13.0	13.5	----
		$t_{s_2} = 120 \text{ sec.}$	13.5	13.5	----
	O_2 .009"	$t_{s_1} = 60 \text{ sec.}$	13.5	13.5	13.5
		$t_{s_2} = 120 \text{ sec.}$	13.5	13.5	13.5
L_5 46.5"	O_1 .003"	$t_{s_1} = 60 \text{ sec.}$	13.0	14.5	----
		$t_{s_2} = 120 \text{ sec.}$	13.0	14.5	----
	O_2 .009"	$t_{s_1} = 60 \text{ sec.}$	12.0	13.5	13.5
		$t_{s_2} = 120 \text{ sec.}$	11.8	13.5	13.5

Continued on Next Page

Table IV (Continued)

Results of Experimental Design Tests (Continued)

			r_1 1.5×10^{-4}	r_2 3.0×10^{-4}	r_3 6.0×10^{-4}
L_6 46.5"	O_1 .003"	$t_{s_1} = 60 \text{ sec.}$	12.8	15.0	----
		$t_{s_2} = 120 \text{ sec.}$	12.8	13.5	----
	O_2 .009"	$t_{s_1} = 60 \text{ sec.}$	13.5	13.0	13.5
		$t_{s_2} = 120 \text{ sec.}$	12.0	13.0	13.5
	O_1 .003"	$t_{s_1} = 60 \text{ sec.}$	----	----	----
		$t_{s_2} = 120 \text{ sec.}$	11.4	11.4	----
L_7 54.5"	O_2 .009"	$t_{s_1} = 60 \text{ sec.}$	----	----	----
		$t_{s_2} = 120 \text{ sec.}$	11.8	11.6	11.6

other variables. This made it possible to complete the design using only one typical injector probe rather than to study the variables over all of the twenty-seven core probes available for injection.

The 300 psia level design was completed with the results shown in Table IV. These are tracer gas stream centerlines taken from curves such as Figure 24 at the various axial stations. Tabulated data and curves for the entire series appear in Appendix A. The analysis of variance for this data showed no significant main effects or interactions between injection rate, time, or sampling orifice at stations 7.2, 18.4, or 54.5. A quick review of Table IV would result in the same conclusions based on the apparently good agreement in R_o at all levels of these variables.

One may notice that at stations 40.9 and 46.5 the variation in R_o values is more obvious. The analysis of variance shows a significant effect of injection rate and sampling orifice size at the 40.9-inch station at the 95% probability level (that is, the conclusion of "significance" of an effect could be incorrect 5% of the time due to chance errors). At the 46.5-inch station, in spite of the obvious variability of the data no main effects or interaction effects were significant. The reason for this is the high random "error" variance which makes the estimation of small effects less precise. Finally, the analysis of variance shows a significant effect of length (core station) at all injection rates. This means, basically, that even with the given variability of the data, it is still possible to detect changes of direction of the streamline.

Except for the effects noted at station 40.9, the experimental design did not point toward a well defined optimum set of conditions for running the tests. Of course, a larger range of levels for each of the variables would eventually show significant effects, but the ranges used were selected on the basis of design data from previous Plugged Core Tests. Therefore, based on these results, the data was reviewed for other indications of optimum ranges for the parameters.

Figure 24

CH₄ Concentration Profiles for Test FFL-17-5

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Even though injection rate did not effect the measurement of R_o , it was noted that higher injection rates gave much better stream centerline definition. The methane concentrations for the high injection rates were higher and analyses were more consistent. In addition peak centerline concentrations relative to concentrations at other points off the centerline were much higher. It was found that injection flow rates of at least 1×10^{-4} lb/sec were necessary to give adequate streamline definition but that flow rates in excess of 3.0×10^{-4} lb/sec did not improve the R_o definition. Several of the early tests were conducted at about 3×10^{-4} lb/sec injection rate. During these tests several of the pressure transducers on the injection probes were damaged. Considering this damage and the fact that core pressure perturbations would be less likely at lower methane rates, an optimum flow rate of 1.6×10^{-4} lb/sec methane was selected.

Sampling rate also was found not to effect the R_o determinations; and therefore, based on the fact that the large sonic sample orifices gave shorter sample acquisition times and more efficient use of hydrogen (shorter duration tests), the larger 9 mil orifices were selected for use during the early tests. With the reduction of pressure data it was found that the 3 mil orifices and lower sampling rates, as in the case of injection rates, gave more consistent core pressures with less likelihood of core pressure perturbations. The 3 mil orifices were subsequently selected for use in all sample probes.

Sample acquisition times of 60 and 120 seconds also gave similar results for R_o measurement. The consistency of measured concentrations at each probe was much higher for the longer times since longer purge times assured a steady-state concentration of sample gas from the probe to the sample cylinder inlet. The sampling time of 120 seconds after steady-state conditions were attained in the reactor was selected as optimum for the remaining tests at 300 psia.

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Except for the general effects of sampling and injection on interelement pressure measurements noted above, no conclusive results were obtained which describe the degree of flow disturbance in the core due to injection or sampling. The analog records taken before and after the initiation of injection showed no pressure disturbances in probes adjacent to the injector probe. The injector probe pressure did indicate some perturbation but this was, to a great extent, due to the fact that injection flow was taking place against the low pressure side of the differential pressure transducers prior to entry into the interelement channel. Analog records taken during and prior to sample acquisition showed that sampling causes some degree of pressure perturbation. This again was due, to a large extent, to the fact that sampling also was taking place from the low pressure side of the differential pressure transducers used in measuring interelement pressures. Additional analysis as well as an experimental program to define the degree of flow disturbance, if any, are under way and will be reported in the final report for the test series.

B. Core Mapping

Following the determination of optimum ranges for critical test parameters, "mapping" of core flow lines using the tracer gas technique was begun. Methane was injected at fifteen of the nineteen available in-core probe locations and at one of the above-core locations. Forty samples were acquired for each test during the steady-state conditions of hydrogen flow rate, methane flow rate, and core pressures. Figures 25 and 26 are cross sectional diagrams of the reactor showing the locations of probes used for this injection and sampling. Pressures throughout the core and lateral support system and both hydrogen and methane flow rates were also recorded for all tests. Each of these important results will be discussed in turn.

1. Concentration Profiles

The concentration of the samples acquired from each reactor probe was measured by a hydrocarbon analyzer and plotted versus radial and axial

Figure 25

Location of Injection and Sampling Probes for the Core

Figure 26

Location of Injection and Sampling Probes for the Seal Chambers

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position in the core. Figures 27, 28 and 29 showing the profiles of the 45° azimuth in the reactor are typical curves obtained in this manner. The remaining curves appear in Appendix A.

The concentrations read on the hydrocarbon analyzer were accurate to within 2% of full scale reading at about a 95% probability level (two standard deviations) as specified by the manufacturer and as verified by tests with gases of known composition. Other errors could be responsible for some additional inaccuracy. These errors might include the presence of carbon containing materials in the sample cylinders or transfer lines, some inconsistency due to occasionally inadequate purging of sample cylinders, and other unknown variables. These errors are estimated to be less than 5% at the 95% probability level. The important thing to notice here is that analyzer error itself is constant at each level of concentration. This is made possible by the fact that an attenuation switch is available on the analyzer to keep a constant millivolt output from the analyzing circuit regardless of the range of concentrations being analyzed. The significance of this fact is that the concentrations plotted on the curves shown in Figures 27 to 29 and in the Appendix have about the same accuracy at concentrations approaching 3000 ppm as those at 1 ppm and lower. (Note that 3000 ppm is the maximum measurable concentration with the available analyzer.)

The curves faired through the four radial points at each axial position are not analytically fitted curves. Rather they were drawn as a best estimate of the actual profile assuming that some type of exponential function such as the Gaussian probability distribution describes the actual physical model. Although an attempt at defining an analytical model for curve fitting the experimental data should be made, it appears doubtful that the estimate of tracer gas stream centerline would be substantially improved. The reason for this is the sparsity of probes available at each axial level. With only

Figure 27

CH_4 Concentration Profiles - FFL-17-11

Figure 28

CH_4 Concentration Profiles - FFL-17-12

Figure 29

CH_4 Concentration Profiles - FFL-17-13

four experimental points it would be possible to fit not one but many theoretical curves. Of course the same consideration holds true for the faired curves; that is, with only four points available many such curves could be drawn. In arriving at the best fit curves presented here, many possible curves were drawn for each set of data points and the one chosen as "best fit" was the one which not only provided the smoothest fit but which also had the characteristics of being logical and consistent with the large body of data obtained throughout the tests.

Based on the analysis of variance performed on the experimental design and on a realistic estimate of the error inherent in the drawing of these smoothed curves, the best estimate of the standard deviation of R_o is about 0.5-inch. Therefore, the prediction of R_o values as given on the curves and in the summary tables can be expected to be accurate to within ± 1.0 -inch at the 95% probability level (two standard deviations). Note that this value is an average value for the entire series taken over every axial and radial position in the reactor. The estimates of individual value for R_o may vary by ± 2.0 -inches or more depending on the location downstream of the injector probe.

2. Pressure Profiles

Pressures were measured at each of the in-core probes shown on Figure 25, on the seal probes shown on Figure 26, and at the core inlet and outlet. A tabulation of this data appears in Appendix B. The core interelement pressures were measured by differential pressure transducers some of which are located in the inlet dome of the pressure vessel and others of which are external to the vessel. Core inlet and outlet pressures were measured by strain gage pressure transducers, by "Heise" test gages accurate to about $\pm 1/2\%$ of full scale, and by the pressure transmitter-recorder

combinations used for flow control. Seal pressures were measured by differential pressure gages and by differential pressure transducers.

The pressure sensors in the ND 20702 reactor are arranged in such a fashion that all pressures are referenced against the core inlet pressure. The seal chamber pressure sensors are connected in series or in groups of two to four in parallel so that no individual sensor is subjected to a pressure over the full range of 50 psi differential. All these sensors are referenced to the core inlet pressure. The interelement sensors from one axial level are referenced to the corresponding seal chamber at that level through a manifold. The above explanation is included here to point out that, although there is some advantage to inter-referencing pressures in this way (viz. over-range protection of sensors and comparison of sensors at one axial location against a common source), there is the disadvantage that errors can become additive in the calculating process.

As discussed in a previous report on Plugged Core Tests,² the sources of error in addition to actual sensor error are:

- a) Calibration of amplifiers and other transmitting elements of the data acquisition system.
- b) Calibration of recording and playback equipment in the tape recorders.
- c) Calibration of FM multiplex playback discriminators.
- d) Calibration of recording oscillographs used in data playback.
- e) Reading error inherent in the scaling of values from the oscillograph traces.

For the data here presented, the total effect of such errors at the 95% probability level or two standard deviations is estimated to be as follows:

Core Inlet Pressure	- 2% of Indicated Value
Individual Seal Pressures	- 2% of Indicated Value
Individual Core Interelement Pressures	- 10% of Indicated Value

All of the tests in the present series were conducted at a nominal core inlet pressure of 300 psia and a nominal core pressure drop of 130 psi. The seal pressure distributions calculated for these runs are typical of the results for test FFL-17-5 shown in Figure 30. The profiles are also typical of these obtained in previous tests with the Plugged Core Reactor.² Figure 31 is a plot of the non-dimensional seal pressure distribution based on the theoretical fluid flow model and the actual dimensions of the ND 20702 reactor.² The points superimposed on the theoretical curve are from a typical tracer gas test (FFL-17-17). Note that the deviations from the curve are practically negligible.

A typical core interelement pressure distribution is plotted radially in Figure 32, showing data for the core probes in test FFL-17-5 projected onto one azimuthal plane. These profiles are, again, typical of the kind of profiles which have previously been observed for the Plugged Core Reactor. The sharp decrease in pressure from the seal chambers to the 13.5 and 7.5-inch radii indicate a condition favorable for radial inflow through the filler strips. The characteristic rising pressure gradient near station 46.5 is, as before, conducive to radial outflow near the aft end of the core. Fluid bundling pressures, tending to be directed in a direction from high to low pressures, would be radially inward between the periphery and the 7.5-inch radius and radially outward at some axial locations from centerline to the 7.5-inch radius. These observations should be kept in mind when we review the flow line results in a later section.

Figure 30

Seal Pressure Profile - FFL-17-5

Figure 31

Non-Dimensional Seal Pressure Distribution

Figure 32

Core Interelement Pressures - FFL-17-5

Because the entire series of tracer tests performed thus far were conducted at the same nominal inlet pressure and core pressure drop, a non-dimensional or normalized core interelement pressure distribution could be drawn with considerably more accuracy than was heretofore possible. Figures 33 and 34 are curves for radial and axial core interelement profiles for normalized data from nine tests. These are: FFL-17-11, 15, 16, 17, 18, 19, 20, 21 and 22. The detailed tabulations and calculated normalized pressures appear in Appendix B. The non-dimensional pressure is defined as core interelement pressure minus core outlet pressure divided by core pressure drop. Agreement among the nine runs was relatively good as indicated by the deviation of individual values on the curves. The mean standard deviation for the entire plot is 0.09 or about 9%. This takes into account variation between tests, azimuthal variation, and random error.

An initial attempt at cross-plotting the normalized profiles to obtain an isobar map of the core for the 300 psia series is shown in Figure 35. The curves are shown for illustrative purposes only since much of the associated analysis has not yet been accomplished. They illustrate the general shape of such curves and point out more graphically the above noted observations concerning the conditions favorable to inflow or outflow. For if we can consider the core as exhibiting a sufficient degree of homogeneity through radial and azimuthal communication, then flow lines can be considered to be perpendicular to the isobars at all points. Several of these flow lines are sketches on the isobar contours to illustrate general anticipated flow paths.

The streamlines, not drawn on the map, would be inward at the core periphery and generally axial over the top half of the core. Near the "sink" at the 40-inch core station flows would be more complex but would generally be flowing into and around the 0.1 normalized pressure line in that area. Since the given isobars are a cross section of a three dimensional plot, the sink is analogous to the top of a mountain cut off by a plane. Azimuthal

Figure 33

Normalized Core Interelement Pressure Profiles (Radial)

Figure 34

Normalized Core Interelement Pressure Profiles (Axial)

Figure 35

Isobar Map of Core

flow or flow into the element channel by diffusion or through a pin hole, might explain the existence of this enclosed isobar.

One must apply these techniques with full realization of the great uncertainties inherent in the isobaric plots. These are, briefly:

- a) Lack of sufficient pressure data radially and axially which necessitated large interpolations of the data.
- b) Lack of definition or basic knowledge of the critical aft end of the core with its rising pressure gradient.
- c) Inaccuracy inherent in making the two dimensional representation or projection of the three dimensional flow patterns in the reactor.
- d) Lack of sufficient azimuthal probes to more nearly approximate the azimuthal variations in pressure.

3. Flow Rates

The primary interest in monitoring flow rates during the tests was to insure that the reactor operation was stable and to insure that its behavior did not vary from test to test. Flow rate measurement has been found to be highly sensitive to changes in reactor pressure profiles and is, therefore, a reliable indicator of uniformity of operation. The data summarized in Table V indicate that the stable, uniform operation from test to test was, indeed, attained. The methane mass flow balance was not attained for most of the tests because of an erroneous sampling procedure. The sample probe was moved to a point where a well mixed sample could be acquired and the resulting data are given for tests FFL-17-20, 21 and 22. The hydrogen flow balance is within 1.5% while the methane balance ranged from deviations of 2 to 20%. Part of the error in the methane balance is probably due to the sampling procedure which is still not completely adequate because of incomplete mixing.

Table V
 Summary of Flow Rate Data for Tracer Gas Tests

Test Number	Core Inlet Pressure psia	Core Pressure Drop psi	Core Inlet Temperature °F	Core Outlet Temperature °F	Core Inlet Flow Rate lb/sec	Core Outlet Flow Rate lb/sec	CH ₄ Inlet Pressure psia	CH ₄ Inlet Temperature °F	CH ₄ Flow Rate lb/sec x 10 ⁴	CH ₄ Outlet Concentration	
										Measured ppm	Calculated ppm
FFL-17-5	298	139	37	60	.346	.348	302	44	2.91		
FFL-17-6	300	130	40	51	.332	.333	258	51	1.71		
FFL-17-7	297	128	28	52	.353	.352	324	47	6.15		
FFL-17-9	305	132	55	59	.344	.340	234	63	1.06		
FFL-17-10	300	122	55	63	.344	.344	273	59	1.06		
FFL-17-11	291	117	71	75	.320	.316	299	71	2.92		
FFL-17-12	294	125	67	71	.349	.336	404	71	3.06		
FFL-17-13	299	130	67	70	.340	.335	394	71	3.53		
FFL-17-15	299	130	60	66	.340	.338	414	61	3.10		
FFL-17-16	307	138	60	66	.340	.338	334	62	3.11		
FFL-17-17	304	137	55	65	.350	.344	274	61	1.71		
FFL-17-18	297	129	49	62	.325	.317	224	63	1.58		
FFL-17-19	299	133	64	63	.342	.343	277	68	1.60		
FFL-17-20	299	127	60	64	.334	.341	374	69	1.89	70	91
FFL-17-21	301	133	53	64	.350	.341	235	58	1.54	55	64
FFL-17-22	298	131	44	62	.350	.341	239	58	1.71	63	64

4. Flow Lines

The concentration versus radial location curves provided an estimate of the tracer gas stream centerline as noted above. Table VI summarizes the R_o data obtained in this way, and also lists the test conditions as to injection and sampling. The reader is again referred to Figures 25 and 26 and Table I for locations of the various injection and sampling probes. Note that in Table VI, the first R_o value in each row is the location of the injector probe. For example, DP 761 is located at the 13.5-inch radius, 7.2-inches from the top of the core. Therefore, for test FFL-17-5 the first R_o given is 13.5.

The data from Table VI are plotted as direction of flow curves on Figures 36, 37, and 38. Figure 36 shows the flow lines for the tests in which injection took place at centerline or the 13.5-inch radius. There appear to be rather well-defined flow lines at both of these locations, especially at the 13.5-inch radius. This would explain why the analysis of variance for the previously discussed experimental design at the 13.5-inch radius did not show many significant effects such as injection or sampling rate effects. The somewhat larger variation at stations 40.9 and 46.5 also corroborate those results since the only effects noted were at these locations.

The flow lines at the 7.5-inch radius are shown on Figure 37. Here the good agreement ends, and it appears that we apparently are observing a multitude of flow lines which vary between tests at the same or at differing injector positions. A number of conclusions might be drawn, but one must be cautious of oversimplification. For example, it is possible that flow lines may be affected by the "ground" state of the core, that is, by the stacking position the elements assume when the flow (friction) and pressure loads of the previous tests are removed. There is no concrete proof of this assertion

Figure 36

Flow Lines for Injection on Centerline and 13.5-Inch Radius

Figure 37

Flow Lines for Injection on 7.5-Inch Radius

Figure 38

Flow Lines for Injection on or Near 17.5-Inch Radius

Table VI
Summary of Results for Tracer Gas Tests

Test Number	Nominal Core Inlet Pressure, psia	Injection Rate, lb/sec x 10 ⁴	Injection Mode	Injection Probe	Sample Orifice Size, Mils	Tracer Gas Stream Centerline R _o at Elevation, L, in Inches						
						- 0.5	7.2	18.4	29.7	40.9	46.5	54.5
FFL-17-5	300	2.91	In-Core	DP 761	3		13.5	13.5	13.5	14.5	13.5	11.4
FFL-17-6	300	1.71	In-Core	DP 761	3		13.5	13.5	13.5	13.0	12.8	11.4
FFL-17-7	300	6.15	In-Core	DP 761	3		13.5	13.5	13.5	13.5	13.5	11.6
FFL-17-9	300	1.06	In-Core	DP 761	9		13.5	13.5	13.5	11.8	12.0	11.8
FFL-17-10	300	1.06	In-Core	DP 705	9		7.5	7.5	12.8	11.2	11.6	12.0
FFL-17-11	300	2.92	In-Core	DP 761	9		13.5	13.5	13.5	13.5	13.0	11.6
FFL-17-12	300	3.06	In-Core	DP 705	9		7.5	7.5	7.5	6.5		
FFL-17-13	300	3.53	In-Core	DP 704	9							1.2
FFL-17-15	300	3.10	In-Core	DP 766	9		17.5	(16.0)	10.0	11.5	15.0	17.5
FFL-17-16	300	3.11	In-Core	DP 720	9							1.2
FFL-17-17	300	1.71	In-Core	DP 714	3			7.5	10.4	9.6	12.6	7.0
FFL-17-18	300	1.58	In-Core	DP 762	3			13.5	13.5	13.5	13.5	11.5
FFL-17-19	300	1.60	In-Core	DP 743	3						4.0	
FFL-17-20	300	1.89	In-Core	DP 716	3				7.5	7.5	14.0	16.0
FFL-17-21	300	1.54	In-Core	DP 763	3				13.5	13.5	13.5	10.6
FFL-17-22	300	1.71	In-Core	DP 740	3				17.5	13.5	13.5	13.5
FFL-17-23	300	(1.6)	In-Core	DP 738	3					17.5		14.2
FFL-17-24	300	(1.6)	In-Core	DP 764	3					13.5	13.5	11.0
FFL-17-26	300	(1.6)	In-Core	DP 738	3					17.5		14.2
FFL-17-28	300	(1.6)	Above Core	I 307	3	15.4		(15.0)	(12.5)	12.8	14.6	

() indicates estimated values.

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here, however. One might assume that the lines never really attain a steady-state position during a test but, instead, slowly traverse a given area so that the position measured is a function of time. The good agreement between sample times of 60 and 120 seconds obtained in the experimental design tests tend to refute this argument.

What we are trying to illustrate is the fact that it is probable that many factors influence these flow lines because the core is not ideally homogeneous and because the plotting of curves in two dimensions as we have done is a gross oversimplification, the only justification for which is the fact that no other more meaningful presentation is possible with the few probes available. These lines, it must be remembered, are really projections of the real flow lines onto the 45° azimuth plane shown in Figures 36, 37, and 38. Thus crossing of "lines" is really possible since the flow can move off the 45° azimuth plane into a different azimuthal plane. All we observe is the projection of the line insofar as we are able to distinguish concentration peaks from the data. Figure 39 is a good illustration of this point. These curves are concentration profiles which show values of concentration at three planes - the 45° , 165° , and 285° azimuths - projected onto one plane. Note that along with the characteristic profiles on the 45° azimuth there is also a similar and higher peak for the 285° azimuth at stations 29.7 and 40.9 whereas there is no such peak for the 165° azimuth. This is a strong indication of a certain amount of flow peripherally from the 45° azimuth to the 285° azimuth. A three dimensional model would be required to describe the phenomenon fully.

Figure 38 shows the flow lines for the 17.5-inch radius, and for the one test in which injection took place over the core. The inflow from the core periphery is apparent, although the outflow at the aft end of the core is not conclusively demonstrated.

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Figure 39

Concentration Profiles at Three Azimuths - FFL-17-12

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A review of the isobar and flowline data in Figures 40 and 35 can now be made, if again, we consider carefully the uncertainties. The inflow from the periphery in the top 40-inches of the core is indicated by both the isobaric and flowline maps, through perhaps the flowline maps indicate a less severe inflow. Centerline streamline is generally axial on the flow line maps. This would also be expected from a consideration of the isobars since the slope of the isobars at the centerline must be zero to be continuous with isobar projections on other azimuthal planes. The isobar maps are relatively flat at the top of the core at radius 7.5 and would indicate a generally axial flow direction as is illustrated by the flow maps. In addition, the isobar slopes at 7.5 begin to change to a positive value at lower axial positions indicating a flow outward, a condition substantiated by flow line maps. Experimental flow lines are shown flowing into and out of the sink region, a situation which is not compatible with the theoretical flow lines unless we assume that flow is actually occurring on azimuthal planes adjacent to the 45° plane. Finally, the isobars at the 13.5-inch radius show a condition very favorable for inward flow, a situation with which the flow maps do not agree.

In summary, both the flow lines and the isobar maps indicate general trends of inflow and outflow, and if allowance is made for the uncertainties involved in making the isobaric and flow line plots based on the sparsity of probes available, show some general agreement. A great deal of additional work, including replications of these tests, must be done before more definite conclusions can be drawn, especially in the lower portions of the core.

IV. SUMMARY AND CONCLUSIONS

A. Experimental Techniques

The feasibility of gas tracer techniques for following flow lines and determining leakage flow paths and direction of flow in a complicated mechanical

Figure 40

Flow Line - Isobar Maps of Core

system such as a reactor was adequately demonstrated. Experimental techniques were developed and optimum test parameters were defined.

B. Core Mapping

A series of tracer tests was successfully completed in which methane was injected at a controlled, measured rate through probes at various core interelement locations and sampled through other probes downstream of the injector. These samples were analyzed for methane content and the resulting concentrations were plotted versus axial and radial core position to give generally well defined tracer gas stream centerline locations. These locations were assumed to be given by points of maximum concentration on these profiles. Core interelement pressures and both methane and hydrogen flow rate were also recorded for each test.

C. Flow Lines

From the concentration profiles noted above, tracer gas stream centerline radial locations were plotted versus core station or distance from the top of the core at the four radial locations for which probes were available: centerline, 7.5-inches, 13.5-inches, and 17.5-inches. These plots showed the direction of flow as a projection on the 45° azimuth from the point of injection to the core outlet. At centerline and the 13.5-inch radius, a well-defined axial streamline was observed. At the 7.5-inch radius, a multiplicity of streamlines was observed depending on injector location and other as yet undefined factors. Since the flow directions "seen" by the probes on the 45° azimuth were in reality projections of lines in other nearby planes, it is possible that the lines observed at this radius were actually flowing in a peripheral direction in some areas of the core. Corroborating data for this assertion was presented which showed other "peak" concentrations on the 285° azimuth as well as on the 45° azimuth. Finally, flow lines near the periphery of the core indicated the existence of inflow from the lateral support system as previously predicted by pressure profile data.²

D. Comparison of Isobars and Flowlines

Analysis of the data continues with the goal of attempting to correlate flow maps with isobar maps showing lines of constant core pressure at a given cross section. To illustrate this technique, an isobar plot of the core was presented using mean normalized pressures calculated from nine tests. The difficulty in drawing such a map from the very few pressure measurements available and the concomitant uncertainties were pointed out. Nevertheless, some agreement between the two maps was observed particularly in the indications of radial inflow near the periphery.

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APPENDIX A

CH₄ CONCENTRATION PROFILES AND DATA TABULATIONS

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Table VII
 Detailed Concentration Data Compilation

Sample Probe	5	5a	6	6a	7	7a	9	9a	10	10a	11	11a	12
Core Inlet	0.50		1.58		0.80		0.30		0.40		0.68		0.80
Core Inlet													
Core Outlet	60		101		133		28.0		26.0		119.0		42.0
Core Outlet	63		101		135		28.0		26.5		120.0		
DP 720	1.30	1.10	5.30	4.90	3.30	1.60	0.60	0.45	1.70	1.00	5.80	2.40	0.98
DP 714	1.90	1.20	6.20	6.20	2.70	2.10	1.00	0.80	3000+	3000+	3.20	2.30	3000+
DP 762	3000+	3000+	3000+	3000+	3000+	3000+	50.0	22.0	4.60	4.00	3000+	3000+	17.7
DP 743	1.80	1.80	8.30	6.20	1.50	1.40	0.80	0.68	0.60	0.50	0.95	1.10	0.88
DP 716	1.10		1.00	7.70	1.00	0.80	0.60	0.50	0.60	0.45	1.02	0.85	130
DP 763	22	3000	155	3000+	180	212	2.10	1.10	0.50	4.20	165	150	
DP 740		1.20	2.80	2.80	0.80	1.40	0.45	0.42	0.35		0.81	1.00	0.85
DP 736	2.00	1.20	8.20	6.30	1.00	1.00	0.55	0.38		0.45	1.25	0.72	1.38
DP 718	2.80	2.10	8.70	7.00	1.00	0.90	0.60	0.60	0.50	0.55	1.50	0.80	4.90
DP 764	7.90	11.0	24.5	23.0	243	240	0.65	0.95	0.60	0.60	145	148	0.89
DP 738	6.00	6.00	5.40	4.10	0.80	0.70	0.40	0.40	0.40	0.40	0.80	0.68	0.58
DP 747	0.70	0.70	7.80	6.30	0.90	0.80	0.30	0.38	0.32	0.39	0.65	0.62	0.50
DP 719	2.40	1.50	7.30	6.40	0.80	0.60	0.28	0.25		0.41	0.79	0.65	0.50
DP 765	3.00	2.70	11.0	9.00	2.90	2.70	0.52	0.65	0.60	0.60	1.20	1.05	0.58
DP 737	4.20	2.50	8.40	6.40	1.20	0.80	0.42	0.35	0.50	0.42	0.75	0.68	0.75
ST 301													41.0
ST 302	23.5		97.0		39.0		8.10		8.80		36.0		39.0
ST 303	18.5		87.0		32.0		7.00		7.40		31.0		29.0
ST 304	20.0		94.0		40.0		9.00		9.30		39.0		48.0
ST 305	31.0		360		1000		76.0		9.80		960		41.0
ST 306	131		200		890		90.0		11.0		860		48.0

Table VII (Continued)

Sample Probe	5	5a	6	6a	7	7a	9	9a	10	10a	11	11a	12
ST 307	17.0		62.0		93.0		7.80		8.00		82.0		37.0
DP 403													
PP 403													
DP 411													
PP 411													
DP 404													
PP 404													
DP 412													
PP 412													1.22
DP 405													
PP 405													
DP 413													
PP 413													1.10
DP 406													0.70
PP 406													
DP 414													0.70
PP 414													
DP 407													
PP 407													0.78
DP 415													0.80
PP 415													
DP 408	6.0		10.0		1.4		0.72		0.80				
PP 408													
DP 708													
DP 706													

Table VII (Continued)

Sample Probe	5	5a	6	6a	7	7a	9	9a	10	10a	11	11a	12
DP 742													
DP 722													0.86
DP 724													1.35
DP 741													0.95
DP 726													1.50
DP 727													1.35
DP 709													
DP 707													
DP 730													1.10
DP 751													
DP 732													31.0
DP 746													1.47
DP 734													38.0
DP 748													
DP 735													0.82
DP 416													
PP 416													
DP 401													
PP 401													
DP 409													
PP 409													
DP 402													
PP 402													
DP 410													
PP 410													

Table VII (Continued)

Sample Probe	13	15	16	17	18	19	20	21	22	23	24	26	28
Core Inlet	0.58	0.48	0.32	4.80	2.75	11.3	0.80	0.41	0.47	3.10	2.10	2.50	1.00
Core Inlet										2.50	1.60	3.20	
Core Outlet	52.0	42.0	53.0	1100	158	244	91.0	63.0	60.0	72.0	71.0	65.0	
Core Outlet					160	86.0	83.0	65.0	69.0	72.0			
DP 720	3000+	17.2											191
DP 714	5.1	21.8	74.0										152
DP 762	19.2	42.0	33.5										395
DP 743	760	18.8	3000+	110	5.00								248
DP 716	2.32	30.5	41.0	270	6.70								300
DP 763		10.0		175	2750								
DP 740	0.88	3.80	1.62	9.80	8.00								15.0
DP 736	3000+	13.2	3000+			2850		1.27					162
DP 718	2.40	22.5	36.0	280	6.70	72.0	3000+	1.00	0.60				208
DP 764	2.35	34.0	23.5	105	3000+	10.0	1.85	3000+	1.40				320
DP 738	1.86	18.0		13.6	4.40	24.0	1.70	1.40	0.48				152
DP 747	1.82	8.80	17.0	13.8	3.50	50.0	1.45	0.48	0.40	1.60	11.0	1.70	119
DP 719	1.75	9.10	14.8	15.2	3.50	51.0	1.15	0.42	0.42	3.20	3.00	4.00	88.0
DP 765	2.05	32.5	23.8	120	8.00	14.8	1.65	3000+	1.40	2.00	1620	1.50	300
DP 737	1.50	17.8	21.0	21.0	3.90	30.0	1.75	0.90	0.45	2.20	1.70	1.70	148
ST 301	125	65.5	73.0	79.0	29.0	92.0	34.0	25.0	27.0	32.5	29.0	35.0	80.0
ST 302	730	60.5	227	78.0	23.0	81.0	30.0	20.5	21.0	26.5	25.0	27.0	105
ST 303	185	54.5	104	95.0	21.0	58.0	29.0	16.3	18.0	22.3	22.0	22.0	140
ST 304	42.0	55.0	55	300	30.0			29.0	35.0	34.0	21.0	24.0	62
ST 305	40.0	48.0		65.0	310	34.0	21.5	1070	288	36.5	980	41.0	52
ST 306	48.5	59.0	49.0	78.0	218	52.0	48.0	145	360	390	182	410	88

Table VII (Continued)

Sample Probe	13	15	16	17	18	19	20	21	22	23	24	26	28
ST 307	38.0	148.0	41.0	56.0	36.0	42.0	54.0	73.0	298	420	69.0	415	132
DP 403		20.3	1.35	8.80	3.70								
PP 403													
DP 411													
PP 411													
DP 404													
PP 404													
DP 412													1.70
PP 412	0.90											0.90	0.90
DP 405													
PP 405													
DP 413					3.50	7.40	1.60	0.45	0.55				
PP 413	0.95	0.65	0.53	7.00		8.10	1.10	0.40	0.49			1.10	0.90
DP 406	0.75					46.0	2.50	0.60	0.70				
PP 406						6.30	2.60	1.00	1.00				
DP 414	0.75					2.60	1.15	0.45	0.45				1.80
PP 414						2.60		0.49	47.0				
DP 407						49.0	1.85	0.52	0.52				1.50
PP 407	0.75	1.30	2.40	6.40	3.50	5.30	1.25	0.40	0.45				
DP 415	0.80		0.65	6.90	3.30	54.0	2.50	0.50	0.70	3.40	1.80	2.70	3.50
PP 415				22.5	4.50	4.20	1.80	0.80	0.75	2.10	1.60	1.90	
DP 408				45.0	13.2	24.0	5.80	0.95	0.80	1.60	1.14	1.40	
PP 408		10.0	3.2	8.00	5.00	5.80	5.00	1.40	0.50	2.10	1.00	1.10	
DP 708													
DP 706													

Table VII (Continued)

Sample Probe	13	15	16	17	18	19	20	21	22	23	24	26	28
DP 742													
DP 722	2.25	21.3	238	21.0	4.00								
DP 724	2.50	95.5	75.0	23.0	4.10	30.0	2.20	0.75	0.70				149
DP 741	1.15	7.50	7.30	11.5	3.80	8.50	1.60	0.68	0.65				37.0
DP 726	3.40	79.0	69.5	730	4.60	90.0	2.60	0.50	0.50				162
DP 727	2.00	12.3	22.8	16.0	4.30	9.00	2.50	0.50	0.60	1.90	1.25	1.50	
DP 709													
DP 707													
DP 730	2.60	8.50	82.0	22.0	5.00								
DP 751		1.08	3.40	7.60	3.60	5.50	1.60	0.50	0.55				26.5
DP 732	16.4	91.0	88.0	39.0	4.90	34.0	2.20	0.85	0.85				215
DP 746	1.15	1.55	4.90	8.00	3.50	9.00	1.50	0.52	0.60				20.5
DP 734	16.5	94.5	99.0	89.0	8.50	100	7.50	3.50	5.40				222
DP 748		7.60	47.5	15.8	4.10	4.70	1.60	0.50	0.52	1.30	0.85	0.90	195
DP 735	2.2	8.00	69.0	21.0	4.10	30.0		0.90	0.80	3.10	1.50	1.00	253
DP 416													
PP 416													
DP 401													
PP 401													
DP 409													
PP 409													
DP 402													
PP 402													
DP 410													
PP 410

Figure 41

CH₄ Concentration Profiles - FFL-17-6

Figure 42

CH₄ Concentration Profiles - FFL-17-7

Figure 44

CH₄ Concentration Profiles - FFL-17-10

Figure 45

CH_4 Concentration Profiles - FFL-17-15

Figure 46

CH₄ Concentration Profiles - FFL-17-16

Figure 47

CH₄ Concentration Profiles - FFL-17-17

Figure 48

CH₄ Concentration Profiles - FFL-17-18

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Figure 49

CH₄ Concentration Profiles - FFL-17-19

Figure 50

CH_4 Concentration Profiles - FFL-17-20

Figure 52

CH₄ Concentration Profiles - FFL-17-22

Figure 53

CH₄ Concentration Profiles - FFL-17-23

Figure 54

CH₄ Concentration Profiles - FFL-17-24

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Figure 55

CH₄ Concentration Profiles - FFL-17-26

Figure 56

CH₄ Concentration Profiles - FFL-17-28

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APPENDIX B

PRESSURE PROFILES AND DATA TABULATIONS

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FFL-17- 5

CORE INLET PRESSURE (PSIA)=298.0
 CORE PRESSURE DROP (PSID)=139.0

CORE INLET TEMPERATURE (F)=37.0
 CORE OUTLET TEMPERATURE (F)=60.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	293.8	18.00	277.	7.16
DP704	257.3	0.	0.	7.16
DP705	240.0	7.50	45.	7.16
DP706	239.7	7.50	165.	7.16
DP707	248.3	7.50	285.	7.16
DP709	233.1	17.50	285.	7.16
DP761	249.6	13.50	45.	7.16
DP766	295.4	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	279.0	18.00	53.	18.40
DP714	216.4	7.50	45.	18.40
DP720	234.5	0.	0.	18.40
DP722	240.0	7.50	165.	18.40
DP730	236.0	7.50	285.	18.40
DP762	229.9	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	253.4	18.00	97.	29.65
DP716	227.3	7.50	45.	29.65
DP724	191.6	7.50	165.	29.65
DP732	185.1	7.50	285.	29.65
DP740	253.1	17.50	45.	29.65
DP743	192.3	0.	0.	29.65
DP751	252.2	17.50	285.	29.65
DP763	187.0	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	208.8	18.00	307.	40.90
DP718	172.1	7.50	45.	40.90
DP726	179.6	7.50	165.	40.90
DP734	157.6	7.50	285.	40.90
DP736	203.5	0.	0.	40.90
DP738	211.8	17.50	45.	40.90
DP746	208.8	17.50	285.	40.90
DP764	170.5	13.50	45.	40.90
DP767	211.7	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	177.1	18.00	0.	46.52
DP719	232.0	7.50	45.	46.52
DP727	214.1	7.50	165.	46.52
DP737	186.6	17.50	45.	46.52
DP747	214.3	0.	0.	46.52
DP748	211.8	17.50	285.	46.52
DP765	185.4	13.50	45.	46.52

FFL-17-5 Pressure Data

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FFL-17- 9

CORE INLET PRESSURE (PSIA)=305.0
 CORE PRESSURE DROP (PSID)=132.0

CORE INLET TEMPERATURE (F)=55.0
 CORE OUTLET TEMPERATURE (F)=63.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	301.0	18.00	277.	7.16
DP705	372.7	7.50	45.	7.16
DP706	248.0	7.50	165.	7.16
DP707	251.9	7.50	285.	7.16
DP709	300.1	17.50	285.	7.16
DP766	302.6	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	286.9	18.00	157.	18.40
DP720	250.6	0.	0.	18.40
DP722	246.1	7.50	165.	18.40
DP730	237.5	7.50	285.	18.40
DP762	236.3	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	262.6	18.00	113.	29.65
DP716	233.5	7.50	45.	29.65
DP724	203.9	7.50	165.	29.65
DP732	202.8	7.50	285.	29.65
DP740	262.6	17.50	45.	29.65
DP743	277.5	0.	0.	29.65
DP751	261.0	17.50	285.	29.65
DP763	196.6	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	220.3	18.00	353.	40.90
DP718	184.1	7.50	45.	40.90
DP726	191.6	7.50	165.	40.90
DP734	169.8	7.50	285.	40.90
DP736	205.3	0.	0.	40.90
DP738	146.5	17.50	45.	40.90
DP746	220.3	17.50	285.	40.90
DP764	157.7	13.50	45.	40.90
DP767	222.5	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	190.2	18.00	45.	46.52
DP719	247.9	7.50	45.	46.52
DP727	227.8	7.50	165.	46.52
DP735	217.1	7.50	285.	46.52
DP737	199.5	17.50	45.	46.52
DP747	228.1	0.	0.	46.52
DP765	173.9	13.50	45.	46.52

FFL-17-9 Pressure Data

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FFL-17-10

CORE INLET PRESSURE (PSIA)=300.0
CORE PRESSURE DROP (PSID)=122.0

CORE INLET TEMPERATURE (F)=55.0
CORE OUTLET TEMPERATURE (F)=59.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	296.3	18.00	277.	7.16
DP705	316.4	7.50	45.	7.16
DP706	245.4	7.50	165.	7.16
DP707	247.5	7.50	285.	7.16
DP709	295.2	17.50	285.	7.16
DP766	297.5	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	283.3	18.00	157.	18.40
DP720	283.1	0.	0.	18.40
DP722	244.7	7.50	165.	18.40
DP730	237.4	7.50	285.	18.40
DP762	232.7	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	260.8	18.00	113.	29.65
DP716	233.6	7.50	45.	29.65
DP724	203.5	7.50	165.	29.65
DP732	217.5	7.50	285.	29.65
DP740	260.8	17.50	45.	29.65
DP743	201.9	0.	0.	29.65
DP751	258.7	17.50	285.	29.65
DP763	194.3	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	221.7	18.00	353.	40.90
DP718	186.9	7.50	45.	40.90
DP726	194.4	7.50	165.	40.90
DP734	154.0	7.50	285.	40.90
DP736	209.0	0.	0.	40.90
DP738	224.2	17.50	45.	40.90
DP746	221.7	17.50	285.	40.90
DP764	159.0	13.50	45.	40.90
DP767	223.0	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	193.9	18.00	45.	46.52
DP719	250.6	7.50	45.	46.52
DP727	229.9	7.50	165.	46.52
DP735	221.6	7.50	285.	46.52
DP737	203.2	17.50	45.	46.52
DP747	232.4	0.	0.	46.52
DP765	177.7	13.50	45.	46.52

FFL-17-10 Pressure Data

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FFL-17-11

CORE INLET PRESSURE (PSIA)=291.0
CORE PRESSURE DROP (PSID)=117.0

CORE INLET TEMPERATURE (F)=71.0
CORE OUTLET TEMPERATURE (F)=75.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	287.5	18.00	43.	7.16
DP705	238.3	7.50	45.	7.16
DP706	231.7	7.50	165.	7.16
DP707	235.3	7.50	285.	7.16
DP709	286.3	17.50	285.	7.16
DP761	293.9	13.50	45.	7.16
DP766	289.1	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	275.0	18.00	157.	18.40
DP714	201.9	7.50	45.	18.40
DP720	200.8	0.	0.	18.40
DP722	233.6	7.50	165.	18.40
DP730	217.7	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	253.4	18.00	187.	29.65
DP716	227.1	7.50	45.	29.65
DP724	194.8	7.50	165.	29.65
DP732	198.8	7.50	285.	29.65
DP740	252.9	17.50	45.	29.65
DP743	196.8	0.	0.	29.65
DP751	251.1	17.50	285.	29.65
DP763	187.3	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	215.9	18.00	45.	40.90
DP718	184.9	7.50	45.	40.90
DP726	190.0	7.50	165.	40.90
DP734	164.4	7.50	285.	40.90
DP736	207.7	0.	0.	40.90
DP738	218.6	17.50	45.	40.90
DP746	215.9	17.50	285.	40.90
DP764	152.3	13.50	45.	40.90
DP767	217.7	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	189.2	18.00	285.	46.52
DP719	245.6	7.50	45.	46.52
DP727	225.9	7.50	165.	46.52
DP735	217.0	7.50	285.	46.52
DP737	194.4	17.50	45.	46.52
DP747	227.6	0.	0.	46.52
DP765	204.6	13.50	45.	46.52

FFL-17-11 Pressure Data

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FFL-17-12

CORE INLET PRESSURE (PSIA)=294.0
 CORE PRESSURE DROP (PSID)=125.0

CORE INLET TEMPERATURE (F)=67.0
 CORE OUTLET TEMPERATURE (F)=70.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	290.2	18.00	277.	7.16
DP704	262.0	0.	0.	7.16
DP705	267.4	7.50	45.	7.16
DP706	233.3	7.50	165.	7.16
DP707	236.2	7.50	285.	7.16
DP709	289.8	17.50	285.	7.16
DP761	231.5	13.50	45.	7.16
DP766	292.2	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	276.9	18.00	53.	18.40
DP714	205.1	7.50	45.	18.40
DP720	203.1	0.	0.	18.40
DP722	228.6	7.50	165.	18.40
DP730	205.3	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	253.9	18.00	97.	29.65
DP716	228.1	7.50	45.	29.65
DP724	193.9	7.50	165.	29.65
DP732	199.2	7.50	285.	29.65
DP740	253.0	17.50	45.	29.65
DP743	193.1	0.	0.	29.65
DP751	250.9	17.50	285.	29.65
DP763	186.9	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	213.7	18.00	307.	40.90
DP718	183.2	7.50	45.	40.90
DP726	179.9	7.50	165.	40.90
DP734	162.0	7.50	285.	40.90
DP736	211.0	0.	0.	40.90
DP738	219.8	17.50	45.	40.90
DP746	213.7	17.50	285.	40.90
DP764	199.4	13.50	45.	40.90
DP767	216.0	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	185.2	18.00	7.	46.52
DP719	241.3	7.50	45.	46.52
DP727	222.2	7.50	165.	46.52
DP735	214.3	7.50	285.	46.52
DP737	194.0	17.50	45.	46.52
DP747	223.7	0.	0.	46.52
DP765	197.0	13.50	45.	46.52

FFL-17-12 Pressure Data

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WANL-TME-1160

FFL-17-13

CORE INLET PRESSURE (PSIA)=299.0
 CORE PRESSURE DROP (PSID)=130.0

CORE INLET TEMPERATURE (F)=67.0
 CORE OUTLET TEMPERATURE (F)=71.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	295.1	18.00	277.	7.16
DP704	250.3	0.	0.	7.16
DP705	244.2	7.50	45.	7.16
DP706	238.7	7.50	165.	7.16
DP707	240.4	7.50	285.	7.16
DP709	292.5	17.50	285.	7.16
DP761	235.4	13.50	45.	7.16
DP766	236.3	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	281.2	18.00	53.	18.40
DP714	209.4	7.50	45.	18.40
DP720	207.8	0.	0.	18.40
DP722	237.9	7.50	165.	18.40
DP730	215.3	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	257.3	18.00	97.	29.65
DP716	231.5	7.50	45.	29.65
DP724	197.3	7.50	165.	29.65
DP732	200.2	7.50	285.	29.65
DP740	256.1	17.50	45.	29.65
DP743	196.9	0.	0.	29.65
DP751	255.4	17.50	285.	29.65
DP763	190.3	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	215.5	18.00	307.	40.90
DP718	186.1	7.50	45.	40.90
DP726	183.5	7.50	165.	40.90
DP734	163.6	7.50	285.	40.90
DP736	212.1	0.	0.	40.90
DP738	239.3	17.50	45.	40.90
DP746	215.3	17.50	285.	40.90
DP764	201.1	13.50	45.	40.90
DP767	205.3	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	185.9	18.00	7.	46.52
DP719	241.9	7.50	45.	46.52
DP727	222.3	7.50	165.	46.52
DP735	214.7	7.50	285.	46.52
DP737	175.3	17.50	45.	46.52
DP747	223.0	0.	0.	46.52
DP765	200.2	13.50	45.	46.52

FFL-17-13 Pressure Data

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 Atomic Energy Act - 1954

WANL-TME-1160

FFL-17-15

CORE INLET PRESSURE (PSIA)=299.0
 CORE PRESSURE DROP (PSID)=130.0

CORE INLET TEMPERATURE (F)=60.0
 CORE OUTLET TEMPERATURE (F)=66.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	295.1	18.00	277.	7.16
DP706	237.5	7.50	165.	7.16
DP707	247.7	7.50	285.	7.16
DP709	293.7	17.50	285.	7.16
DP761	241.0	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	281.2	18.00	53.	18.40
DP714	316.4	7.50	45.	18.40
DP720	220.8	0.	0.	18.40
DP722	215.8	7.50	165.	18.40
DP730	209.9	7.50	285.	18.40
DP742	294.1	17.50	165.	18.40
DP762	230.9	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	257.3	18.00	97.	29.65
DP716	231.6	7.50	45.	29.65
DP724	196.5	7.50	165.	29.65
DP732	199.6	7.50	285.	29.65
DP740	257.3	17.50	45.	29.65
DP743	195.4	0.	0.	29.65
DP751	257.7	17.50	285.	29.65
DP763	190.1	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	215.5	18.00	307.	40.90
DP718	185.3	7.50	45.	40.90
DP726	181.1	7.50	165.	40.90
DP734	163.3	7.50	285.	40.90
DP736	212.5	0.	0.	40.90
DP738	219.3	17.50	45.	40.90
DP746	215.5	17.50	285.	40.90
DP764	201.3	13.50	45.	40.90
DP767	217.1	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	185.7	18.00	7.	46.52
DP719	241.4	7.50	45.	46.52
DP727	220.7	7.50	165.	46.52
DP735	212.5	7.50	285.	46.52
DP737	195.6	17.50	45.	46.52
DP747	223.5	0.	0.	46.52
DP765	200.9	13.50	45.	46.52

FFL-17-15 Pressure Data

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FEL-17-16

CORE INLET PRESSURE (PSIA)=307.0
 CORE PRESSURE DROP (PSID)=138.0

CORE INLET TEMPERATURE (F)=60.0
 CORE OUTLET TEMPERATURE (F)=66.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	302.9	18.00	277.	7.16
DP706	245.5	7.50	165.	7.16
DP707	255.5	7.50	285.	7.16
DP709	301.2	17.50	285.	7.16
DP761	248.8	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	238.1	18.00	53.	18.40
DP714	251.6	7.50	45.	18.40
DP720	253.5	0.	0.	18.40
DP722	235.2	7.50	165.	18.40
DP730	216.8	7.50	285.	18.40
DP762	237.8	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	262.7	18.00	97.	29.65
DP716	237.1	7.50	45.	29.65
DP724	201.9	7.50	165.	29.65
DP732	205.0	7.50	285.	29.65
DP740	262.7	17.50	45.	29.65
DP743	213.5	0.	0.	29.65
DP751	263.2	17.50	285.	29.65
DP763	195.4	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	218.4	18.00	307.	40.90
DP718	188.2	7.50	45.	40.90
DP726	184.5	7.50	165.	40.90
DP734	166.2	7.50	285.	40.90
DP736	216.1	0.	0.	40.90
DP738	221.9	17.50	45.	40.90
DP746	218.7	17.50	285.	40.90
DP764	204.4	13.50	45.	40.90
DP767	220.4	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	136.7	18.00	7.	46.52
DP719	242.4	7.50	45.	46.52
DP727	222.3	7.50	165.	46.52
DP735	214.1	7.50	285.	46.52
DP737	196.6	17.50	45.	46.52
DP747	224.6	0.	0.	46.52
DP765	202.2	13.50	45.	46.52

FEL-17-16 Pressure Data

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FFL-17-17

CORE INLET PRESSURE (PSIA)=304.0
 CORE PRESSURE DROP (PSID)=137.0

CORE INLET TEMPERATURE (F)=55.0
 CORE OUTLET TEMPERATURE (F)=65.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	299.9	18.00	277.	7.16
DP704	213.6	0.	0.	7.16
DP705	226.9	7.50	45.	7.16
DP706	242.2	7.50	165.	7.16
DP707	252.5	7.50	285.	7.16
DP709	298.8	17.50	285.	7.16
DP761	231.4	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	285.2	18.00	53.	18.40
DP720	229.0	0.	0.	18.40
DP722	218.7	7.50	165.	18.40
DP730	210.5	7.50	285.	18.40
DP762	234.2	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	260.0	18.00	97.	29.65
DP716	225.0	7.50	45.	29.65
DP724	199.2	7.50	165.	29.65
DP732	202.1	7.50	285.	29.65
DP740	259.9	17.50	45.	29.65
DP743	199.7	0.	0.	29.65
DP751	258.3	17.50	285.	29.65
DP763	193.3	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	216.0	18.00	307.	40.90
DP718	178.6	7.50	45.	40.90
DP726	166.2	7.50	165.	40.90
DP734	164.4	7.50	285.	40.90
DP736	212.0	0.	0.	40.90
DP738	219.5	17.50	45.	40.90
DP746	205.1	17.50	285.	40.90
DP764	191.0	13.50	45.	40.90
DP767	218.5	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	134.8	18.00	7.	46.52
DP719	235.3	7.50	45.	46.52
DP727	219.7	7.50	165.	46.52
DP735	209.2	7.50	285.	46.52
DP737	189.6	17.50	45.	46.52
DP747	217.7	0.	0.	46.52
DP765	171.7	13.50	45.	46.52

FFL-17-17 Pressure Data

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FFL-17-18

CORE INLET PRESSURE (PSIA)=297.0
CORE PRESSURE DROP (PSID)=129.0

CORE INLET TEMPERATURE (F)=49.0
CORE OUTLET TEMPERATURE (F)=62.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	293.1	18.00	277.	7.16
DP704	226.3	0.	0.	7.16
DP705	241.3	7.50	45.	7.16
DP706	236.0	7.50	165.	7.16
DP707	246.5	7.50	285.	7.16
DP709	292.4	17.50	285.	7.16
DP761	245.5	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	279.3	18.00	53.	18.40
DP714	214.8	7.50	45.	18.40
DP720	221.5	0.	0.	18.40
DP722	211.5	7.50	165.	18.40
DP730	209.1	7.50	285.	18.40
DP762	271.0	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	255.6	18.00	97.	29.65
DP716	207.3	7.50	45.	29.65
DP724	194.6	7.50	165.	29.65
DP732	197.6	7.50	285.	29.65
DP740	255.3	17.50	45.	29.65
DP743	192.7	0.	0.	29.65
DP751	254.7	17.50	285.	29.65
DP763	187.2	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	214.2	18.00	307.	40.90
DP718	169.5	7.50	45.	40.90
DP726	167.5	7.50	165.	40.90
DP734	162.3	7.50	285.	40.90
DP736	210.8	0.	0.	40.90
DP738	214.6	17.50	45.	40.90
DP746	203.1	17.50	295.	40.90
DP764	175.2	13.50	45.	40.90
DP767	216.1	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	184.3	18.00	7.	46.52
DP717	240.6	7.50	45.	46.52
DP727	214.6	7.50	165.	46.52
DP735	206.0	7.50	285.	46.52
DP737	191.4	17.50	45.	46.52
DP747	220.3	0.	0.	46.52
DP745	182.4	13.50	45.	46.52

FFL-17-18 Pressure Data

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Atomic Energy Act - 1954

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 Atomic Energy Act - 1954

WANL-TME-1160

FLL-17-19

CORE INLET PRESSURE (PSIA)=299.0
 CORE PRESSURE DROP (PSID)=133.0

CORE INLET TEMPERATURE (F)=64.0
 CORE OUTLET TEMPERATURE (F)=63.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	295.0	18.00	277.	7.16
DP704	226.5	0.	0.	7.16
DP705	239.5	7.50	45.	7.16
DP706	238.4	7.50	165.	7.16
DP707	247.8	7.50	285.	7.16
DP709	293.9	17.50	285.	7.16
DP761	247.2	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	280.9	18.00	53.	18.40
DP714	213.7	7.50	45.	18.40
DP720	225.2	0.	0.	18.40
DP722	224.7	7.50	165.	18.40
DP730	223.7	7.50	285.	18.40
DP762	229.9	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	256.3	18.00	97.	29.65
DP716	228.1	7.50	45.	29.65
DP724	195.2	7.50	165.	29.65
DP732	242.4	7.50	285.	29.65
DP740	255.9	17.50	45.	29.65
DP743	258.2	0.	0.	29.65
DP763	189.9	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	213.6	18.00	307.	40.90
DP718	175.1	7.50	45.	40.90
DP726	166.4	7.50	165.	40.90
DP734	161.0	7.50	285.	40.90
DP736	210.7	0.	0.	40.90
DP738	215.2	17.50	45.	40.90
DP746	202.4	17.50	285.	40.90
DP764	181.0	13.50	45.	40.90
DP767	215.9	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	183.3	18.00	7.	46.52
DP719	240.0	7.50	45.	46.52
DP727	219.6	7.50	165.	46.52
DP735	203.3	7.50	285.	46.52
DP737	190.7	17.50	45.	46.52
DP747	220.6	0.	0.	46.52
DP765	185.5	13.50	45.	46.52

FLL-17-19 Pressure Data

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WANL-TME-1160

FFL-17-20

CORE INLET PRESSURE (PSIA)=299.0
CORE PRESSURE DROP (PSID)=127.0

CORE INLET TEMPERATURE (F)=60.0
CORE OUTLET TEMPERATURE (F)=64.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	295.2	18.00	277.	7.16
DP704	227.2	0.	0.	7.16
DP705	242.1	7.50	45.	7.16
DP706	239.4	7.50	165.	7.16
DP707	249.1	7.50	285.	7.16
DP709	294.0	17.50	285.	7.16
DP761	243.6	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	281.6	18.00	53.	18.40
DP714	217.6	7.50	45.	18.40
DP720	220.7	0.	0.	18.40
DP722	226.4	7.50	165.	18.40
DP730	224.5	7.50	285.	18.40
DP762	232.3	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	258.2	18.00	97.	29.65
DP716	228.5	7.50	45.	29.65
DP724	139.3	7.50	165.	29.65
DP732	200.7	7.50	285.	29.65
DP740	257.7	17.50	45.	29.65
DP743	210.0	0.	0.	29.65
DP751	256.4	17.50	285.	29.65
DP763	190.9	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	217.5	18.00	307.	40.90
DP718	174.2	7.50	45.	40.90
DP726	172.1	7.50	165.	40.90
DP734	166.4	7.50	285.	40.90
DP736	213.8	0.	0.	40.90
DP738	217.5	17.50	45.	40.90
DP746	205.4	17.50	285.	40.90
DP764	178.3	13.50	45.	40.90
DP767	219.5	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	188.5	18.00	7.	46.52
DP719	246.3	7.50	45.	46.52
DP727	218.4	7.50	165.	46.52
DP735	205.6	7.50	285.	46.52
DP737	195.2	17.50	45.	46.52
DP747	223.7	0.	0.	46.52
DP765	156.3	13.50	45.	46.52

FFL-17-20 Pressure Data

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Atomic Energy Act - 1954

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FFL-17-21

CORE INLET PRESSURE (PSIA)=301.0
CORE PRESSURE DROP (PSID)=133.0

CORE INLET TEMPERATURE (F)=53.0
CORE OUTLET TEMPERATURE (F)=64.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	297.0	18.00	277.	7.16
DP704	231.6	0.	0.	7.16
DP705	243.8	7.50	45.	7.16
DP706	260.1	7.50	165.	7.16
DP707	263.8	7.50	285.	7.16
DP709	296.4	17.50	285.	7.16
DP761	256.4	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	282.3	18.00	53.	18.40
DP714	216.5	7.50	45.	18.40
DP720	223.8	0.	0.	18.40
DP722	225.2	7.50	165.	18.40
DP730	223.7	7.50	285.	18.40
DP762	233.5	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	258.3	18.00	97.	29.65
DP724	212.7	7.50	165.	29.65
DP732	200.8	7.50	285.	29.65
DP740	258.2	17.50	45.	29.65
DP743	207.7	0.	0.	29.65
DP751	257.1	17.50	285.	29.65
DP763	250.8	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	215.6	18.00	307.	40.90
DP718	170.3	7.50	45.	40.90
DP726	167.9	7.50	165.	40.90
DP734	164.9	7.50	285.	40.90
DP736	212.1	0.	0.	40.90
DP738	217.1	17.50	45.	40.90
DP746	209.3	17.50	285.	40.90
DP764	183.3	13.50	45.	40.90
DP767	217.7	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	185.3	18.00	7.	46.52
DP719	242.7	7.50	45.	46.52
DP727	218.2	7.50	165.	46.52
DP735	205.4	7.50	285.	46.52
DP737	172.7	17.50	45.	46.52
DP747	221.7	0.	0.	46.52
DP765	185.6	13.50	45.	46.52

FFL-17-21 Pressure Data

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FFL-17-22

CORE INLET PRESSURE (PSIA)=298.0
 CORE PRESSURE DROP (PSID)=131.0

CORE INLET TEMPERATURE (F)=44.0
 CORE OUTLET TEMPERATURE (F)=62.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	294.1	18.00	277.	7.16
DP704	228.0	0.	0.	7.16
DP705	240.2	7.50	45.	7.16
DP706	258.4	7.50	165.	7.16
DP707	260.7	7.50	285.	7.16
DP709	292.7	17.50	285.	7.16
DP761	242.4	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	280.1	18.00	53.	18.40
DP714	212.0	7.50	45.	18.40
DP720	218.3	0.	0.	18.40
DP722	222.9	7.50	165.	18.40
DP730	220.8	7.50	285.	18.40
DP762	230.8	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	255.7	18.00	97.	29.65
DP724	196.2	7.50	165.	29.65
DP732	198.3	7.50	285.	29.65
DP740	255.7	17.50	45.	29.65
DP743	205.6	0.	0.	29.65
DP751	254.3	17.50	285.	29.65
DP763	190.5	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	213.7	18.00	307.	40.90
DP718	168.6	7.50	45.	40.90
DP726	165.7	7.50	165.	40.90
DP734	163.4	7.50	285.	40.90
DP736	210.3	0.	0.	40.90
DP738	213.7	17.50	45.	40.90
DP746	207.4	17.50	285.	40.90
DP764	175.5	13.50	45.	40.90
DP767	215.7	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	184.0	18.00	7.	46.52
DP719	241.3	7.50	45.	46.52
DP727	213.8	7.50	165.	46.52
DP735	202.7	7.50	285.	46.52
DP737	190.4	17.50	45.	46.52
DP747	220.3	0.	0.	46.52
DP765	183.8	13.50	45.	46.52

FFL-17-22 Pressure Data

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Test Data Used to Derive Non-Dimensional Profiles

TEST DESIGNATION	CORE INLET PRESSURE	CORE EXIT PRESSURE	NUMBER OF DATA CARDS
17 11	291.C	117.0	36
17 15	299.C	130.0	36
17 16	307.C	138.C	35
17 17	304.C	137.0	36
17 18	297.C	129.0	37
17 19	299.C	133.0	36
17 20	299.C	127.0	37
17 21	301.C	133.0	36
17 22	298.C	131.0	36

NON-DIMENSIONAL DATA REDUCTION

ELEVATION		RADIUS			
		C.	7.50	13.50	17.50
7.16	MEAN	0.438	0.582	0.627	0.964
	STANDARD DEVIATION	0.045	0.068	0.149	0.007
	NUMBER OF DATA POINTS	6	25	9	10
18.40	MEAN	0.416	0.419	0.525	
	STANDARD DEVIATION	0.093	0.159	0.104	
	NUMBER OF DATA POINTS	9	26	8	
29.65	MEAN	0.305	0.305	0.216	0.674
	STANDARD DEVIATION	0.145	0.114	0.146	0.006
	NUMBER OF DATA POINTS	9	25	9	17
40.90	MEAN	0.328	0.020	0.100	0.352
	STANDARD DEVIATION	0.015	0.061	0.125	0.038
	NUMBER OF DATA POINTS	9	27	9	27
46.52	MEAN	0.409	0.415	0.173	0.184
	STANDARD DEVIATION	0.021	0.111	0.057	0.011
	NUMBER OF DATA POINTS	9	27	9	9

Figure 57

Core Interlelement Pressures - FFL-17-11

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Figure 58

Core Interelement Pressures - FFL-17-15

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Figure 59

Core Interelement Pressures - FFL-17-16

Figure 60

Core Interelement Pressures - FFL-17-17

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Figure 61

Core Interelement Pressures - FFL-17-18

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~~RESTRICTED DATA~~

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Figure 62

Core Interlelement Pressures - FFL-17-19

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WANL-TME-1160

Figure 65

Core Interelement Pressures - FFL-17-22

APPENDIX C

TEST PROCEDURES

PLUGGED CORE TRACER GAS TEST

Operating Procedures, Check Lists, and Instructions

Run No. _____

Date of Run _____

Ambient Temperature _____

Barometric Pressure _____

Mode of Operation:

Trailer _____

Sphere _____

Supply Pressures:

CH₄

H₂

Initial _____

Final _____

Supply Temperatures:

CH₄

H₂

Initial _____

LN₂ Level:

Initial _____

Final _____

Remarks _____

Lead Technician or Engineer _____

Tracer Gas Test Plan

Run No.

Date of Run

Core Inlet Pressure (PRC-2)

Core Outlet Pressure (PRC-3)

Injection Mode, M_i

Sampling Modes, M_s

Injection Probes, N_i

Injection rate, lb/sec

Flow meter setting:

Hastings meter (M-7)

SCCM

O-7

in.H₂O

Control valve size and trim

Camera Schedule:

Remarks:

[illegible]

Use these procedures with Drawing Nos. 576F108 and 386D763, and methane injection and sampling flow sheet.

	<u>Time</u>	<u>Remarks</u>
I. <u>Facility Preparation</u>		
A. <u>In cell and control consoles</u>		
1. Nitrogen system		
a. Check heater operation	_____	_____
b. Set heater thermostats to _____°F and _____°F	_____	_____
c. Record LN ₂ level in sphere	_____	_____
d. Check operation of RCV-7	_____	_____
e. Open main supply on GN ₂ tank	_____	_____
f. Close vent valves in tank area	_____	_____
g. Open all GN ₂ supply valves in cell and control area; set regulators to 20 psig	_____	_____
(1) Transmitters	_____	_____
(2) Control valves	_____	_____
(3) Operators	_____	_____
(4) Controllers	_____	_____
(5) Handloaders	_____	_____
h. Check operation of low pressure alarm	_____	_____

		<u>Time</u>	<u>Remarks</u>
2.	Vacuum System		
a.	Close V-45 (vacuum vent)	_____	_____
b.	Start coolant flow for Pump 1	_____	_____
c.	Operation of Pumps 1 and 2	_____	_____
d.	Operation of RCV-5, 6, 11	_____	_____
e.	Operation of S-1A, 1B, 3A, 7	_____	_____
f.	Operation of VAC-1A, 1B, 3, 7, and Hastings meter (Calibrate if necessary)	_____	_____
g.	Check oil level in pumps	_____	_____
3.	Flow Measurement System		
a.	Install orifices as follows:		
	O - 1 _____	_____	_____
	O - 2 _____	_____	_____
	O - 3 _____	_____	_____
	O - 7 _____	_____	_____
b.	Open hand valves to orifice taps; close by-pass valves	_____	_____
c.	Open hand valves to M-7 or O-7 per test plan and close valves to meter not required in plan	_____	_____

	<u>Time</u>	<u>Remarks</u>
d. Operation of FR-1, 2, 3, 7	_____	_____
(1) Check ink supply, chart, and drive	_____	_____
(2) Check calibration of re- corders & D/P transmitters	_____	_____
(3) Check recording action (with DPT-1, 2, 3, 7, 8)	_____	_____
e. Check operation of mass flow meter (calibrate with GN ₂ if necessary)	_____	_____
4. Check operation of auxiliary equipment		
a. Duct blowers	_____	_____
b. Cell fans	_____	_____
c. GH ₂ alarms	_____	_____
d. Open cell louvers	_____	_____
5. Check for moisture in system (drains & low-points) and dry with hot GN ₂ as required	_____	_____
6. Install blind flange on 3" - GH ₂ -- 1C, 2C, and 6" - GH ₂ --7F (Vent Stack); close orifice valves downstream of RCV-4	_____	_____

		<u>Time</u>	<u>Remarks</u>
7.	Flow Control System		
a.	Operation of PRC-1, 2, 3, 5, 7, and PC-1		
(1)	<u>Reset</u> <u>Proportional</u> <u>Eand</u>	_____	_____
	_____ PRC-1 _____	_____	_____
	_____ PRC-2 _____	_____	_____
	_____ PRC-3 _____	_____	_____
	_____ PRC-5 _____	_____	_____
	_____ PC -1 _____	_____	_____
	_____ PRC-7 _____	_____	_____
(2)	Check ink supply, chart, and drive	_____	_____
(3)	Check calibration of con- trollers & transmitters	_____	_____
(4)	Check control and/or recording action with PT-1, 2, 3, 5, 7, 8, and HPT-1, 2	_____	_____
b.	Operation of PCV-1, 1A, 1B, 2, 3, 5, 6, 7, 7A and 7B	_____	_____
c.	Operation of RCV-1, 2, 12, 9, 10, (do not open RCV-1 if there is GH ₂ in sphere)	_____	_____

	<u>Time</u>	<u>Remarks</u>
d. Connect PRC-1 to PCV-1A _____		
PCV-1B _____	_____	_____
e. Connect PC-1 to PCV-1 _____	_____	_____
f. Insert proper valve trim in PCV-7, 7A or 7B per test plan _____	_____	_____
g. Connect PRC-3 to PCV-3 _____		
PCV-3A _____	_____	_____
h. Connect PRC-7 to PCV-7 _____		
PCV-7A _____		
PCV-7B _____	_____	_____
i. Check connections on PT-1, 7 _____	_____	_____
8. Install or check rupture discs and safety valves		
a. Vessel: RD-11, 12, 13 _____	_____	_____
b. Flow system: RD-6, 7, 8, 9, 10 SV-13, 14, 15, 3 _____	_____	_____
c. Sphere: RD-1 SV-1, 5 _____	_____	_____
d. Methane System: SV-17, 18 _____	_____	_____

	<u>Time</u>	<u>Remarks</u>
9. Camera System		
a. <u>Movie</u>		
(1) Clean Milliken camera	_____	_____
(2) Install film in magazine		
400 ft. _____	_____	_____
1200 ft. _____	_____	_____
(3) Install Sun Gun on vessel	_____	_____
(4) Install camera on vessel	_____	_____
b. <u>Still</u>		
(1) Clean	_____	_____
(2) Focus	_____	_____
(3) Check lights	_____	_____
(4) Check film & advance timer	_____	_____
(5) Install film	_____	_____
c. <u>Television</u>		
(1) Install TV camera in cell	_____	_____
(2) Check monitor for operations	_____	_____
(3) Focus lenses, etc.	_____	_____
(4) Check control of camera		
movement	_____	_____
(5) Install purge bag and N ₂		
purge line	_____	_____

	<u>Time</u>	<u>Remarks</u>
10. Seal pressure system		
a. Check operation of PCV-401 thru 416	_____	_____
b. Check operation of handloaders and gauges	_____	_____
c. Check operation of millivoltmeters	_____	_____
11. Complete all patching of leads in cell and record on DAS Log	_____	_____
a. Thermocouples	_____	_____
b. Pressure transducers	_____	_____
c. Accelerometers	_____	_____
d. Strain gauges	_____	_____
e. Microphones	_____	_____
f. Displacement gauges	_____	_____
12. Leak test all joints and flanges under GN ₂ pressure where appropriate	_____	_____
13. Sampling and Injection Systems		
a. Install flexible tubing from CH ₄ injectors to vessel probes per test plan	_____	_____
b. Install flexible tubing from vessel probes to sample bombs per test plan	_____	_____

	<u>Time</u>	<u>Remarks</u>
c. Pre-set electrical bomb selector switches per test plan	_____	_____
d. Check operation of solenoids:		
(1) Sample	_____	_____
(2) Vent	_____	_____
(3) Vacuum	_____	_____
e. Sonic orifices:		
(1) Check for cleanliness	_____	_____
(2) Install filters	_____	_____
(3) Install orifices in lines	_____	_____
f. Check for unobstructed flow thru orifices with GN ₂	_____	_____
g. Sample and Injection Panel Valves		
(1) Open all bomb inlet valves	_____	_____
(2) Close all bomb outlet valves	_____	_____
(3) Open reactor probe valves per test plan	_____	_____
(4) Open injector panel valves per test plan	_____	_____
(5) Close all unused valves	_____	_____
(6) Open V-46 (vent)	_____	_____

	<u>Time</u>	<u>Remarks</u>
h. Bomb pressure monitor		
(1) Connect PT-8 to bomb		
No. _____	_____	_____
(2) Open bomb outlet valve	_____	_____
(3) Check connection of PT-8		
to PRC-4	_____	_____
14. Inform site engineer and make record		
of any malfunctioning equipment	_____	_____

NOTE: Item 1B and 1A to proceed concurrently

B. Data Acquisition System Set-up

(See separate procedures and instrumentation lists)

These procedures must be performed in sequence and in their entirety unless otherwise informed by site engineer.

	<u>Time</u>	<u>Remarks</u>
IV. <u>Operation with GH₂ Sphere and GH₂ Trailers at Ambient Temperature</u>		
A. Pre-run Procedures (T-8 hours or less)		
1. Tape recorder on; begin narration (turn Off when not narrating)	_____	_____
2. 117 V.A.C. and 24 V.D.C. power on main and sample control console - On	_____	_____
3. FR-1, 2, 3, 7 power - On	_____	_____
4. PRC-1, 2, 3, 5, 7 power - On	_____	_____
5. Check that DAS system is <u>GO</u>	_____	_____
6. Cell fan - On	_____	_____
7. Cell heaters - Off	_____	_____
8. Duct blowers - On	_____	_____
9. Check system reset	_____	_____
10. Set all controllers on automatic (PRC-1, 2, 3, 5, 7)	_____	_____
11. Vent Flow		
a. <u>Close</u> V-17		
V-20		
V-19	_____	_____

		<u>Time</u>	<u>Remarks</u>
b.	<u>Open</u> V-18 (main stack)	_____	_____
	V-26 (3" stack)		
	V-15 (sphere stack)		
	V-42 a, b (sample vacuum manifold)		
	V-41 a, b, c (sample vent manifold)		
c.	GN ₂ heaters 1 and 2 - On	_____	_____
d.	Vent vessel, piping, and sphere		
	(if no H ₂) to atmospheric pressure	_____	_____
12.	Set PC-1 to minimum	_____	_____
13.	First evacuation		
a.	<u>Close</u> (or check closed)	_____	_____
	RCV-2 PCV-1A V-34		
	RCV-5 PCV-1B V-35		
	RCV-6 PCV-2 V-36		
	RCV-7 PCV-3 S-1A		
	RCV-10 PCV-6 S-1B		
	RCV-11 V-4 S-2A		
	RCV-12 V-31 S-3A		
	V-43 S-7		
	All sample bomb solenoids		
	All sample vent solenoids		
	CH ₄ manifold valve		

		<u>Time</u>	<u>Remarks</u>
b.	<u>Open</u> (or check open)	_____	_____
	PCV-1 V-2		
	V-8 V-39		
	V-9 V-40		
	V-13 PCV-5		
	V-12 RCV-1		
	V-30 RCV-9		
	V-32 V-44		
	V-38		
	PCV-401 thru 416 (30 psig on hand leaders)		
	PCV-7 (or 7A or 7B depending on test plan and 1A7h above)		
c.	Vacuum pump 1 - <u>On</u>	_____	_____
d.	<u>Open</u>		
	RCV-5 S-3A		
	S-1A S-1B		

	<u>Time</u>	<u>Remarks</u>
e. When pressure in system is less than 5 mm Hg abs. (VAC-1B, 2, 3)		
(1) Record all vacuums	_____	_____
(2) <u>Close</u>		
RCV-5 V-8		
RCV-6 V-32	_____	_____
(3) Observe VAC-1A, 1B, 3A; check for rapid loss of vacuum, and remedy before continuing	_____	_____
(4) <u>Close</u>		
S-1A S-3A		
S-1B	_____	_____
(5) Vacuum pump 1 - <u>Off</u>	_____	_____
(6) Open RCV-7	_____	_____

	<u>Time</u>	<u>Remarks</u>
14. Purge		
a. <u>Open</u>		
V-34 to purge seal regulators	_____	_____
V-43 to purge CH ₄ lines	_____	_____
b. When PRC-1, 2, 3 show 30 psig (nominal), <u>close</u>		
RCV-7		
V-43		
V-34	_____	_____
c. <u>Open</u> PCV-2, 3		
(Move set point to Zero)	_____	_____
d. When PRC-1, 2, 3, show 0 psig, <u>close</u> PCV-2, 3		
(Move set point to 100 psig)	_____	_____
e. <u>Open</u>		
V-31 to vent seal regulators	_____	_____
f. <u>Close</u>		
V-31		
15. Second Evacuation and Purge (Can be deleted at discretion of site engineer)		
Repeat III a 13 and III a 14	_____	_____

	<u>Time</u>	<u>Remarks</u>
16. Trailer hook-up (during second purge)		
a. Connect trailer hoses to 3/4-inch GH ₂ inlet tees	_____	_____
b. <u>Close</u> all trailer tube valves	_____	_____
c. <u>Open</u> trailer vent valve and main header valve	_____	_____
d. Close RCV-1 (optional)	_____	_____
e. <u>Open</u> RCV-12 RCV-7	_____	_____
f. After purging for 5 minutes, <u>Close</u> RCV-7	_____	_____
g. <u>Close</u> trailer vent valve when system pressure is slightly above atmospheric	_____	_____
17. Movie Camera		
a. Set camera lens to f ____ at ____ ft.	_____	_____
b. Install bag on camera and sun gun	_____	_____
c. Start GN ₂ purge on camera and sun gun	_____	_____

	<u>Time</u>	<u>Remarks</u>
d. Check cable connections (light <u>On</u>)	_____	_____
e. Check operation visually; M-P camera switches <u>On</u> then <u>Off</u>	_____	_____
18. Still Camera		
a. Set camera lens to f _____ at _____ sec.	_____	_____
b. Check cable connections (light <u>On</u>)	_____	_____
c. Set intervalometer to 4 sec.	_____	_____
d. Remove film plate and lenscap	_____	_____
e. Check flood light operation	_____	_____
f. Check operation visually; still camera <u>On</u> for 2 or 3 seconds, then <u>Off</u>	_____	_____
19. Vent Flare		
a. <u>Open</u> acetylene, air, and GN ₂ valves on cylinders	_____	_____
b. Set regulators:		
(1) Air approximately 20 psig	_____	_____
(2) N ₂ approximately 20 psig	_____	_____
(3) C ₂ H ₂ approximately 4 psig	_____	_____
c. Ignite flare (check visually)	_____	_____
d. Flare <u>Off</u>	_____	_____

	<u>Time</u>	<u>Remarks</u>
20. Methane System		
a. <u>Close</u>		
V-39		
V-40	_____	_____
b. <u>Open</u>		
V-38 (procedure in (a) and (b) may		
be reversed if test plan calls for		
use of PCV-7A or 7B)	_____	_____
21. Sample bomb purge		
a. Check <u>closed</u>		
all sample vent solenoids		
all sample bomb solenoids		
RCV-11		
RCV-10	_____	_____
b. <u>Open</u>		
V-42 a, b,		
all sample vacuum solenoids	_____	_____
c. When bombs are pressurized with		
GN ₂ , <u>close</u> V-42 a, b	_____	_____
d. <u>Open</u>		
RCV-10	_____	_____
e. When bombs are vented,		
close RCV-10	_____	_____
f. Repeat 21 b, c, d, e, five times	_____	_____

	<u>Time</u>	<u>Remarks</u>
g. <u>Close</u> all sample vacuum solenoids		
RCV-10		
RCV-11		
V-42 a, b	_____	_____
22. Check Reset Switch	_____	_____
23. Final DAS calibration and check		
(see separate procedures)	_____	_____
B. <u>Steady State, Transient and Seal Pressure</u>		
<u>Perturbation Runs</u>		
1. Turn on red warning light; turn out cell light; disconnect cell telephone; lock gate; set up barricades, alert guard	_____	_____
2. Turn on lights for still camera	_____	_____
3. Check that all personnel are in control room area or tank farm area only	_____	_____
4. Engage all circuit breakers	_____	_____

	<u>Time</u>	<u>Remarks</u>
5. Pressure Controllers		
a. Mode - Automatic	_____	_____
b. Set point:		
(1) PRC-1 0 psig		
(2) PRC-2 _____ psig		
(3) PRC-3 _____ psig		
(4) PRC-5 _____ psig		
(5) PRC-7 _____ psig		
6. Check GN ₂ supply pressure on manifold (100 psig)	_____	_____
7. Set dome pressures on PCV-401 thru 416 with corresponding hand loader pressures in psig as follows:		
PCV-401 _____ PCV-409 _____	_____	_____
PCV-402 _____ PCV-410 _____	_____	_____
PCV-403 _____ PCV-411 _____	_____	_____
PCV-404 _____ PCV-412 _____	_____	_____
PCV-405 _____ PCV-413 _____	_____	_____
PCV-406 _____ PCV-414 _____	_____	_____
PCV-407 _____ PCV-415 _____	_____	_____
PCV-408 _____ PCV-416 _____	_____	_____

		<u>Time</u>	<u>Remarks</u>
8.	Evacuation and GH ₂ fill		
a.	Open hydrogen trailer tubes and main manifold valve on trailer	_____	_____
b.	<u>Open</u> PCV-1	_____	_____
c.	Vacuum pump 1 - <u>On</u>	_____	_____
d.	<u>Open</u>		
	V-8 S-1A		
	RCV-1 S-1B		
	RCV-5 S-3A		
	V-2 V-32	_____	_____
e.	When pressure throughout system is <u>5 mm</u> Hg abs. or less,		
	(1) Record all vacuums	_____	_____
	(2) <u>Close</u> RCV-9		
	<u>Open</u> CH ₄ Manifold valves	_____	_____
	(3) <u>Close</u>		
	V-32		
	V-8		
	RCV-5		
	RCV-6		
	V-32	_____	_____

	<u>Time</u>	<u>Remarks</u>
(4) <u>Open</u>		
V-34		
V-31	_____	_____
(5) Check VAC-1A, 1B, 3A, for rapid loss of vacuum	_____	_____
(6) <u>Close</u>		
S-1A PCV-5		
S-1B RCV-12		
S-3A V-44	_____	_____
(7) Close V-30 (for all but seal perturbation runs)	_____	_____
(8) Vacuum pump 1 - <u>Off</u>	_____	_____
(9) Open RCV-12	_____	_____
f. <u>Slowly crack</u> V-12 and observe PRC-1, 2, and 3 pressure while filling system with GH ₂	_____	_____
g. When PRC-1, 2, 3, indicate a positive pressure of about 100 psig, <u>close</u> RCV-12 PCV-1	_____	_____
h. Open V-12 fully	_____	_____

	<u>Time</u>	<u>Remarks</u>
i. Final Safety Alert		
(1) All personnel report to Control Room		
(2) Alert Guard		
(3) Alert site personnel	_____	_____
j. Pressurize sphere		
(1) <u>Open</u>		
RCV-1		
RCV-12	_____	_____
(2) Pressurize sphere to _____psig	_____	_____
(3) <u>Close</u>		
RCV-1		
RCV-12	_____	_____
9. Start-up Procedure (time sequenced)		
a. Start stereo tape; narration	_____	_____
b. Check tape-ready indicators	_____	_____
c. Start time code	_____	_____
d. Ignite flare (check visually)	_____	_____
e. Start multipoint recorder (mark)	_____	_____
f. Start flow recorders and pressure recorders (mark)	_____	_____

	<u>Time</u>	<u>Remarks</u>
g. Check for proper functioning and recording		
(1) Flow recorders	_____	_____
(2) Pressure recorders	_____	_____
(3) Multipoint recorder		
(all points)	_____	_____
h. Start tapes and visicorders (mark)	_____	_____
i. Open RCV-1 (if using sphere)	_____	_____
RCV-12 (mark)	_____	_____
j. Ramp PRC-1 to operating pressure of _____ psig (mark)		
(Check pressure on PRC-2)	_____	_____
k. <u>Open</u> RCV-9 (mark)	_____	_____
l. <u>For Seal Perturbation Runs Only</u>		
(1) Ramp PRC-5 to operating pressure of _____psig (mark)_____		
(2) Check stabilization of PRC-1, 2	_____	_____
m. Adjust PRC-1 and PRC-7 for steady-state flow & injection _____		
(1) Check for proper flow rate		
on (a) Hastings meter _____		
(b) FR-7 _____	_____	_____

	<u>Time</u>	<u>Remarks</u>
(2) Check DPT-8 for slight positive deflection	_____	_____
(3) Check injector probe transducer No. ____ on Visicorder for no deflection (if applicable)	_____	_____
n. <u>Open</u> all sample vacuum solenoids	_____	_____
RCV-11 S-7		
Vacuum Pump No. 2		
All sample vent solenoids	_____	_____
<u>NOTE:</u> Hold until S-7 indicates 5 mm Hg or less		
o. Steady State (mark)		
(1) Cameras on		
(2) Sample timer on	_____	_____
p. Sample acquisition (to be performed by console operator without command)		
(1) Sample I		
(a) Close all sample vents and open Bank I bomb solenoids at t_{s1} , = ____ sec.*	_____	_____
(b) Close Bank I bomb solenoids at t_{s1} , = ____ sec.	_____	_____

* Note: t_s is time from steady state "mark" in Step 9 "o" above

	<u>Time</u>	<u>Remarks</u>
(2) Sample II		
(a) Open bank II bomb solenoids		
at t_{s2} = ____ sec.	_____	_____
(b) Close bank II bomb solenoids		
at t_{s2} = ____ sec.	_____	_____
(3) Sample III		
(a) Open bank III bomb sole-		
noids at t_{s3} = ____ sec.	_____	_____
(b) Close bank III solenoids	_____	_____
q. Final check all functions for proper		
data acquisition and sample acqui-		
sition		
(1) PT-8 acquisition		
(2) Flow recorders		
(3) CH ₄ mass flow rate		
(4) Deflection on injector probe		
transducer No. ____		
(5) DPT-8 deflection	_____	_____
r. Cameras - Off - (See camera schedule		
in test plan)		
s. Close RCV-11		
S-7		
Vacuum pump No. 2 - off	_____	_____

	<u>Time</u>	<u>Remarks</u>
10. Shutdown Procedure		
a. At discretion of site engineer, <u>close</u> RCV-12 RCV-9 (mark)	_____	_____
b. Set PRC-2, 3, 7, to Zero and vent system (mark)	_____	_____
c. When pressure on PRC-1, 2, 3, is Zero, (1) Flow and pressure charts <u>OFF</u> (mark)	_____	_____
(2) Visicorder and tapes <u>OFF</u> (mark)	_____	_____
d. Set PRC-1 to <u>Zero</u>	_____	_____
e. Igniter <u>OFF</u>	_____	_____
f. <u>Open</u> RCV-7	_____	_____
g. Slowly <u>Open</u> PCV-1A by ramping set point on PRC-1 to 100 psig	_____	_____
h. Purge for 5 minutes	_____	_____
i. Set PRC-2, 3, to 100 psig	_____	_____
j. Trailer disconnect (1) Close all trailer tube valves	_____	_____

	<u>Time</u>	<u>Remarks</u>
(2) Open trailer vent valve	_____	_____
(3) Open RCV-12	_____	_____
(4) Purge trailer manifold for 2 minutes	_____	_____
(5) Disconnect hoses	_____	_____
(6) Close all trailer valves	_____	_____
k. CH ₄ manifold purge		
(1) Close CH ₄ cylinder and mani- fold valves	_____	_____
(2) Open CH ₄ manifold vent valve	_____	_____
(3) Close V-38	_____	_____
V-39		
V-40		
(4) Open RCV-9		
V-43 (GN ₂ purge)	_____	_____
(5) Purge for 5 minutes	_____	_____
(6) Close V-43		
RCV-9	_____	_____
1. When pressure on PRC-1, 2, 3, is 30 psig		
(1) <u>Close</u> RCV-7	_____	_____
(2) <u>Open</u> PCV-2, 3, by setting PRC-2, 3, to Zero	_____	_____

	<u>Time</u>	<u>Remarks</u>
m. When pressure on PRC-1, 2, 3, is Zero		
(1) Set PRC-2, 3, to 100 psig	_____	_____
(2) Set PRC-1 to Zero	_____	_____
(3) Open PCV-5 V-30	_____	_____
n. Close all sample bomb inlet and outlet valves	_____	_____
11. Complete post operative DAS calibration		
DO NOT Proceed with III B 12 until III 11 is Completed		
12. Final System evacuation and purge		
a. Open or check open RCV-1 V-2	_____	_____
b. Set PCV 401-416 to 100 psig on handloaders	_____	_____
c. Vacuum pump 1 - <u>On</u>	_____	_____
d. <u>Open</u> V-8 S-1A RCV-5 S-1B PCV-1 S-3A	_____	_____

			<u>Time</u>	<u>Remarks</u>
e.	When vessel pressure is <u>5</u> mm Hg abs or less			
	(1) <u>Close</u>			
	RCV-5	S-1A		
	V-8	S-1B		
		S-3A		
	(2) Vacuum pump 1 <u>OFF</u>			
	(3) Open RCV-7 and pressurize system			
	(4) <u>Close</u>			
	RCV-1			
	V-2			
	RCV-7			
f.	<u>Close</u> (or check closed or OFF)			
	RCV-1	PCV-1	S-1A	
	RCV-2	PCV-1A	S-1B	
	RCV-5	PCV-1B	S-2A	
	RCV-6	PCV-2	S-3A	
	RCV-7	PCV-3	S-7	
	RCV-9	PCV-5		
	RCV-10	PCV-6		
	RCV-11	PCV-401 thru 416		
	RCV-12			

		<u>Time</u>	<u>Remarks</u>
f.	(Continued)		
	V-2 V-31		
	V-4 V-32		
	V-8 V-34		
	V-9 V-35		
	V-10 V-36		
	V-11 V-38		
	V-12 V-39		
	V-13 V-40		
	V-15 V-41		
	V-17 V-42		
	V-18 V-43		
	V-26 V-44		
	V-30 Main GN ₂ supply		
			Trailer valves
			GN ₂ heaters
	All hand valves on injector panel		
	All hand valves on reactor probes		
	All hand valves on sample bombs	_____	_____
g.	<u>Open</u> or check open		
	V-19		
	V-20	_____	_____
h.	Record LN ₂ level	_____	_____

	<u>Time</u>	<u>Remarks</u>
13. Record all data in log books	_____	_____
14. Identify all chart records (Visicorder, PRC, and FR)	_____	_____
15. Shut off all power supplies		
Main console	_____	_____
Sample control console	_____	_____
Solenoids	_____	_____
16. Connect Cell Telephone	_____	_____
(Lights, heater, etc., if desired)		
17. Turn Off all cell purge valves	_____	_____
18. Unload all cameras	_____	_____
19. Give site engineer all charts, records, run sheets, etc.	_____	_____
20. Critique procedure and results	_____	_____
21. Final Sample Network Purge & Evacuation		
a. Check that all sample bombs were analyzed and check with site engineer on adequacy of all analyses	_____	_____
b. Close (or check closed) Sample bomb solenoids RCV-11 V-20	_____	_____

	<u>Time</u>	<u>Remarks</u>
c. <u>Open</u>		
RCV-10		
V-41	_____	_____
d. <u>Open</u> all sample vacuum solenoids		
and vent all bombs	_____	_____
e. <u>Close</u> RCV-10	_____	_____
f. <u>Open</u> RCV-11	_____	_____
g. Vacuum Pump No. 2 <u>ON</u>	_____	_____
h. When bombs pressure is 5 mm Hg		
or less, <u>close</u> RCV-11	_____	_____
i. <u>Open</u> V-42. Back fill with		
GN ₂ thru vacuum manifold	_____	_____
j. <u>Close</u>		
V-41 V-18		
V-42 RCV-10	_____	_____
k. <u>Open</u> V-20	_____	_____

WANHEF VALVE LIST

<u>DESIGNATION</u>	<u>DESCRIPTION</u>
RCV-1	Main GH ₂ Sphere supply
RCV-2	A-11 by-pass vent
RCV-3	---
RCV-4	A-11 main vent
RCV-5	Core inlet vacuum
RCV-6	Core outlet vacuum
RCV-7	Main GN ₂ supply
RCV-8	---
RCV-9	Main G CH ₄ supply
RCV-10	Sample bomb vent
RCV-11	Sample bomb vacuum
RCV-12	Main GH ₂ trailer supply
PCV-1	GH ₂ inlet control
PCV-1A	GH ₂ inlet control
PCV-1B	GH ₂ inlet control
PCV-2	GH ₂ core inlet control
PCV-3	GH ₂ core outlet control
PCV-4	Dome loop control
PCV-5	Seal regulators supply control
PCV-6	GH ₂ inlet control
PCV-7	G CH ₄ injection control
PCV-7A	G CH ₄ injection control
PCV-7B	G CH ₄ injection control

VALVE LIST (Continued)

<u>DESIGNATION</u>	<u>DESCRIPTION</u>
V-1	---
V-2	GH ₂ inlet shut-off before PCV-1
V-3	---
V-4	GH ₂ sphere vent
V-5	---
V-6	---
V-7	---
V-8	Tank farm vacuum
V-9	GH ₂ sphere pressure gauge
V-10	LN ₂ to sphere jacket
V-11	LN ₂ to inlet piping jacket
V-12	GH ₂ trailer shut off before RCV-12
V-13	GN ₂ shut off before RCV-7
V-14	---
V-15	GN ₂ purge on sphere stack
V-16	---
V-17	Drain line on 6" stack purge
V-18	6" stack GN ₂ purge
V-19	3" sphere stack drain
V-20	6" stack drain
V-21	---
V-22	---
V-23	GN ₂ check valve after RCV-7
V-24	A-11 vacuum gauge
V-25	A-11 vacuum gauge

VALVE LIST (Continued)

<u>DESIGNATION</u>	<u>DESCRIPTION</u>
V-26	3" stack GN ₂ purge
V-27	A-11 vacuum gauge
V-28	A-11 vacuum gauge
V-29	----
V-30	Main shut-off for seal regulators
V-31	Seal regulators vent manifold
V-32	Seal regulators vacuum manifold
V-33	A-11 purge for PCV-2, 3, lines
V-34	Seal regulators GN ₂ purge
V-35	1/4" stack in inlet piping GN ₂ purge
V-36	1/4" stack in inlet piping shut off
V-37	----
V-38	G CH ₄ supply shut off for PCV-7
V-39	G CH ₄ supply shut off for PCV-7A
V-40	G CH ₄ supply shut off for PCV-7B
V-41 a, b, c	Sample bomb vent manifold purge
V-42 a, b	Vacuum pump vent line purge
V-43	G CH ₄ inlet line purge
V-44	Shut off VAC-1A
V-45	Vacuum line vent (tank farm)
V-46	Main shut off for sample vent system

VALVE LIST (Continued)

DESIGNATION

DESCRIPTION

S-1A	Shut off for VAC-1A (tank farm
S-1B	Shut off for VAC-1B (vessel inlet)
S-2A	Shut off for VAC-2A (core inlet)
S-3A	Shut off for VAC-3A (core inlet)
S-7	Shut off for VAC-7 (sample bombs)
PCV 401-416	Seal regulators