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September, 1965

Westinghouse Astronuclear Laboratory

FINAL REPORT

COMPONENT TEST FFL-17:

PLUGGED CORE TRACER GAS TESTS

(Title Unclassified)

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FINAL REPORT

COMPONENT TEST FFL-17:

PLUGGED CORE TRACER GAS TESTS

(Title Unclassified)

by

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Experimental Engineering Department

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by H.F.C.

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ABSTRACT

A gas tracer technique was developed for the study of leakage flow paths in NRX-A reactors. Parameters related to the technique were optimized and the procedures were employed in fifty-eight flow tests to study leakage flow lines. Methane was injected into the reactor through probes in and above the core and in the seal chambers. Samples taken through probes downstream of the injector, when analyzed, gave a set of concentration profiles throughout the core. The locus of peak concentrations on these profiles represented the path of the tracer gas stream as it flowed through the core. Pressure data was also obtained for probes located on five axial, four radial, and three azimuthal locations.

Pressure contours and flowlines inferred from the data are in good agreement and, in general, are consistent with an assumed potential flow model. Flow in the reactor is axial in the center cylindrical portion of the core and inward from the periphery on the outer radii over the top 40-inches of the core. Below this elevation flows are directed outward to the periphery from points as far into the core as the centerline.

Mechanisms for the observed flow behavior are advanced and a model is suggested which combines the effect of flow into the top and sides of a cylinder, a point source near the bottom of a cylinder, and flow from peripheral pores near the bottom.

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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.⁴ 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 hydraulic 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

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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. 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 for the core to broom outward and produce a condition favorable to outflow from the core into 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. 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: 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.

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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

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provide continuity of flow. This is, of course, quite possible but difficult to describe based on the sparsity of pressure probes available. In addition, a high pressure area observed experimentally near the aft end of the core was not predicted by analytical programs and its effect on flow in that area was unknown.

One of the basic reasons for studying flow phenomena in the core and between the core and lateral support system is to provide better means of predicting areas in which temperature shocking of components and corrosion might occur. The use of this knowledge in the design of reactor hardware to preclude these adverse influences is obvious. A second aspect of its use is in the operation of the reactor, for example, introduction of a corrosion inhibitor, such as methane, into the reactor to prevent corrosion at vulnerable areas. Such a scheme has been suggested; however, the actual application carries with it some difficulties. One, the injection of the corrosion inhibitor must take place in a relatively warm region to prevent freezing of the inhibitor by the cold hydrogen. Second, the effective distribution of the inhibitor by flow and diffusion to the desired area in the reactor must be accomplished.

The description of actual flow behavior not only in the areas left somewhat uncertain by interelement pressure data but throughout the core was left to a more positive experimental approach. The tracer gas technique was chosen as the experimental method because of its relatively simple approach, efficient implementation, and low cost.

C. OBJECTIVE

Based on the above noted uncertainties, prior experimental data, and analytical programs, the Plugged Core Tracer Gas Tests were designed with the following major objectives:

1. To develop tracer gas techniques which might find general use in solving complicated flow problems in reactor hardware.
2. To employ these techniques to define or "map" the leakage flow paths throughout the Plugged Core Reactor (ND 20702).
3. To explore the feasibility of injecting a gaseous corrosion inhibitor into the reactor during power tests.

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D. STATUS OF TEST PROGRAM

The FFL-17 Plugged Core Tracer Gas Test Program was begun in September 1964 with the conceptual design of the test and preliminary feasibility studies concerned with the tracer gas injection and sampling techniques and with the in-field modifications of the ND 20701 reactor. In the months following, the program proceeded from detailed equipment design and procurement through installation of test equipment in Test Cell A at Westinghouse Astronuclear Hydrogen Experimental Site (WANHES). The in-field modification of the ND 20701 to provide probes for injection and sampling of methane was also accomplished.

Initial check-out tests were conducted on January 27, 1965. From January until May 14, 1965, twenty-eight tracer gas tests were conducted in which methane was injected into the reactor under steady-state hydrogen flows at 300 psia core inlet pressure. The results of these tests, which included facility check-out and parameter optimization tests, were reported in WANL-TME-1160.⁵

From May 1965 until July 16, 1965 thirty additional tracer gas tests were conducted to complete the planned test program.⁶ The latter tests included additional 300 psia steady-state tests, 300 psia tests in which the sixteen effective seal chambers were vented to reduce core bundling, and 700 psia steady-state tests. Table I summarizes the tests conducted under the program showing the test series and test numbers involved.

Following the formal testing phase of the program, several errors were found in the previously published sensor lists^{2,5} and a full scale physical probing of the core was undertaken. Four errors were found. The data obtained from all previous tests was corrected to reflect the discovery of the erroneously located probes.

This report is a final report of the work carried out under Component Test FFL-17 through September 1965. It contains the summarized results and conclusions previously published in WANL-TME-1160 as well as the test results, analysis, and conclusions made since May 1965. The data herein presented contains all the corrections to sensor probe locations noted above.

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TABLE I
SUMMARY OF TRACER GAS TEST PROGRAM

Test Description or Objective	Number of Successful Tests Conducted	Core Inlet Pressure, psia	FFL-17 Test Numbers
Check-out and Feasibility	4	300	FFL-17-1, 2, 3, 4
Parameter Optimization	6	300	FFL-17-5, 6, 7, 9, 11
Low Pressure With In-Core Injection	21	300	FFL-17-10, 12 thru 26, 36 thru 43
Low Pressure With Above-Core Injection	3	300	FFL-17-28, 29, 30
Low Pressure With In-Seal Injection	4	300	FFL-17-32, 33, 34, 35
High Pressure With In-Core Injection	3	700	FFL-17-44, 45, 47
Low Pressure Seal Perturbation With In-Core Injection	8	300	FFL-17-49, 50, 51, 53, 54, 56, 57, 58

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For this reason, many of the detailed curves and tabulations previously reported are also included for reference. In addition sufficient descriptive material, previously reported, is included in this report to provide a more or less complete reference document for the FFL-17 program.

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II. EXPERIMENTAL

In that the experimental equipment and techniques were reported in complete detail in previous reports published under the Plugged Core Test Programs,^{2,4,5} the descriptions to follow are brief and to the point. They are included here to facilitate referral to the techniques employed during the tests and to illustrate characteristics of the test model and experimental equipment pertinent to the complete understanding of the test results.

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 Vessels⁷ and the assembly is located in Test Cell A at the Westinghouse Astronuclear Hydrogen Experimental Site (WANHES) as shown in Figures 1 and 2.

The ND 20702 is typical, mechanically speaking, of NRX-A reactor designs through NRX-A2 (ND 10201).^{8,9} It consists of a full core subassembly 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.

The ND 20702 includes several modifications to the basic NRX-A design in order to reduce hydrogen flow requirements of the test to a level within the WANHES capability, in order to reduce cost by the elimination of reactor components not of interest in attaining the test objectives, and in order to permit a more precise study of pressure and flow phenomena in the core and lateral support system. These modifications include:

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FIGURE 1

PLUGGED CORE REACTOR AND PRESSURE VESSEL

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FIGURE 2

TEST MODEL AND EXPERIMENTAL HARDWARE

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1. Substitution of a support assembly for the outer reflector control drum assembly.
2. Plugging of all main propellant flow channels in the elements and inner reflector and around tie rods.¹⁰
3. Substitution of an aluminum dome and external flow control loop to simulate the pressure drop across the upper aluminum shield and screen.
4. Installation of pressurizer probes in the inner reflector to permit remote pressurizing or venting of the seal chambers.
5. Installation of 37 interelement pressure probes in the core, 16 probes in the seal chambers, and other special sensors required in the tests.

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 those above the core. These aft end sampling probes penetrate the vessel through a flange in the aft closure 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.

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 3 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.

Table III lists the locations of the in-core pressure injector-sampling probes in the core while Table IV summarizes the locations of probes in the lateral support system. Figures 4, 5 and 6 further illustrate the relative placement of these probes. These figures and tables

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FIGURE 3

MODIFIED IN-CORE AND SEAL PROBES

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TABLE II

SUMMARY OF PROBE LOCATIONS ABOVE CORE AND IN AFT PLENUM

Probe Designation	Approximate Azimuth Θ (degrees)	Approximate Radius, R (inches)	Length From Top of Fuel, L (inches)
I 301	225	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	225	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

*Negative value indicates probe is above core.

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TABLE III
SUMMARY OF PROBE LOCATIONS IN CORE

Probe Designation	Cluster Assembly Element and Hole No.	Face of Element	Length from Top of Fuel, L (inches)	Nominal Radius, Θ (inches)	Nominal Azimuth, Θ (degrees)
DP 704	0-00-D-13	C	+ 7.16	0	----
DP 705	1-D4-D-13	C	+ 7.16	7.5	45
DP 706	3-D4-D-13	C	+ 7.16	7.5	165
DP 707	5-D4-D-13	C	+ 7.16	7.5	285
DP 708	3-J7-K-18	D	+ 7.16	17.5	165
DP 709	5-J7-K-18	D	+ 7.16	17.5	285
DP 761	1-G7-D-13	C	+ 7.16	13.5	45
DP 766	1-J6-K-2	A	+ 7.16	17.5	45
DP 714	1-D4-D-7	F	+ 18.40	7.5	45
DP 720	0-00-D-7	F	+ 18.40	0	----
DP 722	3-D4-D-7	F	+ 18.40	7.5	165
DP 730	5-D4-D-7	F	+ 18.40	7.5	285
DP 742	3-J7-K-16	E	+ 18.40	17.5	165
DP 762	1-G7-D-7	F	+ 18.40	13.5	45
DP 738	1-J7-K-18	D	+ 18.40	17.5	45
DP 716	1-D4-G-13	C	+ 29.65	7.5	45
DP 724	3-D4-G-13	C	+ 29.65	7.5	165
DP 732	5-D4-G-13	C	+ 29.65	7.5	285
DP 740	1-J9-P-18	D	+ 29.65	17.5	45
DP 743	0-00-G-13	C	+ 29.65	0	----
DP 751	5-J9-P-18	D	+ 29.65	17.5	285
DP 764	1-G7-G-13	C	+ 29.65	13.5	45
DP 718	1-D4-G-7	F	+ 40.90	7.5	45
DP 726	3-D4-G-7	F	+ 40.90	7.5	165
DP 734	5-D4-G-7	F	+ 40.90	7.5	285
DP 736	0-00-G-7	F	+ 40.90	0	----
DP 741	3-J6-H-18	D	+ 40.90	17.5	165
DP 746	5-J6-H-18	D	+ 40.90	17.5	285
DP 765	1-G7-G-7	F	+ 40.90	13.5	45
DP 767	1-J6-H-2	A	+ 40.90	17.5	45

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TABLE III (CONTINUED)

Probe Designation	Cluster Assembly Element and Hole No.	Face of Element	Length from Top of Fuel, L (inches)	Nominal Radius, Θ (inches)	Nominal Azimuth, Θ (degrees)
DP 719	1-D4-G-4	B	+ 46.52	7.5	45
DP 727	3-D4-G-4	B	+ 46.52	7.5	165
DP 735	5-D4-G-4	B	+ 46.52	7.5	285
DP 737	1-J7-K-16	E	+ 46.92	17.5	45
DP 747	0-00-G-4	B	+ 46.52	0	----
DP 748	5-J7-K-16	E	+ 46.52	17.5	285
DP 763	1-G7-G-4	B	+ 46.52	13.5	45

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TABLE IV
SUMMARY OF PROBE LOCATIONS IN INNER REFLECTOR

Approximate Azimuth, Θ (degrees)	Probe Designation	Length From Top of Fuel, L (inches)	Probe Designation	Approximate Azimuth, Θ (degrees)
17	DP 416	4.34	PP 401	197
163	DP 401	7.15	PP 402	343
73	DP 409	9.97	PP 403	253
277	DP 402	12.78	PP 404	103
97	DP 410	15.59	PP 405	263
43	DP 403	18.40	PP 406	223
113	DP 411	21.22	PP 407	287
173	DP 404	24.03	PP 408	347
187	DP 412	26.84	PP 409	7
293	DP 405	29.65	PP 410	127
217	DP 413	32.46	PP 411	37
53	DP 406	35.28	PP 412	233
307	DP 414	38.09	PP 413	133
157	DP 407	40.90	PP 414	337
353	DP 415	43.71	PP 415	167
283	DP 408	46.52	PP 416	107
67	DP 417	Aft Plenum	-----	---

Approximate radius for all probes: 18.21 inches.

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RELATIVE LOCATION OF IN-CORE PROBES

FIGURE 4

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RELATIVE LOCATION OF PROBES IN THE INNER REFLECTOR

FIGURE 5

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FIGURE 6

PLAN VIEW OF PROBE LOCATIONS IN CORE ON THE 45° AZIMUTH

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reflect actual locations of the sensor probes, by physical measurement in most cases, and include changes to probe locations previously published,⁵ notably probes DP 763, DP 764, DP 765, DP 738 and the seal pressurizer probes.

B. FLOW SYSTEMS

The flow systems schematically illustrated in Figures 7 and 8 were used throughout the Tracer Gas Tests to provide controlled, measured hydrogen and methane flows and sample acquisition. High pressure (2400 psia) gaseous hydrogen from supply trailers was fed through diaphragm actuated control valves to the vessel inlet. Inlet pressure was controlled by a pressure-recorder-controller through a feed back loop from pressure transmitters in the inlet piping through the controller to the air operated valve. Similar closed-loop control elements were used to maintain a specified back pressure on the core. Both inlet and outlet flow rates were measured by orifice meters monitored remotely.

Seal perturbations were accomplished by venting of the sixteen effective seal chambers through probes in the inner reflector and then through back pressure regulators to the vent system.

Methane was delivered to the reactor probes from a 2400 psia source through diaphragm actuated valves controlled by a feed back loop from the methane inlet manifold in the same manner as was the hydrogen flow. The flows were monitored remotely by orifice meters and a thermopile mass flow meter. Selection of injector probes was made by a flexible patching arrangement on the front of the sampling and injection panel shown in Figure 2 so that methane could be injected through any one of the 87 probes in the reactor.

Sample acquisition from each probe was controlled by sonic orifices 3, 6 or 9 mils in diameter. The forty samples of methane-hydrogen mixtures taken during each test were collected in 300 ml stainless steel gas cylinders. The selection of each of the 40 probes from the 85 available probes was also made on the patch panel and sample acquisition times were selected through an electrical network to solenoid valves in the sample lines. Samples of the

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HYDROGEN FLOW SYSTEM

FIGURE 7

TRACER GAS INJECTION AND SAMPLING FLOW DIAGRAM

FIGURE 8

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methane-hydrogen mixtures acquired during the tests were analyzed with a flame ionization hydrocarbon analyzer by feeding the gases from the 300 ml containers to the analyzer through quick-disconnect couplings on the sample containers.

C. DATA ACQUISITION AND REDUCTION

Data generated during the test was monitored and recorded remotely using several systems. The pneumatic system used primarily for pressure and flow control was also used to record pressures and flow rates in the inlet and outlet lines. Although this constituted the primary "quick-look" capability, other quick-look data was available from a multipoint potentiometer recorder for temperatures and methane flow rates and from a 24-channel oscillograph for core pressures and component movements.

The permanent dynamic record of the tests was made with the 100-channel FM multiplex data system at WANHES schematically shown in Figure 9. Core pressures and component movements and strains were recorded continuously on high speed tape from signals from strain gage transducers located in the test model.

In addition to these records, a photographic record was made for each test using an 8 x 15 inch frame camera for high precision. Pressures in the inlet and outlet plenums and in the seal chambers were recorded in this way directly from precise test gages in the test cell during the steady-state portions of the test.

Reduction of data from the photographic, oscillographic, potentiometric, and pneumatic recorders was straight forward in that values were scaled directly from the charts or photographs. Multiplexed data was played back through filters for demultiplexing and recorded on the oscillograph. Values scaled from the oscillograph traces were then converted to engineering units, analyzed, and compiled through IBM 7094 computer programs.

D. EXPERIMENTAL TECHNIQUES

Each test was conducted in basically the same manner. Following system check-out of flow controls, data acquisition equipment, and safety devices, the entire flow system and

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SYSTEM LAYOUT, WANHES DATA ACQUISITION SYSTEM

FIGURE 9

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pressure vessel were evacuated and purged twice with dry nitrogen. Gaseous hydrogen flow was then established through the reactor to the vent flare and core inlet pressure and pressure drop were set on automatic control. At the attainment of steady-state hydrogen flows at the control points desired (including seal chamber venting), methane flow was established to the injector probe and placed on automatic control at the desired flow rate.

When steady-state methane and hydrogen flows were attained, sample line purging was established by opening vent solenoids in the sample lines. This insured that the same methane concentration that existed inside the test model also existed at the inlet to the sample acquisition cylinders. During the purging operation, the sample cylinders were evacuated to less than 1 mm of mercury. At a preselected time the purge flow was diverted from the vent to the sample cylinders and samples were acquired over a one to two minute interval at a constant flow rate approximating single channel interelement flow.

Following sample acquisition, solenoids were actuated to seal the sample cylinders, and both methane and hydrogen flows to the reactor were halted. Normal shut-down and securing of the system, including additional purges and evacuation, then preceded analysis of each of the forty samples from the cylinders using the hydrocarbon analyzer.

The entire operating procedure and check lists used consistently during these tests can be found in WANL-TME-1160.

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III. RESULTS

The tests in this series were limited to those in which methane was injected through probes in the seal chambers, above the core, or in the core near the 45° azimuth of the core since that azimuth contains the fullest complement of sampling and injection probes. The assumption inherent in this plan is that, in a gross sense, the behavior of leakage flows at that azimuth is typical of the behavior at other azimuths. The core was mapped as to pressure profiles and flow direction profiles under steady-state hydrogen flow at 300 and 700 psia core inlet pressure and under the vented seal chamber or reduced core bundling mode at 300 psia. A total of forty-five core mapping tests were successfully conducted in which, typically, forty samples were acquired from probes in the core, in the seals, and at the core exit plane. Injection was accomplished at least once through 17 of the 20 available in-core probes on the 45° azimuth as well as in several in-seal probes and above-core probes near the 45° azimuth. The results are discussed below.

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.¹¹

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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 was designed according to Table V 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

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TABLE V
EXPERIMENTAL DESIGN FOR PARAMETER OPTIMIZATION

		Nominal Injection Rate r_1 , lb/sec	Nominal Injection Rate r_2 , lb/sec	Nominal Injection Rate r_3 , lb/sec
		1.5×10^{-4}	3.0×10^{-4}	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

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the probes were equivalent from the point of view of injection and its effect on the 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 results of the experimental design tests showed some effect of sampling and injection rate at the 40.9-inch core station but, in general, did not provide clearly defined optimum conditions for these parameters. One of the reasons for this outcome is the fact that the parameters were not varied over wide ranges since the various rates were selected to be within the range of a hypothetical single channel interelement flow based on a comparison of previous analytically computed and experimentally measured leakage flow rates. Another reason, discovered after more complete tracer gas studies had been conducted, is the fact that the flow on the 13.5-inch radius is basically axial except near the aft end and shows little deviation from that radius regardless of the injector probe employed.

These results did, however, corroborate the fact that the proper range of variables was chosen, in that clearly defined concentration profiles were attained, and a minimum of perturbations to the normal core leakage flow regimes appeared to be indicated from pressure and flow measurements. In view of these considerations, other effects were studied to establish the optimum parameters.

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

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be less likely at lower methane rates, an optimum flow rate of 1.6×10^{-4} lb/sec methane was selected for the 300 psia tests. In several of the injector locations where test results appeared to be uncertain or unusual, injection was repeated at lower rates to minimize, even further, the influence of injection on the observed results. Even in these tests, the use of rates lower than 1.6×10^{-4} lb/sec did not improve the technique or the adequacy of the results.

The methane flow rate for the 700 psia tests was not determined experimentally since only a few 700 psia tests were planned to corroborate the 300 psia results. Instead the rate was determined by scaling up the rate at 300 psia to 2.5×10^{-4} lb/sec in the same proportion as the ratio of calculated full core leakage rates at the two pressures. Similarly, for the tests in which methane was to be injected in the seal chambers, the rate was calculated from known seal flow rates to give a methane concentration as high as possible within the capability of the hydrocarbon analyzer. For the case of injection above the core, methane injection rate was established from known hydrogen flow rates to attempt to match velocities in the plenum between the core and core support plate while providing sufficient methane flow for adequate definition of peak concentrations in the core.

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 at both 300 psia and 700 psia.

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

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were attained in the reactor was selected as optimum for the remaining tests at 300 psia. For the 700 psia series, a purge time of only 60 seconds was dictated by the hydrogen supply capability in that steady-state run times were limited to a relatively short period of three to four minutes.

B. CONCENTRATION PROFILES

1. Data Presentation

Up to forty samples of methane-hydrogen mixtures were acquired during each test from probes selected before hand as being of greatest interest. Samples were analyzed for methane content with a hydrocarbon analyzer and these concentrations were plotted versus radial and axial location in the core to define the direction of flow from the point of injection. The locus of peak concentrations at each axial position was taken as the center of the tracer gas stream. Figures 10 through 14 are typical concentration profiles obtained in this manner. Each of these groups of curves illustrate a typical set of parameters and will be explained in turn. The entire set of profiles for all tests are included in Appendix A with the detailed data tabulations.

Figures 10, 11 and 12 show profiles for steady-state tests in which normal leakage flows were established at 300 psia core inlet pressure and 130 psia core pressure drop with a normal seal pressure distribution. Figure 10 shows the profiles on the 45° azimuth resulting from an in-core injection at the 13.5-inch radius 7.2-inches from the top of the core fuel elements. Figure 11, typical results for injection through probes above the core, shows profiles for injection at the 15.4-inch radius, 0.5-inch above the core. Figure 12 is a typical result for injection in the seal chambers. In each case the concentration data at the three azimuths in the core are presented as individual points. The faired curves are profiles for the 45° azimuth only.

Figures 13 and 14 are typical results for in-core injection on the 13.5-inch radius for two additional sets of operating conditions. Figures 13 is the data from a test at 300 psia

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FIGURE 10

CH₄ CONCENTRATION PROFILES - FFL-17-5

FIGURE 11

CH₄ CONCENTRATION PROFILES - FFL-17-28

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FIGURE 12

CH₄ CONCENTRATION PROFILES - FFL-17-34

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FIGURE 13

CH₄ CONCENTRATION PROFILES - FFL-17-50

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core inlet and 130 psi core pressure drop with the seal pressures vented to values lower than normal to reduce core bundling. Figure 14 is for a steady-state unperturbed test at 700 psia core inlet pressure and 130 psia core pressure drop.

Although a more complete discussion of the ramifications of these curves will be included later in the discussion of flow lines, some general characteristics should be noted here:

(a) Theoretically one would expect peak concentrations downstream of the injector to decrease in magnitude as dilution with hydrogen occurs. This is generally borne out by the data for the in-core and in-seal injections with the exception of some of the data at the 40.9 and 46.5-inch core stations. This is explainable when one considers that the probes are not located directly on the 45° azimuth and that the solid interfaces of the fuel elements interfere with continuous flow characteristics. Thus a given probe can actually miss detecting the tracer gas stream depending on local flow phenomena in the area of the probe.

(b) Injection in the plenum above the core was not as successful as anticipated because of two factors. One, the attainment of isokinetic injection was difficult and flooding of the core inlet plenum with methane occurred. Two, leakage flow through the dome end seal between the core and support plate caused a sweeping action away from the injector so that precise definition of the point of injection into the core was obscured.

(c) Concentrations at the aft end of the core were often orders of magnitude higher than in-core concentrations. Flow from the interelement channels into the main flow channels of the elements, because of graphite permeability, is a possible explanation for this phenomenon. Thus high concentration gas near the injector could have flowed into the flow channels and been sampled after flowing out of the support blocks. A second explanation is the mixing effect which might occur above the support blocks due to the element undercut.

(d) High methane concentrations were found on the 285° azimuth indicating that some peripheral communication was present.

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2. Accuracy

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 fixed or random 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 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 characteristic is that, in terms of random errors in the analyzer, the concentration data obtained in these tests and plotted on the concentration profiles have approximately the same accuracy at the low concentrations near 1 ppm as those approaching 3000 ppm. The fixed errors noted above (such as inadequate purging of sample bottles) would tend to effect the lower concentrations more unfavorably since these are absolute rather than relative in nature. These were minimized by frequent calibration of the analyzer and by analysis of known mixtures using the actual sample cylinders after purging. Since it was impractical and often impracticable to perform such calibrations for each probe and sample container, it must be assumed that some fixed errors are present in the concentration data and that the effect of these errors is greatest at low concentrations. Knowledge of this fact tends to explain the often encountered result of obtaining measured methane concentrations of sample mixtures actually lower than those found in the hydrogen supply.

The curves drawn through the experimental points to give radial concentration profiles are best fit or faired curves. These were drawn through the points with the assumption that an exponential function similar to the Gaussian distribution best describes the physical model present. This might be the case when one considers mass transport of one fluid from a

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point source in a moving stream of a second fluid. Some attempts were made to describe the profiles analytically based on the mechanism of diffusion from a point source but the results failed to agree with experimental values. These efforts were abandoned in favor of the best-fit curve approach to determining the peak concentrations on the profiles.

As in the case of the interpretation of interelement pressure data, the drawing of faired curves through the four radial, experimental points at each axial location involves a basic assumption. That is, that the core exhibits sufficient radial and azimuthal communication through interconnecting channels between elements so as to be considered continuous as to transport properties. This assumption is, as noted, inherent in the use of analytical techniques as well as experimental techniques in defining a continuous function or property along an axial plane. It should be noted that the determination of the degree of communication in the core is one of the objectives of the test series and that the assumption of that which is to be determined represents a commonly employed technique. For if the results are consistent with the assumption, the correctness of the latter is supported.

The exact shape of the faired curves drawn on the concentration profiles represent an attempt to use a typical shape for all the data. Admittedly, the behavior can be considerably different at various core regions and in fact can be discontinuous in many areas in which elements are essentially so tightly stacked as to effectively eliminate interchannel flow. This fact was considered in arriving at the peak concentrations on these curves which were taken as tracer gas stream centerline. Each set of four radial points was fitted by a variety of curve shapes from exponential bell shaped curves and parabolic curves to more or less linear curves. A range of centerline locations was obtained in this way for each axial location. These ranges are plotted on the flowline curves to be presented later and represent the two extremes of possible values for the location of the tracer gas stream.

Considering the results of the analysis of variance experiments, the effects of data acquisition errors, and the determination of maximum ranges obtained from the faired curves, the estimates of tracer gas stream centerline, R_o , have a standard deviation of 0.5-inches on

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the average. 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 values for R_o may vary by up to ± 2.0 -inches depending on the location downstream of the injector probe. In general, very few of the points presented in the flow line curves which follow have uncertainties as high as ± 2.0 -inches and data found to have greater uncertainties are not presented on these curves.

C. FLOW LINES

The radii at which peak methane concentrations occurred are inferred from the concentration profiles. When these points are plotted against axial core station they form a locus of points which represents the path taken by the stream of tracer gas as it flows with the hydrogen through the core. Table VI is a summary of the loci obtained in this manner for all tests. The table also indicates the injector probe and location, the test mode, core inlet pressure, sampling orifice size, and injection rate. Figures 15 through 24 show the same data plotted as leakage flow paths through the core and between the lateral support system and core. These results will be discussed in terms of the area of the core in which they were measured and in terms of the other parameters varied during the tests such as core inlet pressure and seal pressure venting.

1. Normal, Unperturbed Flow at 300 PSIA

The most extensive core mapping was performed at 300 psia core inlet pressure with a pressure drop of 130 psia. Injection was accomplished in the core and seal chambers and above the core while samples were taken at stations in the core and seals and in the aft plenum near the core exit plane.

Flow from the injector probes in the center of the core was found to be generally axial in the top 40-inches of the core as shown by Figure 15. The concentration peaks on this locus were well defined in the upper portions of the core as indicated by the small bands of

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TABLE VI

SUMMARY OF THE LOCI OF TRACER GAS STREAM CENTERLINES

FRL-17 Test Number	Test Mode	Nominal Core Inlet Pressure, psia	CH ₄ Injection Rate, lb/sec x 10 ⁴	Injection Mode	Injector and Nominal Location				Sample Orifice Size, mils	Tracer Gas Stream Centerline, R ₀ , at Elevation, L, In Inches						
					Probe	Azimuth deg.	Radius in.	Elevation in.		- 0.5	7.2	18.4	29.7	40.9	46.5	54.5
5	N	300	2.91	In-Core	DP 761	45	13.5	7.2	3		13.5	13.5	13.5	13.0	13.5	11.4
6	N	300	1.71	In-Core	DP 761	45	13.5	7.2	3		13.5	13.5	12.8		13.5	11.4
7	N	300	6.15	In-Core	DP 761	45	13.5	7.2	3		13.5	13.5	13.5	13.5	13.5	11.6
9	N	300	1.06	In-Core	DP 761	45	13.5	7.2	9		13.5	13.5	12.5	11.0	13.5	11.8
10	N	300	1.06	In-Core	DP 705	45	7.5	7.2	9		7.5	7.5			13.5	
11	N	300	2.92	In-Core	DP 761	45	13.5	7.2	9		7.5	13.5	13.5		13.5	11.6
12	N	300	3.06	In-Core	DP 705	45	7.5	7.2	9		7.5	7.5	7.5	6.5		
13	N	300	3.53	In-Core	DP 704	45	0	7.2	9		0	0	0	0		1.2 & 13.0
15	N	300	3.10	In-Core	DP 766	45	17.5	7.2	9		17.5	14.0	11.4	11.5	17.5	17.5
16	N	300	3.11	In-Core	DP 720	45	0	18.4	9			0	0	0		1.2
17	N	300	1.71	In-Core	DP 714	45	7.5	18.4	3			7.5	10.4		13.5	7.0 & 13.0
18	N	300	1.58	In-Core	DP 762	45	13.5	18.4	3			13.5	13.5		13.5	11.5
19	N	300	1.60	In-Core	DP 743	45	0	29.7	3				0	0	4.0	0 & 13.0
20	N	300	1.89	In-Core	DP 716	45	7.5	29.7	3				7.5	7.5		14.0
21	N	300	1.54	In-Core	DP 763	45	13.5	46.5	3				13.5	13.5	13.5	10.6
22	N	300	1.71	In-Core	DP 740	45	17.5	29.7	3				17.5	(13.5)		13.5
23	N	300	1.65	In-Core	DP 738	45	17.5	18.4	3			17.5				14.2
24	N	300	1.68	In-Core	DP 764	45	13.5	29.7	3				13.5	(13.5)		11.0
26	N	300	1.75	In-Core	DP 738	45	17.5	18.4	3			17.5	10.2			14.2
28	N	300	1.72	Above-Core	I 307	45	15.4	- 0.5	3	15.4		13.5	12.0	13.5		17.0
29	N	300	2.45	Above-Core	I 302	45	1.8	- 0.5	3	1.8	9.8		11.4	10.4	13.0	3.8
30	N	300	2.56	Above-Core	I 304	45	6.9	- 0.5	3	6.9						4.0
32	N	300	25.5	In-Seals	DP 416	7	18.0	6.3	3		17.5	13.5	17.5		13.5	13.0
33	N	300	22.2	In-Seals	PP 404	97	18.0	12.8	3			12.8	17.5	(13.5)	12.2	
34	N	300	25.7	In-Seals	DP 403	43	18.0	18.4	3			13.0	17.5		13.0	14.4
35	N	300	19.4	In-Seals	PP 413	128	18.0	38.1	3						12.8	8.6
36	N	300	1.45	In-Core	DP 718	45	7.5	40.9	3					7.5	12.4	6.5 & 16.0
37	N	300	1.59	In-Core	DP 719	45	7.5	46.5	3					7.5	7.5	5.6 & 16.0
38	N	300	1.85	In-Core	DP 765	45	13.5	40.9	3				13.0	13.5	13.5	10.1
39	N	300	1.10	In-Core	DP 719	45	7.5	46.5	3					7.5	7.5	5.5 & 16.0
40	N	300	0.84	In-Core	DP 719	45	7.5	46.5	3					7.5	7.5	5.5 & 16.0
41	N	300	1.05	In-Core	DP 736	45	0	40.9	3				0	0	(13.5)	0 & 16.0
42	N	300	0.88	In-Core	DP 765	45	13.5	40.9	3					13.5	13.5	10.1
43	N	300	1.00	In-Core	DP 716	45	7.5	29.7	3				7.5	7.5		7.0 & 15.0
44	N	700	1.21	In-Core	DP 704	45	0	7.2	3		0					0 & 14.0
45	N	700	2.18	In-Core	DP 705	45	7.5	7.2	3		7.5	11.6	8.6		(10.8)	15.0
47	N	700	3.07	In-Core	DP 761	45	13.5	7.2	3		13.5	13.5	13.5		13.5	13.0
49	P	300	1.59	In-Core	DP 705	45	7.5	7.2	3		7.5	9.4	8.2		11.0	14.0
50	P	300	2.08	In-Core	DP 761	45	13.5	7.2	3		13.5	13.5	13.5		12.6	12.5
51	P	300	1.97	In-Core	DP 766	45	17.5	7.2	3		17.5	13.5			13.0	17.5
53	P	300	1.51	In-Core	DP 719	45	7.5	46.5	3				9.8	7.5	7.5	5.4 & 16.0
54	P	300	1.51	In-Core	DP 718	45	7.5	40.9	3					7.5		7.0 & 17.5
56	P	300	2.11	In-Core	DP 716	45	7.5	29.7	3				7.5	7.5	14.5	6.4 & 16.0
57	P	300	1.92	In-Core	DP 714	45	7.5	18.4	3			7.5	7.5	8.5	12.6	7.0 & 16.0
58	P	300	1.71	In-Core	DP 740	45	17.5	29.7	3			12.5	17.5		12.8	17.5

() Indicated Estimated Values.
P Perturbed Seal Pressures.
N Normal Seal Pressures.

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uncertainty drawn about the points. In the last ten inches of the core the flow direction changes abruptly toward the periphery. Because the methane stream is diluted appreciably in the bottom portions of the core, the confidence bands around these points are considerably higher. However, the shift in flow direction is not masked by the larger uncertainties.

A high primary peak was also measured on the centerline at the core exit plane and a second flow path between 40-inches and core exit is shown on the centerline in Figure 15. Unfortunately, the effect of graphite permeability renders the interpretation of this path uncertain. For if we assume that hydrogen and methane flow through the walls of the elements from the interelement channels to the main flow channels under the positive pressure gradient that normally exists between the two channels, then the high concentrations picked up by the core outlet probes could have come directly down a flow channel. If this phenomenon occurs, the flow path indicated at the centerline in the aft end of the core is really not an interelement leakage path but a main propellant path. If a true interelement leakage path did exist it would be masked by the effect of the high concentration flow into the flow channel. One piece of evidence tends to deny the existence of a real axial leakage path below 40-inches. This is the absence of any concentration peaks on the centerline at 46.5-inches.

The inference of outward flow was made largely on the basis of several values on the 46.5-inch level and on the existence of a secondary peak on the concentration profiles obtained at the core exit plane. The existence of this outflow could not be inferred with a high degree of confidence on the basis of the points at 46.5-inches alone, but the combined evidence at the two axial levels gives strong support to the flow directions plotted. In addition, the effects of graphite permeability would tend to be less severe as we move radially from the point of injection. Thus the secondary peak, in spite of its lower magnitude, has a higher probability of being caused by a true interelement leakage path than one nearer the centerline.

Figure 16 shows similar results obtained for injection on or near the 7.5-inch radius of the core. Several of the points in the central portion of the core show larger uncertainties than at similar levels on the centerline. These may be a result of local disturbances

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FIGURE 15

FLOW LINES FOR INJECTION ON CORE CENTERLINE,
 300 PSIA, UNPERTURBED SEAL PRESSURES

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FIGURE 16

FLOW LINES FOR INJECTION ON THE 7.5-INCH CORE RADIUS,
300 PSIA, UNPERTURBED SEAL PRESSURES

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which cause flow to be diverted from individual sample probes. The same result is generally observed, however. Flows on the 7.5-inch radius are axial in the top 40-inches of the core and are peripherally directed in the aft end of the core.

The same characteristic dual-peak concentration profiles were measured at the core exit plane with the higher peaks at the 7.5-inch radius and lower secondary peaks from the 12-inch radius to the core periphery. The same comments concerning graphite permeability effects apply here as for the centerline flow lines. That is, the secondary peaks in spite of their lower value have a high probability of being a result of true interelement flows since the influence of permeability decreases as we move radially from the injection point.

The flow line inferred from numerous concentration profiles obtained from injection on the 13.5-inch radius are shown in Figure 17. Except for a small amount of scatter at the 40-inch level, the tests contributing to this curve show great consistency. The flow path is axial over the top 46-inches of the core and bends inward slightly toward the aft end. The absence of a peripherally-directed flow is somewhat in conflict with the previous results especially if we consider the fact that this flow line crosses the two previously presented. There are several possible explanations:

- (a) The flow channels on this radius, especially near the aft end of the core, may not exhibit a high degree of interchannel communication. Thus the flow would continue axially as though it were in a sealed tube and would flow from the core on the same radius.
- (b) Porous flow into the element flow channels could be responsible for the high peak concentrations measured on the aft end probe at about 11-inches from the centerline. A secondary peak similar to those obtained for injection on the centerline and 7.5-inch radius would be masked. In addition, the core outlet probes extend radially only to the 15.4-inch radius. If a secondary peak occurred beyond this radius it would not be picked up by the probes.
- (c) If outflow does occur from the 13.5-inch radius and does not cross the flow lines from the centerline and 7.5-inch radius, it would have to reach the core periphery near Station 50. At this point it would flow into the seal system and would not be picked up by the aft end probes.

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FIGURE 17

FLOW LINES FOR INJECTION ON THE 13.5-INCH CORE RADIUS,
300 PSIA, UNPERTURBED SEAL PRESSURES

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Figures 18 and 19 show flow lines near the core periphery which were obtained from methane injections in the seal chambers and on the 17.5-inch radius. Although the uncertainties are somewhat greater in certain areas of the core - notably core station 40.9 - than for previous flow lines, the general indication of inflow from the seal system is unmistakable in the top 40-inches of the core. In the last ten inches, results are less certain. Several tests indicate an outward flow consistent with flow lines from other radii. Other tests indicate a less severe outflow, but the trend of flow toward the periphery is still evident. Previously discussed influences are again applicable: failure to pick up flow that has entered the seal system, axial flow of gas that has entered the flow holes through pores in the graphite, axial flow in a locked or sealed channel near the 13.5-inch radius, and radial flow along the element undercut.

Considerable effort was exerted in defining the behavior near the high pressure area at core station 46.5 since the isobars drawn from experimental and theoretical considerations indicated a possible back flow from the 46.5-inch elevation to the 40.9-inch elevation.⁵ Figure 20 shows the results of the injections on the 7.5-inch radius at station 46.5. Three tests were conducted at decreasing injection rates to minimize the effect of forcing the tracer gas into the flow channel to a higher core elevation. Even at the lowest injection rate, a clearly defined peak was observed at station 40.9. This could be taken as conclusive evidence of back flow were it not for two confounding effects.

First, the injector probes are sealed into the element flow holes at the top but have a small clearance between the outside diameter of the probe and the flow channel. Methane flow from the tube and up the flow channel in this annular space is possible, although the actual extent is unknown. Flow of methane up the channel to higher elevations in the core and permeation into the interelement channel could account for the apparent back flow. Second, small pressure perturbations due to injection could force methane up the channel to higher elevations. There is some evidence that the former phenomenon is not an influence, for the extremely high peaks observed at 40.9-inches are not evident at higher elevations. The

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FIGURE 18

FLOW LINES FOR INJECTION NEAR THE CORE PERIPHERY,
300 PSIA, UNPERTURBED SEAL PRESSURES

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FIGURE 19

FLOW LINES FOR INJECTION IN THE SEAL CHAMBERS,
300 PSIA, UNPERTURBED SEAL PRESSURES

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FIGURE 20

FLOW LINES FOR INJECTION NEAR THE AFT END OF THE CORE,
300 PSIA, UNPERTURBED SEAL PRESSURES

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latter phenomenon is difficult to evaluate since, in fact, measured pressures at 40.9-inches were lower than at 46.5-inches and the effect of a perturbation on injection would be acting in concert with an existing negative pressure gradient in that area of the core.

2. Seal Venting or Perturbed Flow at 300 PSIA

The effects of perturbing the seal pressure distribution by venting the sixteen effective seals are shown in Figures 21, 22, and 23. The flow lines on the 7.5-inch, 13.5-inch, and 17.5-inch radii as well as those near the aft end are similar to those for unperturbed flow. Within the accuracy of the measured concentration peaks, the reduction of seal pressures appears to have had little effect on the general flow patterns in the core. Additional probes would be required to measure these effects since the magnitude of the change in flow lines which might be expected are well within the inter-probe distances in the core.

3. Normal, Unperturbed Flow at 700 PSIA

The behavior of the core at 700 psia was studied briefly to explore the effect of higher pressures on leakage flows. The results for the three successful tests are shown in Figure 24. The injection rates for these tests were not optimized experimentally, and as a result, the data has considerably greater uncertainty than that obtained in the 300 psia tests. Generally, the same behavior is noted at the centerline and 13.5-inch radii. For the case of injection on the 7.5-inch radius, the leakage path is less consistent with the 300 psia results.

4. Azimuthal Variations

The interpretation of results which led to the flow lines presented above assumed a two dimensional flow model on the 45° azimuthal plane. That this assumption is not wholly correct is obvious when we consider the local variations to continuous flow which uneven bundling of fuel elements would cause. For example, in some areas of the core adjacent faces of elements might be so intimately in contact under high local fluid and mechanical bundling forces that flow between them is negligible. Flow from higher elevations would be diverted from the axial direction both in the 45° plane and in other azimuthal directions.

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FIGURE 21

FLOW LINES FOR INJECTION ON CORE PERIPHERY,
300 PSIA, PERTURBED SEAL PRESSURES

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FIGURE 22

FLOW LINES FOR INJECTION ON THE 7.5-INCH CORE RADIUS,
300 PSIA, PERTURBED SEAL PRESSURES

FIGURE 23

FLOW LINES FOR INJECTION ON THE 13.5-INCH RADIUS AND
NEAR THE AFT END OF THE CORE, 300 PSIA, PERTURBED SEAL PRESSURES

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FLOW LINES FOR INJECTION ON CORE CENTERLINE, 7.5-INCH RADIUS,
AND 13.5-INCH RADIUS, 700 PSIA, UNPERTURBED SEAL PRESSURES

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Experimental evidence of flow in the azimuthal direction is available. In numerous tests in which samples were taken from the 165° and 285° azimuth probes, high methane concentrations were found, especially on the 285° azimuthal plane. Figures 25 and 26 are the data from two tests which illustrate this point; numerous additional instances of the phenomenon are illustrated in the concentration profiles in the Appendix. The significant, consistent indication in each instance is a strong tendency for flow to occur from the 45° azimuth to the 29.7 and 40.9-inch core stations on the 285° azimuth. Concentration peaks at these two points are actually higher in many cases than at corresponding core stations on the 45° azimuth. Moreover, the peaks are apparent regardless of the radius at which methane was injected. Even injection in the seal chambers indicated a strong tendency for flow toward the 285° azimuth.

No conclusive remarks concerning the cause of this behavior will or should be attempted at this point. The availability of probes in the core particularly on the 285° and 165° azimuths is limiting, and any assertion as to possible flow mechanisms carry with them the large inherent uncertainties. The following mechanisms should be considered:

(a) The pressures measured at the 40.9-inch elevation on the 285° azimuth 7.5-inches from core centerline are consistently lower for this test series than at other azimuths. If the plug in the element flow channel were leaking, the pressure in the area of the pressure probe would be essentially core outlet pressure and a relatively large opening would exist for flow directly to the aft plenum. This would form a large sink area at this location which could communicate to other azimuths.

(b) If the low pressures measured at this point were true interelement pressures, a strong argument could be advanced that the interelement channel in this area was large enough to communicate with the core outlet plenum. This mechanism would also act as a flow sink.

(c) A cracked or perforated element in this area could present a large connecting path between the local region and core outlet which would also tend to pull flow into the area.

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FIGURE 25

CONCENTRATION PROFILES FOR THREE AZIMUTHS - FFL-17-13

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FIGURE 26

CONCENTRATION PROFILES AT THREE AZIMUTHS - FFL-17-12

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In view of the strong evidence that flow actually occurred in three dimensions - that is axially, radially, and azimuthally - for these tests, the interpretation of concentration profiles and flow lines must be made with an understanding of what they actually represent. The flow lines drawn for the 45° azimuth are really projections of the flow lines in the general sector of 45° onto one plane. The local changes in direction of the stream as it flows through the reactor are impossible to predict based on the sparsity of probes available for sampling.

D. MATERIAL BALANCES

Flow rates of hydrogen were measured in the vessel inlet and outlet lines during each test. The primary interests in monitoring hydrogen flow rates were twofold: One, flow rates have been found to be highly sensitive to pressure profiles in the reactor. The attainment of anticipated flow rates was, therefore, taken as an excellent means of insuring on-control or stable test operation. Second, the hydrogen flow and methane flow mix in the aft plenum and core outlet lines. Sampling of this mixture and analysis for methane enables one to calculate methane flow rates based on known hydrogen flow rates. This technique constitutes a check on the overall adequacy of injection rate predictions.

Table VII summarizes the rate data for these tests. The magnitude of hydrogen flow rates at 300 psia and 700 psia core inlet pressure were within 5 percent of those measured in previous tests.^{2,4,5} The overall agreement between inlet and outlet flow rates for these tests is about 2 percent on the average. Calculated and measured methane flow rates agree to within an average deviation of 18 percent. The correlation of calculated and measured results for methane concentration are shown in Figure 27.

E. PRESSURE PROFILES

Pressure distributions were obtained for every test in the series. Of these, twenty-four were chosen for reduction, compilation, and analysis of pressure data. These tests represent a sampling from each of the three sets of nominal test conditions. Interelement and seal system pressure data are tabulated in Appendix B for the twenty-four tests. Radial pressure profiles

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TABLE VII
SUMMARY OF FLOW RATE DATA

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	Seal Venting 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-17-23	299	133	67	75	.318	.324		292	73	1.65	72.0	64.3
FFL-17-24	302	129	58	71	.334	.318		315	71	1.68	71.0	64.2
FFL-17-25	303	136	75	73	.327	.334		343	75	1.74	69.0	65.7
FFL-17-26	303	136	68	72	.320	.327		289	79	1.75	65.0	67.8
FFL-17-27	301	135	75	75	.326	.331		301	75	3.40		130.0
FFL-17-28	302	135	75	76	.317	.321		302	80	1.72		67.8
FFL-17-29	301	135	53	50	.334	.347		306	51	2.45		89.8
FFL-17-30	297	131	58	50	.317	.327		294	51	2.56		100.0
FFL-17-31	304	135	62	54	.359	.337		305	54	0.59		21.2
FFL-17-32	302	135	73	74	.344	.341		424	75	25.5	1000	933
FFL-17-33	301	132	70	76	.322	.329		294	75	22.2	460	748
FFL-17-34	299	130	78	79	.344	.339		424	80	25.7	935	943
FFL-17-35	304	135	75	80	.313	.321		234	83	19.4	720	767
FFL-17-36	302	135	79	80	.326	.319		236	78	1.45	58.0	56.0
FFL-17-37	299	127	79	80	.331	.329		274	81	1.59	59.0	59.8
FFL-17-38	303	133	76	81	.330	.326		264	83	1.85	58.0	70.6
FFL-17-39	299	130	54	60	.343	.342		274	75	1.10	29.8	40.3
FFL-17-40	299	130	68	73	.332	.327		272	75	0.84	19.5	32.8
FFL-17-41	302	133	54	66	.335	.327		224	63	1.05	26.8	39.6
FFL-17-42	303	134	52	62	.342	.337		224	62	0.88	28.5	32.3
FFL-17-43	299	130	53	62	.326	.321		277	62	1.00	28.0	38.6
FFL-17-44	702	133	73	80	.589	.588		684	81	1.21		25.7
FFL-17-45	699	130	74	81	.525	.546		689	83	2.18	55.0	51.0
FFL-17-46	699	130	87	87	.557	.557		649	85	1.54	31.0	34.5
FFL-17-47	699	130	84	88	.563	.560		694	85	3.07	71.0	68.4
FFL-17-49	303	131	76	84	.403	.257	.146	286	84	1.59	74.0	77.6
FFL-17-50	296	127	76	84	.393	.251	.142	283	85	2.08	100	104.0
FFL-17-51	299	133	87	82	.402	.260	.142	822	83	1.97	88.0	94.5
FFL-17-53	296	129	80	84	.402	.254	.148	249	84	1.51	70.0	74.5
FFL-17-54	300	129	82	84	.397	.257	.140	223	85	1.51	81.0	73.7
FFL-17-56	296	130	81	83	.397	.254	.143	279	81	2.11	108	104.0
FFL-17-57	301	132	77	82	.399	.260	.139	294	81	1.92	94.0	92.4
FFL-17-58	294	128	80	83	.386	.246	.140	233	83	1.71	96.0	86.8

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TABLE VII (CONTINUED)
SUMMARY OF FLOW RATE DATA

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

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FIGURE 27

CORRELATION BETWEEN CALCULATED AND
MEASURED METHANE CONCENTRATIONS

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in the core are also plotted on curves in the Appendix. Tests FFL-17-5 through 22, previously reported,⁵ are included to account for several errors in pressure probe locations in the previous data. The corrections, in every case, were minor.

Pressures were measured at each of the in-core probes shown on Figure 4, on the seal probes shown on Figure 5, and at the core inlet and outlet. A tabulation of probe locations appears in Table III. 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 precise test gages accurate to about $\pm 1/2$ percent 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 sources of error are:

1. Transducer calibration, linearity, and offset.
2. Calibration of amplifiers and other transmitting elements of the data acquisition system.
3. Calibration of recording and playback equipment in the tape recorders.
4. Calibration of FM multiplex playback discriminators.
5. Calibration of recording oscillographs used in data playback.
6. Reading error inherent in the scaling of values from the oscillograph traces, photographs, and pneumatic charts.

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

Core Inlet Pressure	$\pm 2\%$ of Indicated Value
Individual Seal Pressures	$\pm 2\%$ of Indicated Value
Individual Core Interelement Pressures	$\pm 5\%$ of Indicated Value

Where values for individual sensors are not reported, one of the following conditions may be presumed to have existed:

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1. The transducer was inoperative or its range exceeded.
2. Excessive noise existed on the data channel making data reduction for the channel meaningless.
3. That particular probe was used for methane injection during the test and hence the pressure measured was not indicative of that in the core.

Because most of the pressure sensors are located internal to the pressure vessel, transducer damage in many cases could not be corrected. It will be noted that the same sensor data are consistently missing from the tabulated results for this reason.

1. Seal Pressure Distribution

Seal pressures were measured with differential gages which were referenced as shown in Figure 28. The differential pressure across one or more seals was measured and the absolute seal pressure determined by successively subtracting this value from the reference or seal pressure above it. It should be noted that all seal pressures were then referenced against core inlet pressure. This pressure was measured by three separate instruments: strain gage pressure transducer P703, pneumatic pressure transmitter PT-2, and a Heise gage. The accuracy of this measurement and the entire seal pressure profile could be further checked by calculating the aft end pressure (P710), by successive subtraction of the seal differential pressures from the core inlet pressure (P703), and comparing this with the measured value. The aft end pressure was also measured by three separate instruments: strain gage pressure transducer P710, pneumatic pressure transmitter PT-3, and a Heise gage. The values of the differential pressure gages and Heise gages were recorded on photographic film approximately every two seconds.

A parallel seal pressure measurement system of 0 to 50 psid strain gage differential pressure transducers was also employed. This system is depicted by the dotted lines in Figure 28. The results obtained are in generally good agreement with the data as measured by the pressure gages. However, no attempt was made to calculate an average seal profile as measured by both systems because of the generally superior results of the gages and because of incomplete pressure measurements due to differential pressure transducer failure.

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FIGURE 28

SEAL PRESSURE MEASUREMENT SCHEMATIC

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Seal pressures were normalized and the mean normalized values at each point were estimated for each mode of testing. The normalized pressure was calculated as follows:

$$\text{Normalized Pressure} = \frac{\text{Seal Pressure} - \text{Core Outlet Pressure}}{\text{Core Pressure Drop}}$$

Mean normalized values for each set of nominal test conditions were calculated by taking the average of values for all tests within the test mode. The values for each of the nominal test conditions are tabulated in Table VIII. Several curves representative of those found for the three nominal test conditions are presented in Appendix B. Three mean normalized seal pressure profiles, one for each nominal test, are presented in Figures 29 through 31. Normalized values have standard deviations of about 1.5 percent.

2. Core Interelement Pressure Distribution

Core interelement pressures were measured through probes between elements by differential pressure transducers located on the core support plate. Generally, the pressures were monitored at three azimuthal, five axial, and four radial positions, as shown in Table III. The differential pressure transducers at each axial station were referenced against the seal pressure at the same elevation. Hence these pressures were based on core inlet pressure in a manner similar to that noted in the previous section. For ease of comparison and presentation, core interstitial pressures are also presented here as mean normalized values. All pressure data from any one of the three nominal test conditions was normalized by the expression,

$$\text{Normalized Pressure} = \frac{\text{Interelement Pressure} - \text{Core Outlet Pressure}}{\text{Core Pressure Drop}}$$

The mean was calculated for each set of tests as a function of core radial and axial position but irrespective of its azimuthal location. The calculation of a mean normalized interstitial pressure in this manner is based on the assumption of azimuthal symmetry. Mean normalized interstitial pressure profiles are presented in Figures 32 through 37. Tabulations of normalized data are presented in Appendix B.

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TABLE VIII

NORMALIZED MEAN SEAL PRESSURE DISTRIBUTIONS

Core Inlet Pressure (psia)		300	700	300
Core Pressure Drop (psi)		130	130	130
Number of Seals Vented		0	0	16
Number of Tests Included	Elevation	4	4	6
DP 416	4.3	.999	.996	.998
DP 401	7.2	.969	.980	.972
DP 410	15.6	.895	.889	.831
DP 403	18.4	.865	.855	.783
DP 412	26.8	.729	.700	.596
DP 405	29.7	.679	.645	.536
DP 413	32.5	.627	.589	.480
DP 406	35.3	.542	.497	.395
DP 414	38.0	.457	.409	.316
DP 407	40.9	.359	.323	.234
DP 415	43.7	.258	.226	.158
DP 408	46.5	.140	.112	.074

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FIGURE 29

MEAN NORMALIZED SEAL PRESSURE PROFILE
NOMINAL 300 PSIA, UNPERTURBED TESTS

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FIGURE 30

MEAN NORMALIZED SEAL PRESSURE PROFILE
NOMINAL 300 PSIA, PERTURBED TESTS

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FIGURE 31

MEAN NORMALIZED SEAL PRESSURE PROFILE
NOMINAL 700 PSIA, UNPERTURBED TESTS

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NOMINAL CORE INLET PRESSURE = 300 PSIA
 NOMINAL CORE PRESSURE DROP = 150 PSI
 NO SEALS VENTED

FIGURE 32

MEAN NORMALIZED CORE RADIAL PRESSURE PROFILES
 NOMINAL 300 PSIA, UNPERTURBED TESTS

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NOMINAL CORE INLET PRESSURE = 300 PSIA
NOMINAL CORE PRESSURE DROP = 130 PSI
NO SEALS VENTED

FIGURE 33

MEAN NORMALIZED CORE AXIAL PROFILES
NOMINAL 300 PSIA, UNPERTURBED TESTS

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NOMINAL CORE INLET PRESSURE 700 PSIA
NOMINAL CORE PRESSURE DROP 130 PSI
NO SEALS VERIFIED

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FIGURE 34

MEAN NORMALIZED CORE RADIAL PROFILES
NOMINAL 700 PSIA, UNPERTURBED TESTS

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FIGURE 35

MEAN NORMALIZED CORE AXIAL PROFILES
NOMINAL 700 PSIA, UNPERTURBED TESTS

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NOMINAL CORE INLET PRESSURE 300 PSIA
NOMINAL CORE PRESSURE DROP 130 PSI
16 SEALS VENTED

FIGURE 36

MEAN NORMALIZED CORE RADIAL PROFILES
NOMINAL 300 PSIA, PERTURBED TESTS

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FIGURE 37

MEAN NORMALIZED CORE AXIAL PROFILES
 NOMINAL 300 PSIA, PERTURBED TESTS

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It has been suggested² that core interstitial flow is laminar and incompressible. If we further assume it is isentropic, a stream function and potential function can be hypothesized to exist.¹² These streamlines and equipotential lines can be shown to be orthogonal. In other words, any streamlines inferred from studies of the tracer gas results should be perpendicular to lines of constant pressure or isobars. Hence the construction of a core isobar plot would provide a means of correlating pressure data and tracer gas streamline data. Core isobar contours are presented in Figures 38, 39 and 40. These contours were derived from the mean normalized core radial and axial plots presented in Figures 32 through 37. The isobar contours and radial and axial profiles were drawn through the experimental points based on the following considerations:

- (a) Best fit to experimental points.
- (b) Consistency and continuity of isobar contours.
- (c) Consideration of a physically consistent flow model for all tests.
- (d) Tracer gas results.
- (e) Theoretical considerations.

The radial pressure profiles and isobar plots are based on the assumption of azimuthal symmetry. This assumption appears to be generally correct, within the accuracy of interelement pressure measurements. Hence the pressure profiles and isobar plots are drawn as the best fit to all points, at a given elevation, irrespective of their azimuthal position. In addition, axial pressure profiles were considered to insure a physically consistent set of radial profiles in progressing from elevation to elevation. Finally, the pressure profiles yield a consistent isobar plot in which isobars do not cross one another and form a reasonable family of curves consistent with a continuous flow pattern.

The sparsity of pressure probes and large interpolations of data leave the analyst with some latitude in drawing the core pressure profiles and isobar plots. The curves presented should not be taken as a precise mapping of core flow phenomenon but rather as a consistent and reasonable description of the overall flow patterns. An examination of the experimental

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NOMINAL CORE INLET PRESSURE = 300 PSIA
NOMINAL CORE PRESSURE DROP = 130 PSI
NO SEALS VENTED

FIGURE 38

MEAN NORMALIZED CORE ISOBARs
NOMINAL 300 PSIA, UNPERTURBED TESTS

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NOMINAL CORE INLET PRESSURE = 700 PSIA
NOMINAL CORE PRESSURE DROP = 130 PSI
NO SEALS VENTED

FIGURE 39

MEAN NORMALIZED CORE ISOBARS
NOMINAL 700 PSIA, UNPERTURBED TESTS

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NOMINAL CORE INLET PRESSURE = 300 PSIA
NOMINAL CORE PRESSURE DROP = 130 PSI
16 SEALS VENTED

FIGURE 40

MEAN NORMALIZED CORE ISOBARS
NOMINAL 300 PSIA, PERTURBED TESTS

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points plotted on these figures would suggest a multiplicity of possible pressure profiles. If one were to attempt to draw pressure profiles giving strict consideration only to those few experimental points available, the pressure fields inferred would indeed be questionable. However, far more information is available than that derived by experimentation. A qualitative knowledge of flow impedance is available from a consideration of reactor dimensions and configuration. The classical relations of fluid mechanics need be observed. Most important a physically consistent model or models must be hypothesized and be compatible not only with theory but be in agreement with all experimental data. A single flow model or set of assumptions may not be valid throughout the entire core region. One might expect the tightly packed elements in the region of the core band to require a different approach and explanation from the flow phenomenon occurring in less tightly packed portions of the core or in the region of the support blocks.

The axial gradients in the upper and central portions of the core were drawn with the following flow mechanism as a guide: Radial inflow is not significant at radial distances less than 12 to 13-inches; flow is generally axial; axial pressure gradients are approximately linear. Pressure data on the centerline and 7.5-inch radius agree with this hypothesis. Steep pressure gradients are encountered in the first 7-inches of the core, indicative of the high flow impedance as a result of the tightly packed core in the region of the core band. The 13.5-inch radius pressure profiles are drawn in a manner similar to those of the centerline and 7.5-inch radius for the same reasons.

Of equal influence in the drawing of the pressure profiles was an analysis of the history of the transducers used in measuring core pressures. The consistency and reasonableness of pressure values and their variation from test to test was studied for indications of fixed and random transducer errors, and the confidence given to each point was so derived. For example, the experimental point at the 7.5-inch radius and the 40.90-inch elevation has been given little weight. This point was consistently lower than could be expected by a consideration of gradients in the area. An examination of one of the transducer results used in arriving at this value, as well as the results of tracer gas inflow into this area, suggests a communication of

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core outlet pressure to this point. Factors such as a leaking plug in the coolant channel or pinhole leakage to the core outlet could have disturbed these measurements. Units found reading consistently high or low were suspected as being influenced by fixed errors but were not deleted from the normalized plots unless as to be clearly in error.

These factors, as well as the additional data acquisition and analysis since the last report in this series was issued, produced isobar contours which differ somewhat from the ones reported previously.⁵ The two plots agree in their indication of overall flow patterns but vary slightly in the magnitude and direction of pressure gradients in certain areas. These variations are well within the latitude which is inherent in drawing smooth curves through the experimental points in consideration of the above noted factors such as consistency with a flow model.

F. UNCERTAINTIES

Many of the limitations of the test model and experimental technique have been discussed in the presentation of results in order to add to the readers' appreciation for the confidence placed on certain interpretations. These and other uncertainties will be reviewed here for re-emphasis.

1. Sampling Perturbations

Ideally, it would be desirable to sample interchannel flows at essentially zero sampling rate to minimize perturbing the local flow conditions in the area of the sample probe. Since test duration is limited by hydrogen availability and other considerations, a realistic sampling time of one to two minutes was specified. The quantity of sample gas required in hydrocarbon analysis further specified the range of sampling flow rates possible. The net result of these experimentally dictated design parameters was the specification of sampling rates within the range of interchannel flow rates.

Obviously some perturbation to normal leakage flow results from the removal, locally, of gas at the rate normally supplied by one interelement channel. Hopefully, because of the relatively large spacing of probes, the local effect is damped out quickly by the main leakage flow in the area of the perturbation. In general, there was experimental justification

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for the assumption of this damping effect. The pressures in the sample tubes were monitored continuously by pressure transducers. These pressures were not significantly effected by the sampling process in most cases. In some cases, however, the transducers indicated pressure drops on the order of 25 psi. This could be caused as a result of the venting down of the pressure probe during sampling. It is probable that this effect became apparent only when the local interchannel flow was too small to maintain the sonic conditions in the sampling orifice. In that case a small channel or a local constriction would be responsible for the flow restriction and this local constriction would tend to dampen out the perturbing effects rapidly as conditions in the constriction itself approach sonic flow.

2. Injection Perturbations

In order to attain the desired injection flow rate into the interelement channels, it was necessary in most cases to maintain a slight pressure differential between the methane supply manifold and the measured local pressure. This pressure differential varied from probe to probe depending on the impedance to flow between the probe and the channel and along the channel itself. This fact, suggests, as do the previous observations on sampling, that there were significant variations in gap sizes and local impedances throughout the core. Unfortunately it is impossible to assess the degree of the local perturbation because the transducer itself was in the inlet of the injector tube and could not be expected to give a reliable steady-state indication of static pressure downstream in the interelement channel. There is valid evidence that the local perturbation was damped out relatively quickly in areas beyond the probe. Interelement pressures at adjacent radial core stations and at stations on lower elevations on all azimuths were not significantly effected.

3. Graphite Permeability

Because the elements used in the ND 207 reactor are uncoated, the permeability of graphite to hydrogen and methane flows must be considered as a confounding effect on the

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data. Basically, the problem is caused by possible flow between the interelement channel and the main element flow channels. The phenomenon manifests itself in three ways which contribute to the uncertainty in the interpretation of results:

- (a) Influence on injection.
- (b) Influence on pressure measurement.
- (c) Influence on profiles obtained at the core outlet plane.

Figure 41 illustrates the installation of the interelement probes. The probe is sealed at the top of the element but not along the entire length. A flow channel exists between the probe and the inside diameter of the flow channel. When a particular probe is being used as an injection probe, the methane is free to flow throughout the flow channel in the annular space between the probe and the element. The higher methane supply pressures required for the injection tends to promote this flow while the porous inflow from the higher interelement pressures upstream tends to counteract it. The net effect is that in some cases, methane flow can occur up the tube for some distance until the injection pressure is balanced by the effects of this inflow. It is then possible at steady-state to have a situation in which methane is being forced through the walls of the element into the interelement channels over a given area upstream of the desired point of injection. This would tend to have a masking effect on the conclusion that back flow occurred in some areas near the 46-inch elevation, but it would not significantly effect the other observations. There is some evidence that this porous outflow of methane did occur and that the effect was small. On several tests concentration peaks were observed upstream of the injector probe; however, these concentrations were several orders of magnitude smaller than the peaks observed downstream of the probe.

The influence of graphite permeability on pressure measurement is the reverse of the effect on injection. When the probe is being used for pressure measurement, the pressure at the inlet to the probe communicates along the probe-to-flow hole annulus while porous inflow counteracts this effect with higher pressure gas. The overall pressure sensed by the transducer would be greater than or equal to the actual local pressure depending on the relative

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FIGURE 41

PRESSURE-INJECTOR-SAMPLING PROBE INSTALLATION

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impedances along the interelement channel and through the element walls. For example, a high channel impedance relative to porous impedance would promote inflow from the interelement channel to the probe channel and measured pressures would be higher than normal.

It has been suggested that the consideration of this inflow would explain the high pressure levels measured for the 46.5-inch elevation. The above discussion points this out as a distinct possibility. However, other factors tend to refute the argument. The numerous, consistent tracer gas results show a strong tendency for flow to be diverted from the high pressure area to a lower pressure area in the peripheral direction. Even if we assume that the high local pressures near the 7.5-inch probe at the 46.5 core station force the methane stream away, the relatively clear cut peaks as far away as the 14-inch radius are difficult to justify based on this mechanism. In addition, we are left with the problem of explaining why the pressure rise is greater near the center of the core than near the periphery where, if we postulate the inflow mechanism, a higher pressure rise can be expected. The solution of these problems will hopefully be available soon as a result of other experimental programs.¹³

The third influence of graphite permeability, that of masking the concentration profiles obtained at the core exit plane, was discussed previously. Although the data suggest some influence of the effect on results, the degree of influence is unknown.

4. Sparsity of Probes

It goes without saying that the results and conclusions derived from the pressure and concentration data obtained from the 37 in-core probes must be tempered by a realization that, relative to local flow behavior, the probe spacing was extremely large. Average axial spacing was on the order of 11-inches, average radial spacing was about 6-inches, and, of course, azimuthal spacing was 120 degrees. Hopefully, the results are indicative of gross pressure and flow patterns throughout the core. Local variations cannot be reliably inferred unless, of course, they occur in the areas of individual probes.

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5. Flow Discontinuities

Underlying the interpretation of all pressure and concentration data obtained in these tests is the assumption that the leakage flow throughout the reactor is continuous. That is to say, it is assumed that the intercommunication of interelement flow channels in the radial, axial, and azimuthal directions provides a continuum for flow and pressure fields. This assumption makes possible the description of flow behavior by the drawing of smooth curves through discrete concentration and pressure data points. The consistency of results and the correlation between flow and pressure fields indicates that the assumption is correct in a gross sense. It must be realized that in local areas discontinuities can exist. In fact, in a complex mechanical arrangement such as the core, it would be highly improbable that no such discontinuities exist. Thus, in given areas it is probable that tightly bundled elements give rise to sudden changes in flow and pressure gradients. These discontinuities do not violate any laws of flow in a continuum. Rather, they are geometrical in nature and the flows adjust according to the geometric configuration. The existence and influence of these discontinuities cannot be conclusively inferred because of the sparsity of probes; however, the possibility of their effects should be considered in interpreting test results.

6. Normalization

The presentation of pressure data in mean normalized form has both good and bad effects on the interpretation of experimental results. Because the averaging process masks individual deviations from the mean behavior, it is not possible to determine whether or not the behavior of individual channels or discrete regions in the core change from test to test. Some evidence that the core does not change from test to test is noted in the fact that in those tests in which injection was repeated two or three times through the same probe, the same results were obtained.

The beneficial effect of averaging hopefully outweighs the ill effects. For in the taking of a statistical mean, the true value for the pressure at a point is more closely approached as the number of trials increases. Of course, it is assumed that the mean is a measurement of

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a single value of the parameter. If the core does change significantly from test to test, then the true value for pressure at any point is varying and individual pressure measurements may not represent samples from the same universe of values.

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IV. ANALYSIS AND SIGNIFICANCE OF RESULTS

A. EXPERIMENTAL TECHNIQUE

Aside from any conclusions and observations one may derive from the tracer gas experiments, the program has produced a valuable technique for the study of flow phenomena in NRX-A reactors and components. A large part of the program effort was directed toward the design and implementation of the tracer gas technique. Some optimization studies were conducted to define test parameters, and during the course of the core mapping tests, additional improvements in equipment and parameter levels were made. Of course, more extensive optimizing should be performed before the technique can be considered generally applicable. Also, many of the uncertainties in the data are caused by inadequacies in injection and sampling techniques. Fortunately, the experience gained during these tests will enable us to improve the design of control equipment, instrumentation, and the test model configuration to the extent that many of these uncertainties will be eliminated in future tests.

One of the stated objectives of the program was to explore the possibility of injecting a corrosion inhibitor into suspected high corrosion areas of the reactor during actual nuclear tests. Although no specific tests in the program were conducted for this purpose, the objective was attained by observing the distribution of methane flowing from various injector probes.

The injection of an inhibitor in the core is confronted by several limiting problems. The adequate distribution of the inhibitor gas from a point source is difficult to attain. This is inferred from the rather narrow concentration profiles downstream of the injector in most tests in which injection took place in the core. Secondly, perturbation of the core pressure fields is probable if sufficient inhibitor gas is to be injected.

Injection of an inhibitor in the seal chambers appears feasible based on test results. The inflow from the seal system occurs relatively uniformly over the top 40-inches of the core. The outflow near the bottom would present some problem, but it would be possible to change the direction of this flow by altering the seal pressure distribution slightly. This could be

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accomplished by lowering the last effective seal. In addition, multiple injectors in the top seal chamber would be required to insure uniform azimuthal concentrations. This contention is supported by sparse data which suggests little azimuthal mixing in the seal chambers.

Finally, injection over the core at first glance appears feasible and, indeed, desirable. A uniform concentration throughout the core is attained. Unfortunately the distribution on the periphery is diluted in inhibitor gas because of inflow. Of course this comment would not apply in reactors in which the peripheral design differed in the degree of inflow permitted.

B. CORE FLOW CHARACTERISTICS

1. Correlation of Flow and Pressure Data

It is customary to present data from two sources - in this case tracer gas and pressure measurements - independently and to compare the results of the two sources of measurement for compatibility, consistency, and correlation. It is then customary to attempt to draw a conclusion from the data or by induction to build a model or mechanism which explains both sets of results. Although inductive reasoning was used in the analysis of much of the data from these experiments, by and large a somewhat different approach has been employed here in the interpretation and presentation of the flow and pressure fields in the core. In effect, we have assumed that certain conditions, both geometric and hydraulic, exist in the ND 207 core. The interpretation of raw concentration and pressure data to give the flow and pressure fields presented previously was based on these assumptions.

This being true, the analysis of the data as to consistency, compatibility, and correlation is undertaken in a reverse sense. That is, since compatibility, consistency, and correlation were, in general, built into the given interpretations, analysis must determine in terms of statistical probabilities how well the two sources agree. Specifically, we have taken certain liberties in interpreting both concentration and pressure data to arrive at a map of the core which, at least in an overall sense, is consistent from the point of view of two sets of experimental results and a theoretical model. The adequacy of the interpreting process must

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be examined in terms of the magnitudes of deviations of the raw experimental points from the smoothed curves which represent the correlative interpretations.

It was previously suggested that the fluid flow phenomena taking place in the core interstices behaved as a potential flow field. Fundamental to this hypothesis is the concept of a continuum. Any flow model embracing the idea of a potential flow field must be supported in fact by a system having both radial and axial communication. In particular, the application of a potential flow field theory to the core as a whole is analogous to treating the core by and large as a porous medium or as a system of communicating channels in which the flow in a particular interelement channel interacts with flow in neighboring channels. Within the framework of this model, local disturbances and discontinuities can exist in terms of sources, sinks, and solid barriers; however, the characteristics of a continuum must be exhibited in all directions when the core is viewed in toto.

With these concepts at hand, the results for each area of the core will be reviewed and examined in terms of the correlation between flow and pressure data, physical configuration, and flow model. It is important that the previously noted uncertainties be kept in mind. These will not be referred to except in instances in which a discussion of errors has an important influence on the interpretation of data and results. The following discussions will apply primarily to steady-state unperturbed flow.

(a) Central Core Region

The central core region is loosely defined as extending to the 13.5-inch radius and may generally be considered in two broad areas. The first extends from the core inlet to approximately the 40-inch elevation; the second, from 40-inches to the aft end of the core or core exit plane.

Tracer gas flow lines are predominantly axially directed in the top 40-inches of the central region of the core. The isobars were drawn flat in this region in agreement with these streamlines. That is, no radial gradients were included in the curves between center-line and the 13.5-inch radius indicating a generally axial stream function with no inflow into

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the region. Obviously, these isobars could have been drawn differently to show some radial gradients. This latitude in interpretation was examined previously. In terms of specific probabilities, the license taken in the drawing of axial and radial pressure profiles to match streamlines on the centerline, 7.5-inch, and 13.5-inch radii was quite limited. For example, the axial pressure profile at the centerline passes through every point but one. The faired curve misses the mean normalized point at station 7.2 by less than one half standard deviation of the values comprising the mean. This curve therefore can be considered as the curve of maximum likelihood considering the experimental points with the exception of one deviation of less than 0.5σ . In terms of probabilities, we can expect the true mean to be within the interval between the point and the position of the faired curve about 65 percent of the time.

The faired curve on the 7.5-inch radius also passes through all the mean normalized points and essentially coincides with the axial centerline profile to about core station 30. The curve was drawn beyond the three standard deviation limit at the 40.9-inch station which, in effect, ignores the point entirely. The experimental point at this elevation is consistently low. The value is derived from three separate sensors at each of the three instrumented azimuths. Examination of each of the pressure values recorded by these sensors showed that the sensor at the 285 degree azimuth (DP 734) was consistently recording core outlet pressure. This seems indicative of a leak past the graphite plug sealing the probe from the core outlet. This piece of information substantiates a theory advanced to account for azimuthal flows discovered in the tracer gas portion of this experiment. Deletion of the 285° azimuth data and recalculation of the point for the 45° and 165° azimuths modifies the mean value of the point to about 0.2. This value is more in line with the pressure profile as drawn, being within one standard deviation of the line.

The existence of such a leak, as postulated, has a perturbing influence on core flows in that it acts as a flow sink. Significantly, both the tracer gas results and pressure results point out its apparent existence. The influence that this sink has on overall core flow behavior is uncertain. Its presence should be noted for an appreciation of the other results, especially in the sense that it contradicts the assumption of complete azimuthal symmetry.

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The axial pressure profile for the central core region on the 13.5-inch radius involves two deviations from experimental points. The faired curve and experimental points at both the 18.4-inch and 29.7-inch core stations deviate by about one standard deviation. There are adequate explanations for this deviation. The radial and azimuthal values at which all pressure probes are plotted are approximate. The 13.5-inch radius is a mean value about which all probes located in that radial vicinity can be grouped. Variations in true radial position from the mean radial position could be as much as one inch. In areas of relatively small pressure gradients this error can be negligible, but where pressure gradients are larger this error becomes significant. For example, the probe at the 29.7-inch elevation is in actuality located closer to the 12.5-inch radius than the 13.5-inch radius. The steep pressure gradients found in this area introduce a significant error when the values recorded by this unit are plotted at the 13.5-inch radius. It is readily apparent from examination of the radial pressure profiles that effectively displacing this probe toward the core centerline would bring the point in greater agreement with the pressure profile as drawn.

(b) Aft End of Core

The aft end of the core extending from approximately the 40-inch elevation to the core exit plane consists of three basic regions: An interstitial region between the 40 and 50-inch elevations, and undercut interstitial region between the 50 and 52-inch elevations, and the support blocks extending from the 52 to 54-inch elevations. The aft end of the support blocks are at core outlet pressure. The only probes in this region are located at elevations 40 and 46-inches.

The pressure field associated with this region of the core is characterized by a pressure rise between the 40.9-inch and 46.5-inch elevations. The rise is quite significant - on the order of 15 to 20 percent of core pressure drop - at centerline and 7.5-inches from centerline. The gradient diminished in magnitude toward the periphery of the core, disappearing entirely at the 17.5-inch radius.

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It has been suggested that this pressure rise is an "artificial" phenomenon which was obtained by a leak into the probe channel from higher pressure regions at core elevations upstream of the 46-inch level. This leak could be porous inflow or a leakage passed the probe sealant at the top of the element. In either event, the effect must be considered significant enough to cause a general pressure increase throughout the central core at this elevation.

The tracer gas flow lines and pressure profiles are in excellent agreement in this area if we take certain liberties, this time, with tracer gas results. The sparsity of sampling probes in this region renders the detection of rapidly changing flow directions extremely difficult. The probes at the core outlet, therefore, affect the profiles significantly. In order to obtain agreement between flow and pressure fields in this region, it is necessary to postulate the existence of porous flow into the element flow channel from the interstices. This explains the high concentration peaks consistently found near the radius of injection. It also enforces the selection of the secondary peaks noted at other radii away from the injector as being the actual interelement flow paths.

Some interpretation in the inferring of the pressure fields in this area should also be noted. The pressure profiles between the 46-inch elevation and the aft end of the core reflect an estimate of the relative impedances of the core. To draw pressure profiles from the 46-inch elevation to the 52-inch elevation with no pressure drop across the support block implies that the flow impedance between the 46 and 52-inch elevations is comparable to that observed in the tightly bundled first 7-inches of the core. The pressure gradients would be comparable. This is not consistent, particularly when one considers the relatively generous undercut between the 50 and 52-inch elevation to aid the venting of interstitial core flows. Rather, it appears more probable that the pressure gradients, and hence flow impedances, would be more nearly comparable to those observed in the mid core region. The shapes of the axial pressure profiles have been drawn to reflect this.

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Regardless of how the profiles are drawn in the last several inches of the core, there still exists a large pressure drop across the support blocks. The gaps between the support blocks are larger than interelement gaps with one exception. Every support block has a "shelf" which axially locks it with the adjacent blocks under the axial pressure loading of the core. These forces could make a rather effective seal along portions of the support block interfaces and constitute a point of high flow impedance. In addition the pressure loading of the elements on the top surface of the support blocks could effectively form a high impedance flow path for interelement leakage. The pressure profiles and tracer gas flow lines are compatible with this assertion. Pressure gradients are high in the last several inches of the core toward the center and streamlines flow outward toward the periphery as if to avoid the high impedance area.

(c) Core Periphery

Tracer gas streamlines indicate radial inflow from the seals to 13.5-inch radius from core inlet through at least core station 38-inches. Pressure data shows little or no pressure drop across the filler strips, but substantial pressure drops from the core periphery to the 13.5-inch radius. Such a pressure gradient, when considered in light of one postulated flow model, would be conducive to radial inflow from the seal region.

From core station 40-inches to core outlet the tracer gas streamlines offer evidence of radial outflow. Evidence of this outflow is not restricted to a study of the core peripheral region but extends into the core to the 7.5-inch radius and as high as the 40-inch core station. Pressure profiles in this region would also lead us to consider the possibility of radial outflow. Several low pressure measurements at the 13.5-inch radius at elevations 46.5 and 40.9-inches suggests a low pressure region or "trough" on the pressure contours which would be conducive to radial outflow. In addition the previous discussions of the high pressure "ridge" at the 46-inch core station and the possibility of high impedances through the support blocks support the contention that outflow along the last several inches of the core periphery should be expected.

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Measured flowlines also suggest the possibility of flow from the 46.5-inch elevation to the 40.9-inch elevation. Flow streamlines in this direction would be consistent with a potential field flow model considering the high pressure region at the 46.5-inch elevation. However, a full explanation of the experimental data is not without contradiction. It appears that the changes in pressure and flow direction gradients which occur in this region of the core are larger than those in other areas. The sparsity of probes and, hence large interpolations of data required, do not allow for a full understanding of the fluid mechanisms involved in this region of the core.

The interelement pressure measurements indicate that a measureable perturbation of the seals and core was attained in the seal perturbation tests. The normalized axial pressure profiles for the core (Figures 33 and 37), the normalized seal pressure profiles (Figures 29 and 30), and the normalized fluid bundling pressure profiles presented in Appendix B all illustrate the effectiveness of the seal perturbations and the communication of the perturbation into the interior of the core. The venting action had its most significant influence on the core at the lower elevations on the core periphery and decreased in influence toward the top and center of the core.

The fact that the tracer gas studies did not indicate a significant change in streamline behavior is readily explainable. The effect of the perturbation on pressure fields was not as significant as might be inferred from a consideration of reduced bundling pressures in certain areas. A review of the isobar contours in Figures 38 and 40 indicates that the only significant effect of the perturbations on the pressure fields was to cause a widening and deepening of the low pressure trough in the mid-core and aft-end regions. Isobars in the top, center, and peripheral areas of the core were, by and large, unchanged. Since the tracer gas probes were only located at the 13.5 and 17.5-inch radii, the relatively small changes in the slopes of the isobars could not be detected.

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2. Core Flow Map

When the above allowances in data interpretation are made, the flow fields and pressure fields derived from the consideration of experimental data, reactor geometry and theory, form a consistent map of core flow behavior. Figure 42 shows the best overall estimate of flow directions in the core within the limitations of these experiments. Flows in the core can be summarized as follows:

- (a) Axial flow in a cylindrical portion of the core between the inlet and 40-inches elevation and between centerline and about 13-inch radius.
- (b) Inflow from the lateral support system extending to the 13.5-inch radius from the core inlet to about 38-inches.
- (c) Core outflow along the last several inches of the periphery into the seal region.
- (d) Peripherally directed flow over the last 10-inches of the core from the centerline outward.

Although the resulting correlation between flow and pressure fields, within the accuracy of the data, cannot be considered as proof of the initial assumptions and hypotheses, the overall interpretation of data under these assumptions and hypotheses appears justified in light of the consistency and agreement of results with the assumed flow mechanisms.

3. Suggested Flow Mechanisms

The relatively good agreement between experimentally measured pressure and flow fields during the tracer gas tests suggest that a model or physical mechanism might be built up on the basis of potential flow considerations and assumed physical configurations to simulate the actual results. In that such a model would represent simplifications to the actually complex physical reactor, it could serve as a tool for better understanding the flow behavior of the core.

Such a model is illustrated by the series of conformal maps shown in Figures 43 and 47. These maps show streamlines and equal potential lines for a series of simplified models

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FIGURE 42

CORE FLOW MAP

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which are combined to give a better approximation to the measured pressure and flow maps. They are not intended to be accurate in every detail, though some care has been given to drawing them in accordance with graphical mapping techniques, but are sketches which illustrate in an approximate and general way the influence of various flows.

Figure 43 shows the flow through a cylinder from the open top with outflow through pores in the periphery near the bottom. The bottom and sides of the cylinder are sealed.

Figure 44 increases the complexity of the model by the addition of a porous membrane over the sides of the cylinder to allow for inflow along the top portion of the periphery. This would correspond to the observed inflow from the seal system in the reactor.

In Figure 45, the bottom is also shown as a porous medium, allowing some outflow to occur. This corresponds to the outflow from the support blocks. The shape of the isobars and streamlines are arbitrarily established. The actual direction of flow would be established by the relative impedances through the bottom and through the peripheral slot.

The resulting map shows what might be anticipated in a normal reactor with no sources or sinks and with inflow along the top and periphery. Figure 46 approximates the maps resulting from tracer gas studies. This final degree of complexity is obtained by adding a point source at elevation 46 and radius 7.5. Figure 47 is similar with the exception of the point source which is relatively stronger than the one in Figure 46 when compared with the axial flow. Note that in both cases, streamlines from the source are bent around to the peripheral direction by the over-riding strength of the axial flows. In both cases, however, the point source gives rise to the high pressure area as noted in actual Plugged Core results.

It is not suggested that this model is the only explanation for the flow characteristics measured in the Tracer Gas Tests. Perhaps other models could be built in this way to simulate actual results. Rather it is offered as one possible model which might help to clarify core flow behavior.

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FIGURE 43

FLOW INTO THE TOP OF A CYLINDER
AND FLOW OUT A PERIPHERAL SLOT

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FIGURE 44

FLOW INTO THE TOP AND SIDES OF A CYLINDER
AND FLOW OUT A PERIPHERAL SLOT

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FIGURE 45

FLOW INTO THE TOP AND SIDES OF A CYLINDER
AND FLOW OUT THE BOTTOM AND A PERIPHERAL SLOT

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FIGURE 46

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FLOW INTO TOP AND SIDES OF A CYLINDER WITH
WEAK POINT SOURCE AND FLOW OUT THE BOTTOM AND A PERIPHERAL SLOT

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603915-5B

FIGURE 47

FLOW INTO TOP AND SIDES OF A CYLINDER WITH A STRONG POINT SOURCE
AND FLOW OUT THE BOTTOM AND A PERIPHERAL SLOT

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V. SUMMARY AND CONCLUSIONS

A. EXPERIMENTAL TECHNIQUE

A gas tracer technique was developed for the study of leakage paths in the NRX-A reactors. The technique consists of injecting a tracer gas such as methane into the reactor under steady-state flows with ambient temperature hydrogen. The methane can be injected through probes in the core, above the core, or in the lateral support system seal chambers. The path of the methane flowing through the reactor is inferred from concentration data obtained through probes located downstream of the injector.

Parameters such as injection and sampling rate were optimized and analytical techniques were developed. The procedures were used to study the flow behavior in the ND 20702 core. Results indicate that the technique can also be useful as a means of injecting a corrosion inhibitor into certain areas of the core if this is desired during power tests.

B. CORE MAPPING

Fifty-eight flow tests were conducted to study the flow paths through the core and between the core and lateral support system. Methane was injected into the core through numerous probes at approximately the flow rate in an individual interelement channel. Forty samples were acquired in each test and analyzed for methane content to give a set of concentration profiles for the core. The loci of peak concentrations on these radial profiles served to indicate the flow paths in the core.

Pressure data was also obtained for each test and presented in the form of isobar contours throughout the core. Based on a potential flow model, one would expect flow lines to be orthogonal with the isobar contours. Within the accuracy of the data and in consideration of uncertainties, there was good agreement between pressure and flow fields based on this model.

The majority of tests were conducted at 300 psia core inlet pressure and 130 psi core pressure drop. Several tests conducted at 700 psia and the same pressure drop gave results

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which were similar to those for 300 psia. Tests conducted at 300 psia in which the fluid bundling on the core was reduced by venting of the seal chambers indicated that such venting had insignificant effects on core flow behavior within the accuracy of the data and the adequacy of the technique.

An overall flow map of the core was presented which represented the summary of pressure and flow results and their interpretation based on a potential flow model, the experimental points, and reactor geometry. The pattern of flow is generally axial in the central cylindrical portion of the core from centerline to the 13-inch radius as far as 40-inches from the top of the core. Peripheral flows are inward from the seals to the 13-inch radius in the top 40-inches of the core and outward in the last 10-inches into the seal chambers. Flows in the aft end of the core are peripherally outward from a high pressure area near the 7.5-inch radius at the 46-inch level to a low pressure area near the core periphery below the 40-inch elevation. Although generally supported by the data, the assumption of azimuthal symmetry was found to be not wholly correct in that flow occurred azimuthally from the 45° azimuth to a "sink" area on the 285° azimuth.

Possible mechanisms for the high and low pressure areas in the aft end of the core and the sink on the 285° azimuth were advanced. Leaks in core probes, pinholes and cracks in elements, element porosity, and other causes could explain the phenomena. The local communication of a channel between 46-inches and elevations higher in the core with no flow impedance would account for the high pressure "source" at the 46-inch station. This suggested an overall simplified flow model for the core which was built up from the superposition of several models:

1. Axial flow in a cylinder from the top and out through pores at the bottom extending around the periphery.
2. Inflow to a cylinder from pores extending around the periphery and part of the way down the sides.

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3. High impedance flow through the bottom of a cylinder.
4. Flow from a point source within the cylinder near the bottom.

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APPENDIX A

CH₄ CONCENTRATION PROFILES AND DATA TABULATIONS

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TABLE A-I

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

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TABLE A-I (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													

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TABLE A-I (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													

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TABLE A-I (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

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TABLE A-I (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													

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TABLE A-I (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													

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TABLE A-1 (CONTINUED)

Sample Probe	29	30	32	33	34	35	36	37	38	39	40	41	42	43
Core Inlet	0.10	0.10	0.80	0.90	0.56	0.55	1.09	0.33	0.77	0.52	0.52	0.51	0.38	0.40
Core Inlet	0.10	0.40					1.36	0.37	0.58	0.44	0.42	0.53	0.36	0.38
Core Outlet	24.0	32.0	1000	460	935	720	58.0	59.0	58.0	29.5	19.5	26.8	28.5	28.0
Core Outlet	23.0	29.0					58.0	59.0	58.0	30.0	19.5	26.8	28.6	28.0
DP 704	140	172	1.10											
DP 705	250	165	1.90											
DP 761	100	105	0.70											
DP 766	38.0	38.0	2100											
DP 720	94.0	130	3.00	1.40	0.60	1.10		1.05	1.05	0.95	0.82	0.53	0.47	0.51
DP 714	87.0	110	1.80		0.50	1.20		1.00	1.00	0.95	0.78	0.54	0.43	0.50
DP 762	101	115	2.80	3.30	2.00	2.50		1.70	1.50	1.00	1.00	0.70	0.60	0.60
DP 743	181	210	0.85		0.75	1.10	1.80	0.85	0.90	0.78	0.72	0.48	3000+	1.05
DP 716	220	150	1.35	1.80	1.25	1.30	2.60	1.00	0.95	1.00	0.80	0.55	0.62	
DP 763	136	120	3.30	3.50	3.20	2.40	3.50	1.60	3000+	0.75	0.63	3000+	0.95	0.52
DP 740	5.30	4.80	50.0	15.0	29.9	1.20	1.80	1.05	1.40	0.75	0.48	0.75	0.48	0.42
DP 736	102	132	2.60	3.00	2.20	2.00	2.90	1.70	3.00	1.40	1.12	0.65		1.35
DP 718	142	120	2.00	3.40	1.20	1.70		3000+	3.50	3000+	3000+	1.00	0.37	520
DP 764	126	120	2.40	3.90	2.00	2.50	2.00	1.70	5.00	1.50	1.00	0.75	0.65	0.60
DP 738	90.0	102	1.00	1.30	0.90	0.90	1.50	0.81	1.25	0.88	0.72	0.48	0.47	0.40
DP 747	52.0	92.0	0.70	0.80	0.68	0.70	1.20	0.55	0.92	0.72	0.56	0.41	0.40	0.36
DP 719	40.0	80.0	0.60	2.00	0.58	0.70	1.80		1.60			0.46	0.40	0.43
DP 765	149	120	1.80	9.60	1.15	1.70	2.20	1.50		1.30	0.80		0.80	0.75
DP 737	76.0	106	0.80	1.90	0.75	0.90	1.50	0.72	1.00	0.79	0.60	0.44	0.38	0.37
ST 301	67.0	71.0	520	285										
ST 302	92.0	84.0			350		25.7	25.0	19.5	12.8	8.30	8.50	111	10.8

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TABLE A-I (CONTINUED)

Sample Probe	29	30	32	33	34	35	36	37	38	39	40	41	42	43
ST 303	120	106	320	250	270	230	87.0	800	14.8	480	295	7.00	10.5	7.50
ST 304	46.0	45.0	400	1180	385	1480	2350	720	39.0	390	23.5	11.8	9.00	330
ST 305	31.0	25.0	900	2600	525	1600	16.5	17.5	1650	9.00	5.90	770	7.10	7.20
ST 306	26.0	27.0	810	1450	1480	860	39.0	38.0	68.0	19.3	12.2	25.5	16.5	16.8
ST 307	25.0	26.0	920	1250	1480	875	44.0	45.0	52.0	22.3	14.0	22.0	19.8	
DP 416														
PP 401														
DP 401														
PP 402														
DP 409														
PP 403														
DP 402														
PP 404														
DP 410														
PP 405														
DP 403			480	85.0										
PP 406														
DP 411														
PP 407														
DP 404														
PP 408					119	0.50	1.40	1.00	1.25	1.80	0.92	0.57	0.38	0.68
DP 412	0.70	0.90												
PP 409														
DP 405														
PP 410														

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TABLE A-I (CONTINUED)

Sample Probe	29	30	32	33	34	35	36	37	38	39	40	41	42	43
DP 413						1.70								
PP 411			1.20	1.20										
DP 406			1.20		1.05	0.90								
PP 412					0.50	0.60								
DP 414	0.60	0.50												
PP 413					1.50									
DP 407	0	0.25												
PP 414			1.70	0.90										
DP 415	1.80	1.20												
PP 415														
DP 408														
PP 416			3.20	40.0										
DP 708														
DP 706			3.00	2.50										
DP 742					0.62	0.68	1.60	0.65	0.85	0.70	0.53	0.60	0.35	0.42
DP 722			1.90	5.00	1.00	1.00	2.60	1.25	1.25	0.98	0.82	0.72	0.45	0.47
DP 724	102	120	1.75	3.50	1.10	1.25	2.10	1.10	1.18	0.79	0.82	0.70	0.46	0.48
DP 741					1.15	1.00	2.10	1.05	1.08	0.98	0.83	0.75	0.38	0.52
DP 726	126	135	1.80	2.20	1.50	1.50	3.10	1.60	1.50	1.10	0.95	0.78	0.50	0.50
DP 727	34.0		1.10	1.22	0.88	0.95	1.30	1.18	1.70	1.10	0.90	0.55	0.56	0.50
DP 709														
DP 707														
DP 730			1.00	0.90	0.80	0.85	1.20	0.52	0.70	0.67	0.50	0.37	0.35	0.32
DP 751					1.50	1.00	2.10	1.18	1.15	0.95	0.80	0.75	0.39	0.48

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RESTRICTED DATA

TABLE A-I (CONTINUED)

Sample Probe	29	30	32	33	34	35	36	37	38	39	40	41	42	43
DP 732	120	192			2.15	3.40	3.60	2.50	1.90	1.70	1.70	0.75	0.59	0.70
DP 746					3.40	1.10	1.15	0.90	1.13	1.20	0.86	0.55	0.46	0.65
DP 734	130	195			210	44.0	7.80	7.50	6.00	3.90	2.50	2.40	1.55	3.0
DP 748					0.55	0.60								
DP 735	140	215			1.10	2.50	3.00	1.50	1.50	1.40	1.05	0.65	0.50	0.60

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TABLE A-I (CONTINUED)

Sample Probe	44	45	47	49	50	51	53	54	56	57	58
Core Inlet		0.25	0.58	0.40	0.45	0.48	0.82	0.35	0.40	0.38	0.51
Core Inlet			0.50	0.40	0.35	0.48	0.75	0.28	0.30	0.35	0.50
Core Outlet		55.0	71.0	73.5	100	88.0	70.0	81.0	108	94.0	96.0
Core Outlet		55.0	72.0	74.0	100	88.0	70.0	81.0	108	94.0	96.0
DP 704		5.20	3.20	3.60	3.50	3.50	4.80		5.00	3.00	3.90
DP 705	3.00		0.53		0.73	2.15	0.78	0.55	0.61	1.65	0.58
DP 761	0.55	0.29		0.70		1.35	1.50	0.90	0.71	0.60	0.60
DP 766	0.85		0.85	0.55	0.75		0.82	0.70	0.75	0.60	0.80
DP 720	0.72	0.74	0.68	0.73	0.65	1.20	0.84		0.70	0.60	0.65
DP 714	0.75	0.90	0.65	4.30	0.75	1.30	0.85		1.20		1.00
DP 762	0.85	1.32	3000+	1.75	3000+	2.30	1.00		1.02	1.25	1.80
DP 743	0.60	0.52	1.00	0.62	0.85	1.70	1.40	0.55	0.61	0.60	0.58
DP 716	0.72	14.7	0.82	6.70	0.85	2.75	3.40	0.80		240	
DP 763	0.55		4.70	0.82	3.00	1.50	1.45	0.85	0.90	0.70	1.70
DP 740	0.90	0.68	0.75	0.80	0.91	4.50	1.35	1.00	1.10	0.90	
DP 736	0.95	1.35	0.80	0.70	0.80	2.00	2.20	1.40	1.00	0.95	1.00
DP 718	0.55	3.25	0.69	0.77	0.48	1.95	3000+		3000+	3.80	0.80
DP 764	0.88	1.20	4.30	0.95	4.10	1.75	2.35	1.30	1.25	1.00	1.40
DP 738	0.62	0.42	0.62	0.55	0.65	1.12	1.32	0.65	0.22	0.60	0.60
DP 747	0.52	0.27	0.52	0.42	0.58	0.85	1.00	0.55	0.60	0.50	0.50
DP 719	0.59	0.55	0.55	0.75	0.78	1.00		0.50	0.40	0.40	0.60
DP 765			0.55	0.68	0.45	1.42	2.35	0.48	0.45	0.41	0.60
DP 737	0.50	0.31	0.46	0.48	0.65	0.88	1.60	0.70	0.62	0.45	0.58
ST 301											
ST 302	91.0	26.0	18.4	27.5	23.5	32.0	30.0	27.0	34.0	27.5	24.0

TABLE A-I (CONTINUED)

Sample Probe	44	45	47	49	50	51	53	54	56	57	58
ST 303	12.2	19.0	17.5	1.51	17.5	22.0	1200	440	125	20.0	19.0
ST 304	2.10	19.2	19.8	19.4	27.9	32.0	1250	3000+	1610	260	80.0
ST 305	1.02	13.3	36.0	15.5	114	27.0	23.5	22.0	31.0	24.0	370
ST 306	1.78	34.0	735	40.0	520	79.0	45.0	15.0	66.0	56.0	410
ST 307	1.78	37.5	49.0	43.0	70.0	118	50.0	58.0	76.0	68.0	850
DP 416											
PP 401											
DP 401											
PP 402											
DP 409											
PP 403											
DP 402											
PP 404											
DP 410											
PP 405											
DP 403											
PP 406											
DP 411											
PP 407											
DP 404											
PP 408											
DP 412											
PP 409											
DP 405											
PP 410											
DP 413											

TABLE A-I (CONTINUED)

Sample Probe	44	45	47	49	50	51	53	54	56	57	58
PP 411											
DP 406											
PP 412											
DP 414											
DP 415											
PP 415											
DP 408											
PP 416											
DP 708											
DP 706											
DP 742	0.30	0.28									
DP 722		0.55	0.65	0.95	0.75	1.12	1.86	0.80	0.60	0.65	0.80
DP 724		0.44	0.88	0.75	0.50	1.95	1.38	0.78	0.58	0.60	0.80
DP 741		0.52	0.60	0.75	0.50	1.25	2.68	0.75	0.60	0.72	0.80
DP 726		0.90	1.00	0.75	0.50	2.10	1.66	0.30	0.70	0.95	0.95
DP 727	0.30	0.93					2.05			0.43	0.75
DP 709											
DP 707											
DP 730	0.43	0.27	0.42	0.40	0.58	0.85	1.35	0.50	0.50	0.40	0.50
DP 751	0.29	0.50	0.65	0.75	0.65	0.95	1.42	0.62	0.50	0.50	0.68
DP 732	0.75	6.80	4.00	13.0	2.10	3.30	23.0	2.50	6.30	7.00	96.0
DP 746	0.70	1.72	0.72	0.77	0.68	1.10	0.60	0.80	0.72	0.60	0.70
DP 734	0.75	17.0	9.20	4.50	6.00	21.0	9.50	11.0	20.0	17.0	3.80
DP 748	0.78	0.86	0.72	0.68	0.82	1.05	0.85	0.65	1.00	0.75	0.65
DP 735	0.90	1.50	0.75	0.75	0.75	1.25	1.10	1.30	0.85	1.00	1.10

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FIGURE A-1

CH₄ CONCENTRATION PROFILES - FFL-17-5

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CH₄ CONCENTRATION PROFILES - FFL-17-6

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~~Atomic Energy Act~~

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~~RESTRICTED DATA~~
~~Atomic Energy Act 1954~~

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FIGURE A-3

CH₄ CONCENTRATION PROFILES - FFL-17-7

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~~RESTRICTED DATA~~
~~Atomic Energy Act 1954~~

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FIGURE A-4

CH₄ CONCENTRATION PROFILES - FFL-17-9

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FIGURE A-5

CH₄ CONCENTRATION PROFILES - FFL-17-10

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~~RESTRICTED DATA~~
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RESTRICTED DATA

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FIGURE A-6

CH₄ CONCENTRATION PROFILES - FFL-17-11

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RESTRICTED DATA

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FIGURE A-7

CH₄ CONCENTRATION PROFILES - FFL-17-12

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FIGURE A-8

CH₄ CONCENTRATION PROFILES - FFL-17-13

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~~1954~~

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FIGURE A-9

CH₄ CONCENTRATION PROFILES - FFL-17-15

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~~RESTRICTED DATA~~
~~1954~~

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~~RESTRICTED DATA~~

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FIGURE A-10

CH₄ CONCENTRATION PROFILES - FFL-17-16

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FIGURE A-11

CH₄ CONCENTRATION PROFILES - FFL-17-17

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FIGURE A-12

CH₄ CONCENTRATION PROFILES - FFL-17-18

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FIGURE A-13

CH₄ CONCENTRATION PROFILES - FFL-17-19

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FIGURE A-15

CH₄ CONCENTRATION PROFILES - FFL-17-21

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FIGURE A-16

CH₄ CONCENTRATION PROFILES - FFL-17-22

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FIGURE A-17

CH₄ CONCENTRATION PROFILES - FFL-17-23

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FIGURE A-18

CH₄ CONCENTRATION PROFILES - FFL-17-24

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FIGURE A-19

CH₄ CONCENTRATION PROFILES - FFL-17-26

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~~1754~~

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~~RESTRICTED DATA~~
~~Atomic Energy, 1975~~

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FIGURE A-20

CH₄ CONCENTRATION PROFILES - FFL-17-28

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~~Atomic Energy, 1975~~

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FIGURE A-21

CH₄ CONCENTRATION PROFILES - FFL-17-29

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FIGURE A-23

CH_4 CONCENTRATION PROFILES - FFL-17-32

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FIGURE A-24

CH₄ CONCENTRATION PROFILES - FFL-17-33

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~~RESTRICTED DATA~~
 1954

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FIGURE A-25

CH₄ CONCENTRATION PROFILES - FFL-17-34

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CH₄ CONCENTRATION PROFILES - FFL-17-35

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FIGURE A-28

CH₄ CONCENTRATION PROFILES - FFL-17-37

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~~Atomic Energy, 1975~~

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~~RESTRICTED DATA~~

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FIGURE A-29

CH₄ CONCENTRATION PROFILES - FFL-17-38

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~~RESTRICTED DATA~~

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FIGURE A-30

CH₄ CONCENTRATION PROFILES - FFL-17-39

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FIGURE A-31

CH_4 CONCENTRATION PROFILES - FFL-17-40

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FIGURE A-32

CH₄ CONCENTRATION PROFILES - FFL-17-41

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FIGURE A-33

CH₄ CONCENTRATION PROFILES - FFL-17-42

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FIGURE A-35

CH₄ CONCENTRATION PROFILES - FFL-17-44

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FIGURE A-36

CH₄ CONCENTRATION PROFILES - FFL-17-45

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FIGURE A-37

CH₄ CONCENTRATION PROFILES - FFL-17-47

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FIGURE A-38

CH₄ CONCENTRATION PROFILES - FFL-17-49

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FIGURE A-39

CH₄ CONCENTRATION PROFILES - FFL-17-50

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FIGURE A-40

CH₄ CONCENTRATION PROFILES - FFL-17-51

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WANL-TME-1258

CH₄ CONCENTRATION PROFILES - FFL-17-54

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~~RESTRICTED DATA~~

WANL-TME-1258

FIGURE A-43

CH₄ CONCENTRATION PROFILES - FFL-17-56

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~~RESTRICTED DATA~~

WANL-TME-1258

FIGURE A-44

CH₄ CONCENTRATION PROFILES - FFL-17-57

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FIGURE A-45

CH₄ CONCENTRATION PROFILES - FFL-17-58

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~~Atomic Energy Act of 1954~~

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APPENDIX B

PRESSURE PROFILES AND DATA TABULATIONS

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~~Atomic Energy Act of 1954~~

WANL-TME-1258

TABLE B-I

MEAN NORMALIZED CORE PRESSURE DATA,
300 PSIA, UNPERTURBED TESTS

TEST DATA USED:

<u>Test Designation</u>	<u>Core Inlet Pressure</u>	<u>Core Pressure Drop</u>
17 5	298.0	139.0
17 9	305.0	132.0
17 10	300.0	122.0
17 11	291.0	177.0
17 12	294.0	125.0
17 13	299.0	130.0
17 15	299.0	130.0
17 16	307.0	138.0
17 17	304.0	137.0
17 18	297.0	129.0
17 19	299.0	133.0
17 20	299.0	127.0
17 21	301.0	133.0
17 22	298.0	131.0

(No Seals Vented All Tests)

DATA REDUCTION:

<u>Elevation (Inches)</u>		<u>Radius (Inches)</u>			
		<u>0</u>	<u>7.50</u>	<u>13.50</u>	<u>17.50</u>
7.16	Mean	0.523	0.630	0.609	0.967
	Number of Data Points	9	40	12	20
18.40	Mean	0.451	0.430	0.512	0.854
	Number of Data Points	14	39	11	13
29.65	Mean	0.313	0.307	0.093	0.672
	Number of Data Points	14	40	15	27
40.90	Mean	0.317	0.032	0.154	0.347
	Number of Data Points	14	42	13	28
46.52	Mean	0.414	0.427	0.201	0.203
	Number of Data Points	14	41	14	15

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~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

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Atomic Energy Act, 1954

WANL-TME-1258

TABLE B-II

MEAN NORMALIZED CORE PRESSURE DATA,
700 PSIA, UNPERTURBED TESTS

TEST DATA USED:

<u>Test Designation</u>	<u>Core Inlet Pressure</u>	<u>Core Pressure Drop</u>
17 44	702.0	140.5
17 45	700.0	130.4
17 46	700.0	132.9
17 47	700.0	130.8

(No Seals Vented All Tests)

DATA REDUCTION:

Elevation (Inches)		Radius (Inches)			
		0	7.50	13.50	17.50
7.16	Mean	0.557	0.594	0.614	0.964
	Number of Data Points	3	8	3	7
18.40	Mean	0.390	0.342	0.448	0.847
	Number of Data Points	4	9	4	4
29.65	Mean	0.217	0.162		0.628
	Number of Data Points	4	8		8
40.90	Mean	0.263	0.040		0.328
	Number of Data Points	4	12		9
46.52	Mean	0.384	0.451	0.089	0.154
	Number of Data Points	4	8	5	4

CONFIDENTIAL
RESTRICTED DATA

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TABLE B-III

MEAN NORMALIZED CORE PRESSURE DATA,
300 PSIA, PERTURBED TESTS

TEST DATA USED:

<u>Test Designation</u>	<u>Core Inlet Pressure</u>	<u>Core Pressure Drop</u>
17 49	300.0	130.0
17 50	307.0	131.5
17 51	305.0	136.9
17 53	304.0	132.8
17 56	300.0	130.3
17 57	318.0	132.5
17 58	298.0	125.6

(16 Seals Vented All Tests)

DATA REDUCTION:

<u>Elevation (Inches)</u>		<u>Radius (Inches)</u>			
		<u>0</u>	<u>7.50</u>	<u>13.50</u>	<u>17.50</u>
7.16	Mean	0.659	0.611	0.583	0.929
	Number of Data Points	6	14	6	13
18.40	Mean	0.287	0.393	0.387	0.765
	Number of Data Points	7	13	7	7
29.65	Mean	0.252	0.090		0.530
	Number of Data Points	7	14		13
40.90	Mean	0.291	0.085	0.007	0.241
	Number of Data Points	7	21	7	19
46.52	Mean	0.338	0.406	0.087	0.118
	Number of Data Points	7	14	7	6

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~~RESTRICTED DATA~~
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TABLE B-IV
SEAL PRESSURE TABULATIONS

TEST NUMBER FFL-17-		3	4	5	6	44	45	46	47	50	51	53	56	57	58
Core Inlet Pressure (PSIA)		310.0	310.0	298.0	299.0	702.0	700.0	700.0	700.0	307.0	305.0	304.0	300.0	318.0	298.0
Core Pressure Drop (PSI)		134.0	133.5	139.0	131.0	140.5	130.4	132.9	130.8	131.5	136.9	132.8	130.3	132.5	125.6
Number of Seals Vented		0	0	0	0	0	0	0	0	16	16	16	16	16	16
Sensor	Elevation	Pressures (PSIA)													
DP 416	4.34	309.9	309.8	297.7	298.9	701.5	699.5	699.5	699.5	306.5	304.5	303.8	299.8	317.8	297.8
DP 401	7.16	305.7	305.9	293.7	295.0	699.2	697.4	697.3	697.4	303.1	301.1	300.4	296.4	314.5	294.4
DP 409	9.47	303.0	303.5	291.0	293.5	696.7	696.1	685.0	695.9	299.0	298.0	296.2	292.8	310.2	291.0
DP 402	12.80	298.5	299.0	285.0	288.7	691.0	691.8	690.0	691.0	291.5	290.0	288.2	285.0	302.7	283.5
DP 410	15.60	295.7	295.9	282.7	285.0	686.4	685.5	685.3	685.6	284.9	282.2	281.4	277.9	296.0	276.5
DP 403	18.40	291.6	291.9	278.7	281.1	681.6	681.1	680.8	681.2	278.8	274.1	275.3	271.9	289.9	270.6
DP 411	21.20	284.7	285.0	272.0	275.0	674.1	674.1	673.2	674.2	271.9	266.5	266.8	263.5	281.0	262.3
DP 404	24.00	279.0	279.0	266.3	269.0	667.5	667.8	666.8	668.0	264.0	257.5	259.0	256.0	273.2	255.0
DP 412	26.80	272.6	273.4	259.7	263.1	659.4	660.9	660.0	661.2	254.3	249.1	250.3	247.4	264.9	247.1
DP 405	29.65	265.7	266.4	252.7	256.5	651.5	653.8	652.9	654.1	246.2	241.1	242.3	239.4	256.9	239.6
DP 413	32.50	258.6	259.4	245.7	249.5	643.5	646.4	645.5	646.7	238.8	233.7	234.9	232.1	249.5	232.6
DP 406	35.30	246.9	247.7	233.7	238.2	630.3	634.5	633.3	634.7	227.4	222.2	223.6	221.0	238.1	221.8
DP 414	38.10	235.3	236.1	221.7	226.8	617.8	623.2	621.7	623.3	217.1	210.8	213.3	210.9	227.8	212.0
DP 407	40.90	221.9	222.7	207.7	213.8	607.8	613.2	608.8	610.4	206.2	199.9	202.4	200.2	216.9	201.6
DP 415	43.70	208.2	209.0	193.2	200.6	593.9	600.6	595.9	597.8	196.2	189.5	192.2	190.2	206.8	192.1
DP 408	46.52	191.9	192.4	175.7	186.6	577.5	585.6	581.0	583.2	185.1	178.1	181.0	179.3	195.5	181.6

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TABLE B-V
CORE INTERELEMENT PRESSURE TABULATIONS

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~~RESTRICTED DATA~~

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~~RESTRICTED DATA~~
~~FORM NO. 17-5~~

WANL-TME-1258

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
DP706	239.7	7.50	165.	7.16
DP707	248.3	7.50	285.	7.16
DP709	293.1	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
DP738	276.0	17.50	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
DP764	170.5	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
DP746	208.8	17.50	285.	40.90
DP767	211.7	17.50	45.	40.90
DP765	185.4	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	187.0	13.50	45.	46.52
DP408	177.1	18.00	0.	46.52
DP719	232.6	7.50	45.	46.52
DP727	214.1	7.50	165.	46.52
DP737	186.6	17.50	45.	46.52
DP747	214.4	0.	0.	46.52
DP748	211.8	17.50	285.	46.52

FFL-17-5 PRESSURE DATA

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~~FORM NO. 17-5~~

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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	236.4	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	204.0	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
DP764	157.7	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
DP746	220.3	17.50	285.	40.90
DP767	222.5	17.50	45.	40.90
DP765	173.9	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	196.6	13.50	45.	46.52
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

FFL-17-9 PRESSURE DATA

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~~RESTRICTED DATA~~

~~CONFIDENTIAL~~
~~RESTRICTED 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	283.2	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
DP738	280.8	17.50	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
DP764	159.0	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
DP746	221.7	17.50	285.	40.90
DP767	223.0	17.50	45.	40.90
DP765	177.7	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	174.3	13.50	45.	46.52
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

FFL-17-10 PRESSURE DATA

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~~RESTRICTED DATA~~

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~~RESTRICTED DATA~~
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WANL-TME-1258

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
DP738	272.3	17.50	45.	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
DP764	152.3	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
DP746	215.9	17.50	285.	40.90
DP767	217.7	17.50	45.	40.90
DP765	204.6	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	187.3	13.50	45.	46.52
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

FFL-17-11 PRESSURE DATA

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~~RESTRICTED DATA~~
~~Atomic Energy Act~~

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~~RESTRICTED DATA~~

WANL-TME-1258

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	267.5	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
DP738	270.9	17.50	45.	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	199.1	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
DP764	199.4	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
DP746	213.7	17.50	285.	40.90
DP767	216.0	17.50	45.	40.90
DP765	199.6	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	186.9	13.50	45.	46.52
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	194.6	17.50	45.	46.52
DP747	223.9	0.	0.	46.52

FFL-17-12 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

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~~RESTRICTED DATA~~
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WANL-TME-1258

FFL-17-13

CORE INLET PRESSURE (PSIA)=229.0
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	294.2	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	296.3	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
DP764	201.1	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	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
DP746	215.5	17.50	285.	40.90
DP767	205.8	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	190.3	13.50	45.	46.52
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	195.3	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

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act, 1954~~

WANL-TME-1258

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	220.9	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
DP738	277.4	17.50	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	195.8	0.	0.	29.65
DP751	257.7	17.50	285.	29.65
DP764	201.8	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
DP746	215.5	17.50	285.	40.90
DP767	217.1	17.50	45.	40.90
DP765	200.9	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	190.1	13.50	45.	46.52
DP408	185.9	18.00	7.	46.52
DP719	241.4	7.50	45.	46.52
DP727	220.7	7.50	165.	46.52
DP735	212.8	7.50	285.	46.52
DP737	195.6	17.50	45.	46.52
DP747	223.6	0.	0.	46.52

FFL-17-15 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act, 1954~~

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

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Astronuclear
Laboratory

WANL-TME-1258

FFL-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	288.1	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
DP738	284.6	17.50	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
DP764	204.4	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	166.1	7.50	285.	40.90
DP736	216.1	0.	0.	40.90
DP746	218.7	17.50	285.	40.90
DP767	220.4	17.50	45.	40.90
DP765	202.2	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	195.8	13.50	45.	46.52
DP408	186.9	18.00	7.	46.52
DP719	242.4	7.50	45.	46.52
DP727	222.4	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

FFL-17-16 PRESSURE DATA

~~CONFIDENTIAL~~

~~RESTRICTED DATA~~

~~Atomic Energy Act of 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

FFL-17-17

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

WANL-TME-1258
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	218.6	7.50	165.	18.40
DP730	210.5	7.50	285.	18.40
DP762	234.2	13.50	45.	18.40
DP738	281.8	17.50	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	199.9	0.	0.	29.65
DP751	258.3	17.50	285.	29.65
DP764	191.0	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	212.6	0.	0.	40.90
DP746	205.1	17.50	285.	40.90
DP767	218.6	17.50	45.	40.90
DP765	191.7	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	193.3	13.50	45.	46.52
DP408	184.8	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

FFL-17-17 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

FFL-17-18

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

WANL-TME-1258
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	214.9	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
DP738	278.9	17.50	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	254.9	17.50	285.	29.65
DP764	175.2	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
DP746	203.1	17.50	285.	40.90
DP767	216.1	17.50	45.	40.90
DP765	182.4	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	187.2	13.50	45.	46.52
DP408	184.8	18.00	7.	46.52
DP719	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

FFL-17-18 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

WANL-TME-1258

FFL-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	294.0	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	280.8	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	229.8	13.50	45.	18.40
DP738	279.3	17.50	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
DP764	181.0	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
DP746	202.4	17.50	285.	40.90
DP767	215.9	17.50	45.	40.90
DP765	185.5	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	190.0	13.50	45.	46.52
DP408	183.3	18.00	7.	46.52
DP719	240.0	7.50	45.	46.52
DP727	215.6	7.50	165.	46.52
DP735	203.3	7.50	285.	46.52
DP737	190.9	17.50	45.	46.52
DP747	220.6	0.	0.	46.52

FFL-17-19 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy, 1954~~

WANL-TME-1258

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
DP738	281.6	17.50	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	199.3	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
DP764	178.3	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
DP746	205.5	17.50	285.	40.90
DP767	219.5	17.50	45.	40.90
DP765	186.3	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	190.9	13.50	45.	46.52
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

FFL-17-20 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy, 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act 1954~~

WANL-TME-1258

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	282.8	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
DP738	281.3	17.50	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
DP764	183.3	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	167.5	7.50	165.	40.90
DP734	164.9	7.50	285.	40.90
DP736	212.1	0.	0.	40.90
DP746	209.3	17.50	285.	40.90
DP767	217.7	17.50	45.	40.90
DP765	185.6	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	250.8	13.50	45.	46.52
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	192.7	17.50	45.	46.52
DP747	221.9	0.	0.	46.52

FFL-17-21 PRESSURE DATA

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~~RESTRICTED DATA~~

FFL-17-22

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

WANL-TME-1258
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	292.9	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	280.0	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
DP738	280.1	17.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	256.0	18.00	97.	29.65
DP724	196.2	7.50	165.	29.65
DP732	198.9	7.50	285.	29.65
DP740	256.0	17.50	45.	29.65
DP743	205.6	0.	0.	29.65
DP751	254.8	17.50	285.	29.65
DP764	175.5	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	213.9	18.00	307.	40.90
DP718	168.6	7.50	45.	40.90
DP726	165.5	7.50	165.	40.90
DP734	163.4	7.50	285.	40.90
DP736	210.4	0.	0.	40.90
DP746	207.4	17.50	285.	40.90
DP767	215.7	17.50	45.	40.90
DP765	183.9	13.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP763	190.5	13.50	45.	46.52
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	220.0	0.	0.	46.52

FFL-17-22 PRESSURE DATA

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~~RESTRICTED DATA~~

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~~RESTRICTED DATA~~

WANL-TME-1258

FFL-17-44

CORE INLET PRESSURE (PSIA)=702.0
CORE PRESSURE DROP (PSID)=140.5

CORE INLET TEMPERATURE (F)=73.0
CORE OUTLET TEMPERATURE (F)=80.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	699.2	18.00	277.	7.16
DP706	643.1	7.50	165.	7.16
DP707	652.2	7.50	285.	7.16
DP709	697.5	17.50	285.	7.16
DP761	650.8	13.50	45.	7.16
DP766	697.5	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	681.6	18.00	53.	18.40
DP714	613.2	7.50	45.	18.40
DP720	620.3	0.	0.	18.40
DP722	611.7	7.50	165.	18.40
DP730	611.4	7.50	285.	18.40
DP738	679.1	17.50	45.	18.40
DP762	628.2	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	651.5	18.00	97.	29.65
DP724	585.7	7.50	165.	29.65
DP732	593.1	7.50	285.	29.65
DP740	651.2	17.50	45.	29.65
DP743	593.7	0.	0.	29.65
DP751	649.9	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	607.8	18.00	307.	40.90
DP718	576.4	7.50	45.	40.90
DP726	573.4	7.50	165.	40.90
DP734	556.8	7.50	285.	40.90
DP736	600.4	0.	0.	40.90
DP746	607.2	17.50	285.	40.90
DP767	609.4	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	577.5	18.00	7.	46.52
DP719	635.6	7.50	45.	46.52
DP727	611.9	7.50	165.	46.52
DP737	585.1	17.50	45.	46.52
DP747	615.6	0.	0.	46.52
DP763	584.7	13.50	45.	46.52

FFL-17-44 PRESSURE DATA

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RESTRICTED DATA

WANL-TME-1258

FFL-17-45

CORE INLET PRESSURE (PSIA)=700.0
CORE PRESSURE DROP (PSID)=130.4

CORE INLET TEMPERATURE (F)=74.0
CORE OUTLET TEMPERATURE (F)=80.5

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	697.4	18.00	277.	7.16
DP704	640.7	0.	0.	7.16
DP706	642.8	7.50	165.	7.16
DP707	649.2	7.50	285.	7.16
DP709	696.2	17.50	285.	7.16
DP761	648.4	13.50	45.	7.16
DP766	693.1	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	681.1	18.00	53.	18.40
DP714	615.8	7.50	45.	18.40
DP720	619.2	0.	0.	18.40
DP730	613.1	7.50	285.	18.40
DP738	679.9	17.50	45.	18.40
DP762	628.2	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	653.8	18.00	97.	29.65
DP724	590.4	7.50	165.	29.65
DP732	590.2	7.50	285.	29.65
DP740	655.7	17.50	45.	29.65
DP743	597.4	0.	0.	29.65
DP751	653.2	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	613.2	18.00	307.	40.90
DP718	585.1	7.50	45.	40.90
DP726	561.6	7.50	165.	40.90
DP734	557.4	7.50	285.	40.90
DP736	606.9	0.	0.	40.90
DP746	613.5	17.50	285.	40.90
DP767	614.5	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	585.6	18.00	7.	46.52
DP719	647.9	7.50	45.	46.52
DP727	618.9	7.50	165.	46.52
DP737	589.4	17.50	45.	46.52
DP747	622.1	0.	0.	46.52
DP763	585.2	13.50	45.	46.52
DP765	561.3	13.50	45.	46.52

FFL-17-45 PRESSURE DATA

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WANL-TME-1258

FFL-17-46

CORE INLET PRESSURE (PSIA)=700.0
CORE PRESSURE DROP (PSID)=132.9

CORE INLET TEMPERATURE (F)=87.0
CORE OUTLET TEMPERATURE (F)=87.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	697.3	18.00	277.	7.16
DP704	642.9	0.	0.	7.16
DP706	641.0	7.50	165.	7.16
DP707	650.6	7.50	285.	7.16
DP709	695.6	17.50	285.	7.16
DP761	647.1	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	680.8	18.00	157.	18.40
DP714	609.4	7.50	45.	18.40
DP720	617.7	0.	0.	18.40
DP730	611.1	7.50	285.	18.40
DP738	680.3	17.50	45.	18.40
DP762	625.0	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	652.9	18.00	113.	29.65
DP724	586.5	7.50	165.	29.65
DP732	582.7	7.50	285.	29.65
DP740	652.3	17.50	45.	29.65
DP743	592.9	0.	0.	29.65
DP751	637.2	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	608.8	18.00	353.	40.90
DP718	579.5	7.50	45.	40.90
DP726	569.9	7.50	165.	40.90
DP734	583.2	7.50	285.	40.90
DP736	599.4	0.	0.	40.90
DP741	609.2	17.50	165.	40.90
DP746	608.9	17.50	285.	40.90
DP767	610.3	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	581.0	18.00	0.	46.52
DP719	636.1	7.50	45.	46.52
DP727	613.5	7.50	165.	46.52
DP737	586.9	17.50	45.	46.52
DP747	616.7	0.	0.	46.52
DP763	587.7	13.50	45.	46.52

FFL-17-46 PRESSURE DATA

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WANL-TME-1258

FFL-17-47

CORE INLET PRESSURE (PSIA)=700.0
CORE PRESSURE DROP (PSID)=130.8

CORE INLET TEMPERATURE (F)=84.0
CORE OUTLET TEMPERATURE (F)=88.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	697.4	18.00	277.	7.16
DP704	641.8	0.	0.	7.16
DP706	640.8	7.50	165.	7.16
DP707	650.4	7.50	285.	7.16
DP709	695.8	17.50	285.	7.16
DP766	694.9	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	681.2	18.00	157.	18.40
DP714	613.2	7.50	45.	18.40
DP720	618.7	0.	0.	18.40
DP730	611.4	7.50	285.	18.40
DP738	680.9	17.50	45.	18.40
DP762	625.6	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	654.1	18.00	113.	29.65
DP724	587.4	7.50	165.	29.65
DP732	592.4	7.50	285.	29.65
DP740	653.2	17.50	45.	29.65
DP743	599.7	0.	0.	29.65
DP751	653.2	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	610.4	18.00	353.	40.90
DP718	583.6	7.50	45.	40.90
DP726	581.1	7.50	165.	40.90
DP734	558.6	7.50	285.	40.90
DP736	601.6	0.	0.	40.90
DP746	611.1	17.50	285.	40.90
DP767	611.9	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	583.2	18.00	0.	46.52
DP719	639.1	7.50	45.	46.52
DP727	614.2	7.50	165.	46.52
DP737	588.6	17.50	45.	46.52
DP747	618.3	0.	0.	46.52
DP763	578.1	13.50	45.	46.52

FFL-17-47 PRESSURE DATA

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~~Atomic Energy, Washington~~

WANL-TME-1258

FLL-17-49

CORE INLET PRESSURE (PSIA)=300.0
CORE PRESSURE DROP (PSID)=130.0

CORE INLET TEMPERATURE (F)=76.0
CORE OUTLET TEMPERATURE (F)=84.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	296.4	18.00	293.	7.16
DP704	247.6	0.	0.	7.16
DP706	240.9	7.50	165.	7.16
DP707	249.9	7.50	285.	7.16
DP709	295.4	17.50	285.	7.16
DP761	246.6	13.50	45.	7.16
DP766	294.1	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	271.8	18.00	73.	18.40
DP714	219.2	7.50	45.	18.40
DP720	200.1	0.	0.	18.40
DP730	213.2	7.50	285.	18.40
DP738	268.5	17.50	45.	18.40
DP762	220.3	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	239.7	18.00	353.	29.65
DP724	169.2	7.50	165.	29.65
DP732	178.7	7.50	285.	29.65
DP740	239.5	17.50	45.	29.65
DP743	206.7	0.	0.	29.65
DP751	239.4	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	200.4	18.00	285.	40.90
DP718	186.7	7.50	45.	40.90
DP726	223.8	7.50	165.	40.90
DP734	159.6	7.50	285.	40.90
DP736	209.7	0.	0.	40.90
DP746	201.1	17.50	285.	40.90
DP765	176.3	13.50	45.	40.90
DP767	205.1	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	179.5	18.00	45.	46.52
DP719	235.3	7.50	45.	46.52
DP727	214.6	7.50	165.	46.52
DP747	215.8	0.	0.	46.52
DP763	186.3	13.50	45.	46.52

FLL-17-49 PRESSURE DATA

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Atomic Energy

WANL-TME-1258

FFL-17-50

CORE INLET PRESSURE (PSIA)=307.0
CORE PRESSURE DROP (PSID)=131.5

CORE INLET TEMPERATURE (F)=75.5
CORE OUTLET TEMPERATURE (F)=76.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	303.1	18.00	293.	7.16
DP704	253.2	0.	0.	7.16
DP706	247.4	7.50	165.	7.16
DP707	255.8	7.50	285.	7.16
DP709	302.1	17.50	285.	7.16
DP766	302.7	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	278.8	18.00	73.	18.40
DP714	226.6	7.50	45.	18.40
DP720	204.1	0.	0.	18.40
DP730	234.6	7.50	285.	18.40
DP738	277.2	17.50	45.	18.40
DP762	226.0	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	246.2	18.00	353.	29.65
DP724	191.9	7.50	165.	29.65
DP732	185.1	7.50	285.	29.65
DP740	245.9	17.50	45.	29.65
DP743	214.1	0.	0.	29.65
DP751	240.6	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	206.2	18.00	285.	40.90
DP718	192.1	7.50	45.	40.90
DP726	197.2	7.50	165.	40.90
DP734	162.5	7.50	285.	40.90
DP736	215.0	0.	0.	40.90
DP741	203.0	17.50	165.	40.90
DP746	206.7	17.50	285.	40.90
DP765	173.7	13.50	45.	40.90
DP767	209.5	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	185.1	18.00	45.	46.52
DP719	240.6	7.50	45.	46.52
DP727	218.1	7.50	165.	46.52
DP737	190.1	17.50	45.	46.52
DP747	220.0	0.	0.	46.52
DP763	191.7	13.50	45.	46.52

FFL-17-50 PRESSURE DATA

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~~Atomic Energy Research~~

WANL-TME-1258

FFL-17-51

CORE INLET PRESSURE (PSIA)=305.0
CORE PRESSURE DROP (PSID)=136.9

CORE INLET TEMPERATURE (F)=86.5
CORE OUTLET TEMPERATURE (F)=82.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	301.1	18.00	277.	7.16
DP704	253.8	0.	0.	7.16
DP706	246.0	7.50	165.	7.16
DP707	254.8	7.50	285.	7.16
DP709	300.0	17.50	285.	7.16
DP761	232.5	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	274.1	18.00	157.	18.40
DP714	219.4	7.50	45.	18.40
DP720	202.1	0.	0.	18.40
DP730	228.9	7.50	285.	18.40
DP738	270.4	17.50	45.	18.40
DP762	212.4	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	241.1	18.00	113.	29.65
DP724	186.4	7.50	165.	29.65
DP732	180.9	7.50	285.	29.65
DP740	241.1	17.50	45.	29.65
DP743	205.1	0.	0.	29.65
DP751	240.7	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	199.9	18.00	353.	40.90
DP718	185.5	7.50	45.	40.90
DP726	183.8	7.50	165.	40.90
DP734	161.8	7.50	285.	40.90
DP736	209.1	0.	0.	40.90
DP741	198.4	17.50	165.	40.90
DP746	201.4	17.50	285.	40.90
DP765	172.8	13.50	45.	40.90
DP767	203.2	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	178.1	18.00	0.	46.52
DP719	234.8	7.50	45.	46.52
DP727	212.1	7.50	165.	46.52
DP737	185.6	17.50	45.	46.52
DP747	209.7	0.	0.	46.52
DP763	171.1	13.50	45.	46.52

FFL-17-51 PRESSURE DATA

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WANL-TME-1258

FILE-17-53

CORE INLET PRESSURE (PSIA)=304.0
CORE PRESSURE DROP (PSID)=132.8

CORE INLET TEMPERATURE (F)=79.5
CORE OUTLET TEMPERATURE (F)=84.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	300.4	18.00	277.	7.16
DP706	244.5	7.50	165.	7.16
DP707	252.9	7.50	285.	7.16
DP709	298.9	17.50	285.	7.16
DP761	250.6	13.50	45.	7.16
DP766	301.7	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	275.3	18.00	157.	18.40
DP714	220.0	7.50	45.	18.40
DP720	213.5	0.	0.	18.40
DP730	227.1	7.50	285.	18.40
DP738	273.9	17.50	45.	18.40
DP762	223.5	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	242.3	18.00	113.	29.65
DP724	187.7	7.50	165.	29.65
DP732	178.7	7.50	285.	29.65
DP740	241.7	17.50	45.	29.65
DP743	208.0	0.	0.	29.65
DP751	241.5	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	202.4	18.00	353.	40.90
DP718	188.2	7.50	45.	40.90
DP726	187.1	7.50	165.	40.90
DP734	163.5	7.50	285.	40.90
DP736	211.1	0.	0.	40.90
DP741	200.0	17.50	165.	40.90
DP746	203.8	17.50	285.	40.90
DP765	164.2	13.50	45.	40.90
DP767	204.7	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	181.0	18.00	165.	46.52
DP719	235.6	7.50	45.	46.52
DP727	212.2	7.50	165.	46.52
DP737	183.7	17.50	45.	46.52
DP747	215.8	0.	0.	46.52
DP763	175.6	13.50	45.	46.52

FFL-17-53 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
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FFL-17-56

CORE INLET PRESSURE (PSIA)=300.0
CORE PRESSURE DROP (PSID)=130.3

CORE INLET TEMPERATURE (F)=80.5
CORE OUTLET TEMPERATURE (F)=83.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	296.4	18.00	277.	7.16
DP704	264.0	0.	0.	7.16
DP706	241.3	7.50	165.	7.16
DP707	249.7	7.50	285.	7.16
DP709	294.9	17.50	285.	7.16
DP761	249.3	13.50	45.	7.16
DP766	297.7	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	271.9	18.00	157.	18.40
DP714	220.8	7.50	45.	18.40
DP720	214.3	0.	0.	18.40
DP730	226.5	7.50	285.	18.40
DP738	268.6	17.50	45.	18.40
DP762	220.1	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	239.4	18.00	113.	29.65
DP724	186.5	7.50	165.	29.65
DP732	180.1	7.50	285.	29.65
DP740	239.0	17.50	45.	29.65
DP743	206.5	0.	0.	29.65
DP751	239.3	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	200.2	18.00	353.	40.90
DP718	187.0	7.50	45.	40.90
DP726	173.8	7.50	165.	40.90
DP734	200.2	7.50	285.	40.90
DP736	209.5	0.	0.	40.90
DP741	199.0	17.50	165.	40.90
DP746	201.9	17.50	285.	40.90
DP765	176.0	13.50	45.	40.90
DP767	203.6	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	179.3	18.00	0.	46.52
DP719	232.8	7.50	45.	46.52
DP727	211.4	7.50	165.	46.52
DP737	186.8	17.50	45.	46.52
DP747	214.2	0.	0.	46.52
DP763	186.7	13.50	45.	46.52

FFL-17-56 PRESSURE DATA

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~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

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~~RESTRICTED DATA~~
~~Atomic Energy 1754~~

FFL-17-57

CORE INLET PRESSURE (PSIA)=318.0
CORE PRESSURE DROP (PSID)=132.5

WANL-TME-1258
CORE INLET TEMPERATURE (F)=77.0
CORE OUTLET TEMPERATURE (F)=82.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	314.5	18.00	277.	7.16
DP704	278.3	0.	0.	7.16
DP406	308.2	7.50	165.	7.16
DP706	259.6	7.50	165.	7.16
DP707	268.0	7.50	285.	7.16
DP709	312.7	17.50	285.	7.16
DP761	268.0	13.50	45.	7.16
DP766	315.5	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	289.9	18.00	283.	18.40
DP720	230.7	0.	0.	18.40
DP730	242.5	7.50	285.	18.40
DP738	289.2	17.50	45.	18.40
DP762	237.9	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	256.9	18.00	187.	29.65
DP724	203.5	7.50	165.	29.65
DP732	197.1	7.50	285.	29.65
DP740	257.0	17.50	45.	29.65
DP743	222.4	0.	0.	29.65
DP751	255.9	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	216.9	18.00	7.	40.90
DP718	203.0	7.50	45.	40.90
DP726	204.0	7.50	165.	40.90
DP734	172.9	7.50	285.	40.90
DP736	225.5	0.	0.	40.90
DP741	217.0	17.50	165.	40.90
DP746	218.5	17.50	285.	40.90
DP765	190.8	13.50	45.	40.90
DP767	220.0	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	195.5	18.00	165.	46.52
DP719	249.5	7.50	45.	46.52
DP727	227.1	7.50	165.	46.52
DP737	202.1	17.50	45.	46.52
DP747	229.9	0.	0.	46.52
DP763	203.6	13.50	45.	46.52

FFL-17-57 PRESSURE DATA

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~~Atomic Energy 1754~~

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~~RESTRICTED DATA~~
~~Atomic Energy Act 1954~~

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CORE INLET PRESSURE (PSIA)=298.0
CORE PRESSURE DROP (PSID)=125.6

CORE INLET TEMPERATURE (F)=79.5
CORE OUTLET TEMPERATURE (F)=83.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	294.4	18.00	277.	7.16
DP704	262.3	0.	0.	7.16
DP707	247.6	7.50	285.	7.16
DP709	293.2	17.50	285.	7.16
DP761	248.4	13.50	45.	7.16
DP766	232.1	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	270.6	18.00	157.	18.40
DP714	215.9	7.50	45.	18.40
DP720	211.3	0.	0.	18.40
DP730	216.7	7.50	285.	18.40
DP738	268.0	17.50	45.	18.40
DP762	227.5	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	239.6	18.00	113.	29.65
DP724	181.4	7.50	165.	29.65
DP732	184.2	7.50	285.	29.65
DP743	182.7	0.	0.	29.65
DP751	238.6	17.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	201.6	18.00	353.	40.90
DP718	181.1	7.50	45.	40.90
DP726	183.2	7.50	165.	40.90
DP734	173.5	7.50	285.	40.90
DP736	200.8	0.	0.	40.90
DP746	197.1	17.50	285.	40.90
DP765	165.6	13.50	45.	40.90
DP767	204.9	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	181.6	18.00	0.	46.52
DP719	234.3	7.50	45.	46.52
DP727	212.4	7.50	165.	46.52
DP737	187.2	17.50	45.	46.52
DP747	217.1	0.	0.	46.52
DP763	177.5	13.50	45.	46.52

FFL-17-58 PRESSURE DATA

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act 1954~~

FIGURE B-1

SEAL PRESSURE PROFILE - FFL-17-5

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~1994~~

603904-84

SEAL PRESSURE PROFILE - FFL-17-44

FIGURE B-2

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~1994~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

WANL-TME-1258

FIGURE B-3
SEAL PRESSURE PROFILE - FFL-17-58

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Astronuclear Energy, Inc.~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

WANL-TME-1258

FIGURE B-4

CORE INTERELEMENT PRESSURES - FFL-17-16

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act, 1954~~

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FIGURE B-5

CORE INTERELEMENT PRESSURES - FFL-17-17

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act, 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

WANL-TME-1258

FIGURE B-6

CORE INTERELEMENT PRESSURES - FFL-17-19

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act of 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

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FIGURE B-7

CORE INTERELEMENT PRESSURES - FFL-17-45

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
Atomic Energy Act, 1954

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

WANL-TME-1258

○ 285° AZIMUTH
□ 165° AZIMUTH
△ 45° AZIMUTH
X CENTERLINE
17-47

FIGURE B-8

CORE INTERELEMENT PRESSURES - FFL-17-47

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

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FIGURE B-9

CORE INTERELEMENT PRESSURES - FFL-17-49

CONFIDENTIAL
RESTRICTED DATA

Astronuclear
Laboratory

WANL-TME-1258

○ 265° AZIMUTH
□ 165° AZIMUTH
△ 45° AZIMUTH
X CENTERLINE

17-50

FIGURE B-10

CORE INTERELEMENT PRESSURES - FFL-17-50

CONFIDENTIAL
RESTRICTED DATA

CONFIDENTIAL
RESTRICTED DATA
 Atomic Energy Act, 1954

Astronuclear
 Laboratory

WANL-TME-1258

- 285° AZIMUTH
- 165° AZIMUTH
- △ 45° AZIMUTH
- X CENTERLINE

17-51

FIGURE B-11

CORE INTERELEMENT PRESSURES - FFL-17-51

CONFIDENTIAL
RESTRICTED DATA
 Atomic Energy Act, 1954

CONFIDENTIAL
RESTRICTED DATA
 Atomic Energy Act 1954

WANL-TME-1258

○ 285° AZIMUTH
 □ 165° AZIMUTH
 △ 45° AZIMUTH
 X CENTERLINE

FIGURE B-12

CORE INTERELEMENT PRESSURES - FFL-17-53

CONFIDENTIAL
RESTRICTED DATA
 Atomic Energy Act 1954

FIGURE B-13

NORMALIZED FLUID BUNDLING PRESSURES,
 300 PSIA UNPERTURBED TESTS

FIGURE B-14

NORMALIZED FLUID BUNDLING PRESSURES,
300 PSIA PERTURBED TESTS

FIGURE B-15

NORMALIZED FLUID BUNDLING PRESSURES,
 300 PSIA, UNPERTURBED TESTS