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ALTERNATE METHODS OF INVESTIGATING FLOW INDUCED VIBRATIONS

by

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1.0 INTRODUCTION

This summary on various flow induced vibration tests considers the four major types of tests which could accomplish, in part or in entirety, the experimental verification of design concepts for the support system for the NRX-A design. Requirements of the tests are discussed and alternate methods and schedules are being considered. On the basis of technical desirability as well as schedule requirements, firm recommendations are presented.

2.0 DISCUSSION

In considering all of the various types of experimental devices which could be used to study flow induced vibrations, two (2) goals must be considered. These are:

1. An experimental device which will insure the flow stability of prototype components of the NRX-A; and,
2. An experimental device which can study, evaluate and map the regions of flow stability and instability.

The former is necessary as a verification of the NRX-A design; the latter is necessary for the assurance of flow stability in present and future design modifications as well as fundamental understanding of the phenomenon. As a minimum, any of the planned or proposed tests should obtain information on the characteristics of movable reactor components (especially the fuel clusters). The desired information is:

1. Radial Motion
2. Tangential Motion
3. Axial Motion
4. Seal Pressure Distribution
5. Interaction of Main and Leakage Flow

In addition, the test equipment should have the provision of being able to vary the pressure distribution along the axis of the reactor and have an inherent flexibility for quick and convenient modifications necessitated by design changes. To date, four (4) general categories of tests have been proposed to obtain information on the aeroelastic flow instabilities. These are:

2.1 Full Reactor Test

The obvious use of a complete reactor proto-type used for a cold flow experiment. While this method, if properly instrumented, would yield all the five (5) necessary points of information, the variability of the seal pressure as well as modification flexibility would be extremely difficult to obtain. The modification of the reactor would be very time consuming.

Plugging the NRX-A1 core for pressure difference simulation will be treated separately. This test will not have the variable pressure distribution feature incorporated in the seal system and can in no way be considered to yield the same type of usable information obtainable from G 3.

2.2 Plugged Core Test

Plugged core tests (as discussed in Test Specification G 3) which use as the test instrument a dummy or proto-type reactor with the fuel element orifices replaced with solid plugs, permit testing without regard to the scheduling problems and the complexity of the Nevada Test Site. The design modifies the seal and support system to provide the variability required and still permits the use of existing hardware. The only reactor characteristic which this type of test does not evaluate is the interaction of the main cold flow through the fuel elements and the leakage flow coming through the interspatial passage between the elements and through the seal and support components. The fact that individual fuel elements are not excited to any type of vibration by internal flow has been substantiated experimentally. This increases the validity of the plugged core tests, and eliminates the possibility of flow induced

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vibration from any interaction between the main and leakage flow. Test data obtained from plugged core tests would be the most usable since the range of conditions with regard to flow-pressure level and operating temperature are much wider than those obtained by a reactor test such as NRX-A1. Because of this, stability of the reactor could be mapped over a wider flow region and the confidence in the margin of stability improved.

The possible ways in which the components can be assembled for test G 3 can be broken down to six combinations of pressure vessels and reactor components plus the limitations which may be imposed by the flow system. These combinations with the limiting dates are shown on Table I (Section 3.0, Schedules). Three (3) possibilities for pressure vessels exist. These are: 1) the adaptation of a proto-type pressure vessel designed for Nevada reactor tests; 2) a new pressure vessel designed and built in accordance with the Pennsylvania Code; and, 3) the remote possibility of acquiring a suitably "used" pressure vessel. The reactor would come from two sources; either the present build-up of the reactor to be used in G 1 (ND-201) or the hardware presently planned for the G 3 tests, namely build ND-207. The availability of pressure vessels will be discussed first.

2.2.1 Modified Proto-Type Pressure Vessel

Modifications which would be required to convert the proto-type vessels for use with G 3, Plugged Core Flow Tests, would consist of the design and extension required in the top of the vessel to allow room for the support ring test components; and, the incorporation of inlet ports to the bottom of the vessel for hydrogen gas. In addition, a support for the graphite reflector and a new bottom closure would have to be designed and made. The estimated time for the limiting components required would be: a design time of 3 weeks, an additional 3 weeks for bids and approvals, and a fabrication time of 5 weeks. An 11 week lapse would make the

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vessel available approximately November 28. This vessel would not be in conformance to the Pennsylvania State Code for Pressure Vessels and its use for a special test would require negotiation with the Pennsylvania Industrial Board. Its use would probably be limited to NRX A1 conditions of

Reflector Inlet Pressure	230 psia
Core Inlet Pressure	190 psia
Chamber Pressure	60 psia

2.2.2 A New Pressure Vessel

The preliminary design and specification for a new pressure vessel in conformance with specification WANL-E-675432 "Large Diameter Flow Vibration Test Vessel" and drawing NT 700163. Verbal contact with vendors indicate cost of \$38,000 to \$42,000 with 9 to 16 weeks delivery.

2.2.3 Used Pressure Vessels

The remote possibility exists that we may be able to find a pressure vessel capable of containing the entire inner components of the reactor; namely, the core and lateral support system. While this possibility is being pursued, its successful attainment is questionable.

2.2.4 Reactor ND-201

This reactor is presently being assembled for G 1 series tests. The reflector presently has 300 additional holes for observation. For gas pressure distribution tests these holes would have to be plugged and the interior, possibly the exterior of the graphite barrel would have to be remachined. It is estimated that this remodification would cost \$6,000 and take three (3) weeks. This reactor could continue to be used for G 1 series tests until such time

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as a pressure vessel were available. At that time the observation holes would be plugged and the instrumentation would be installed. The axial coolant holes are also missing in this reactor and other means must be provided for bringing the instrumentation probes to the exterior. Three (3) weeks would be required for flow instrumentation.

2.2.5 Reactor ND-207

This reactor will have all hardware available on November 1 with sufficient components available to start assembly on October 1 and be completed by November 4.

2.2.6 System Limitations

The flow system presently in the process of fabrication for test A 11 will be available for the G 3 tests with only minor modifications. While limited A 11 tests will be conducted with gas drawn directly from tank trailers, this type of operation is severely limited (about 0.5 pps) and would furnish only 50% of the required flow needed for the plugged core tests (flow requirements for the plugged flow tests are given in the G 3 test specification appended hereto). The gaseous storage sphere which will permit us to test at high flow rates for long periods of time will be delivered at a presently estimated date of October 15. Installation, insulation of sphere, weld connections, and intergration into the flow system will require approximately two (2) weeks. This would indicate that the flow system at its design capacity would be available on November 1.

2.3 Radially Symmetric Cluster Tests

Radially symmetric sealed multi-cluster tests would range from a minimum of 7 to a number somewhat less than the full reactor of 286 clusters.

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This type of radially symmetric multi-cluster unit would increase in the following progression: 7, 19, 37, 61, 91, 127, etc. As the number of clusters increased, the simulation of the full core would improve but other desirable features of this type of experimental apparatus would decrease; namely, the modification flexibility and the speed and ease of assembly and disassembly. All types of motion, as well as pressure distribution, can be measured adequately in this type of test within the limits of scale factors. The information thus obtained is directly applicable to the design concepts of the requirements of NRX-A. The A 11 test was chosen to be a 7 cluster configuration in order to maximize its flexibility as a research tool, obtain information at the earliest possible date and permit the widest variation in future design modifications. Major design changes can be made quickly with a minimum of difficulty.

2.4 Sector Tests

Sector tests combine all the undesirable features of the radially symmetric multi-cluster tests with the additional difficulties inherent in a sector or "pie" test. While the radial motion can probably be simulated rather well for flow instability, the tangential motion would be severely compromised because of the solid boundary introduced on the flat side of the sector. Extreme difficulties would be encountered in maintaining an adequate seal on the sector boundary for the seal and support system. Preliminary calculations indicate that maintaining wall rigidity would also be a problem. At reactor design conditions, a 1" thick stainless steel plate which would serve as part of the axial sector boundary would have a central deflection of approximately 0.20 inches. Either extremely thick webbing or the use of an auxiliary pressure vessel would be required in such a design. At design flow conditions a gas flow of approximately 12 pps would be required which would require core plugging. In general, the use of a sector test at simulated conditions of operation for the NRX-A would be an extremely difficult test to perform and would present information which would be of limited value, especially

for the case of a tightly bundled reactor core such as the NRX-A. When the periphery becomes more rigid the probability of radial oscillations is reduced and the probability of tangential oscillations is increased. Hence, the restraint of the solid sector boundary would severely limit the type of oscillations to be encountered. At best, this type of test could produce some qualitative but little quantitative information. The sector tests are the least desirable of all alternates.

2.5 Summary of Configuration

In summary then, the radially symmetric multi-cluster test (A 11) will provide information at a very early date, which, when combined with the flexibility obtainable from G 3, the Plugged Core Flow Tests, would provide information on the stability and behavior characteristic of the seal and support system at the earliest possible date and in the greatest possible detail.

3.0 SCHEDULES AND COSTS

Table No. 1 lists the various combinations of pressure vessels with reactors. In each case the limiting data listed represents the latest available date of either the reactor or the pressure vessel. As previously discussed, there is a difference in the pressure vessels availability date and this at present favors a new pressure vessel rather than modifying the proto-type vessel. Table No. 2 shows the variation in cost which would be incurred by using the various combinations of reactors and pressure vessels. In essence, a proto-type vessel would reduce the cost by approximately \$20,000 but limit the attainable pressure by as yet an undetermined value. This pressure limitation in light of the ASME Code could probably be extremely severe. The use of reactor ND-201 would increase the cost by approximately \$6,000 for plugging the holes as well as an additional \$3,000 necessary for modifications required by the instrumentation due to the lack of axial cooling holes.

The only major improvement in the date would be if a used pressure vessel with suitable heads could be found. Such a vessel would be usable only if it met pressure requirements and could be modified quickly and economically. Since this is a low probability, Table 3 presents the most desirable combination of reactor ND-207 combined with a new pressure vessel.

4.0 CONCLUSIONS AND RECOMMENDATIONS

In order to obtain experimental justification of the NRX-A lateral support and seal system with regard to flow stability and pressure distribution the following program based on the facts advanced previously can be summarized:

1. It is recommended that testing of the 7 cluster configuration start at the earliest time at conditions up to those expected in the NRX-A1 cold flow tests. As soon as storage capacity is available the flow ranges would be extended to those representing full design operating conditions.
2. It is recommended that A 11 tests be temporarily terminated as soon as the test equipment for G 3 becomes available. At present the pressure vessel seems to be the limiting item.

The optimum combination from a minimal time viewpoint is a proto-type vessel with ND-201 with an availability of October 28. Allowing three (3) weeks for final assembly, transport to WANHEF and installation in the test cell would permit an initial test date of approximately November 18. This combination would, however, limit or even sacrifice test G 1. ND-207 can be completed one (1) week later coincident with the pressure vessel, and G 1 could be left intact.

Presently the most expeditious approach would be the use of a coded vessel with ND-207 which would be capable of maximum pressure operation.

TABLE 1
SCHEDULE VARIATIONS FOR G 3 - PLUGGED CORE TESTS

Availability	(D)	(E)
Pressure Vessel	Reactor ND-201 (Oct. 28)	Reactor ND-207 (Nov. 4)
	<u>Limiting Date</u>	<u>Limiting Date</u>
Proto-Type (Dec. 15)	Dec. 15	Dec. 15
New Pressure Vessel (Nov. 4)	Nov. 4	Nov. 4
Used Pressure Vessel (Unknown)	??	??

TABLE 2
PLUGGED CORE TESTS COST ESTIMATES
 (New Coded Pressure Vessels)

	New Pressure Vessel Reactor ND-207	New Pressure Vessel Reactor ND-201
<u>M & S</u>		
Lateral Support System Parts		
Graphite Reflector Modifications	\$ 6,700	\$ 9,700
Graphite Reflector Hole Plugging	--	6,000
Aluminum Barrel	10,000	10,000
Special Parts	5,000	5,000
Sub-Total	\$ 21,700	\$ 30,700
Flow System Modifications	20,000	20,000
Two Remote Operating Pressure Control Valves	5,000	5,000
Dummy Orifices	6,600	6,600
Miscellaneous Hardware	4,000	4,000
	\$ 57,300	\$ 66,300
<u>STE</u>		
Pressure Vessel - 304 Stainless Steel - 750 psig - New Working Pressure	40,000	40,000
Multiplexing Equipment for 80 Points at \$650. 00/Point	52,000	52,000
54 Amplifiers	50,670	50,670
60 Signal Conditioners for Transducers, etc.	42,000	42,000
Core Handling Equipment	50,000	50,000
	\$234,670	\$234,670
<u>INSTRUMENTATION</u>		
4 High Pressure Microphones	2,400	2,400
60 Pressure Transducers	20,000	20,000
20 Thermocouples	500	500
6 Pressure Gauges	300	300
20 Displacement Gauges	840	840
8 Accelerometers	4,440	4,440
12 Strain Gauges	120	120
6 Orifice Flowmeters	1,800	1,800
Instrumentation Accessories	4,000	4,000
	\$ 34,400	\$ 34,000
TOTAL	\$326,370	\$335,370

TABLE 2 (Con't.)
(Proto-Type Pressure Vessels)

	Proto-Type Pressure Vessel Reactor ND-207	Proto-Type Pressure Vessel Reactor ND-201
<u>M & S</u>		
Lateral Support System Parts		
Graphite Reflector Modifications	\$ 6,700	\$ 9,700
Graphite Reflector Hole Plugging	---	6,000
Aluminum Barrel	10,000	10,000
Special Parts	5,000	5,000
Sub-Total	\$ 21,700	\$ 30,700
Flow System Modifications	20,000	20,000
Two Remote Operating Pressure Control Valves	5,000	5,000
Dummy Orifices	6,600	6,600
Miscellaneous Hardware	4,000	4,000
	<u>\$ 57,300</u>	<u>\$ 66,300</u>
<u>STE</u>		
Pressure Vessel Modification	19,000	19,000
Multiplexing Equipment for 80 Points at \$650. 00/Point	52,000	52,000
54 Amplifiers, etc.	50,670	50,670
60 Signal Conditioners for Transducers, etc.	42,000	42,000
Core Handling Equipment	50,000	50,000
	<u>\$213,670</u>	<u>\$213,670</u>
<u>INSTRUMENTATION</u>		
4 High Pressure Microphones	2,400	2,400
60 Pressure Transducers	20,000	20,000
20 Thermocouples	500	500
6 Pressure Gauges	300	300
20 Displacement Gauges	840	840
8 Accelerometers	4,440	4,440
12 Strain Gauges	120	120
6 Orifice Flowmeters	1,800	1,800
Instrumentation Accessories	4,000	4,000
	<u>\$ 34,400</u>	<u>\$ 34,400</u>
TOTAL	\$305,370	\$314,370

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TABLE 3

G 3 - PLUGGED CORE FLOW TESTS

(New Pressure Vessel, Reactor ND-207)

	1963						1964								
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
SCHEDULE:															
Test Vessel Design	—														
Test Vessel Procurement	—	—	—	—											
Reactor Procurement	—	—	—	—											
Reactor Assembly				—	—										
Installation					—										
Test					—	—	—	—	—						
Report Initial						—									
Report Final								—	—	—					
MANPOWER: (1)															
E & S	2	5	6	6	6	5	5	5	3	3	1	2			
Drafting	2	4	4	3	3	2	1	1	1	1	1				
Technicians	1	2	5	10	12	7	5	5	5	2					

TEST SPECIFICATION

A 11 - FLOW INDUCED VIBRATION TEST

Revision No: 2

Date: 7/14/63

1. TEST NUMBER: A 11

2. TITLE: FLOW INDUCED VIBRATION TEST

3. PURPOSE:

To flow test a NRX-A reactor proto-type core assembly to investigate and evaluate the types of vibrations which may result from hydrogen coolant flow phenomena and determine the effectiveness of the designed lateral support and seal systems to reduce or eliminate these vibrations in order to insure structural integrity of the core.

4. REQUIRED DESIGN DATA:

- 4.1 Determine vibration amplitudes and frequencies for various flow conditions.
- 4.2 Determine the type and degree of constraint or seal conditions required to minimize or reduce these vibrations.

5. TEST PLAN:

- 5.1 Description - Testing will be accomplished by flowing hydrogen gas through an instrumented seven cluster reactor proto-type core. The core will be assembled using reactor grade hardware and fitted within a pressure vessel containing a simulated lateral support and seal system, inner reflector, top

Engineer: _____

Approved: _____

support plate, support rings, and diffuser or shield. The test equipment will be positioned such that the core will be mounted in a vertical position to achieve a downward or upward firing configuration.

The vibration tests will be of short duration and will include specified pressure, temperature and flow histories. Various types of instrumentation will be utilized to measure the degree and mode of vibrations which may be induced in the fuel element clusters as a result of the selected flow conditions. Comparison will be made utilizing different cores, various support and seal configurations and flow conditions.

- 5.2 Components Under Test - Three different reactor proto-type core will be evaluated. The first core will be utilized for preliminary shake-down tests and will consist of unfueled, uncoated, fuel elements (graphite) and graphite filler strips without pyro-tile. The second core will be similar to the first with the exception of using fueled and coated fuel elements (natural or depleted uranium). The third core assembly will be similar to the second core.

Various test core geometries and orificing schedules will be evaluated as a part of the vibration test program. Changes in core geometries will primarily reflect planned, fixed openings between fuel elements or fuel cluster assemblies. These models will be tested with an orificed core as established by the fluid flow multi-channel analysis digital computer program. The orificing schedule for the first core will be based on fuel clusters situated in the center of the reactor core and will essentially utilize 0.060" orifices. Subsequent cores will utilize orificing schedules designed to compare fueled and unfueled cores located in the center of the reactor as well as positions adjacent to the inner reflector. Plugged core tests will be made in order to determine the effects of hydrogen flow between the fuel elements and between the filler strips and lateral support and seal rings.

The initial lateral support system to be tested will be a simulated (smaller diameter) NRX-A design and will include the complete complement of 18 segmented rings. Loading of the individual segments will be accomplished using helical coil springs with different preload and spring rates. The lateral support and seal system is designed in such a manner that the pressure distribution in the lateral seal cavities can be measured and varied externally without total disassembly. Subsequent support and seal systems to be tested will follow reactor design requirements.

- 5.3 Experimental Set-Up - The flow vibration tests will be carried out in a new hydrogen facility located at the Westinghouse Waltz Mill test site. This test facility will have a capability for carrying out high flow rate hydrogen test programs. The test facilities will include a partially buried, open front test cell, a remotely located tank farm for storage of gaseous and cryogenic fluids, and a remotely located control room to carry out test operations. Testing of the flow vibration apparatus will be essentially a blow-down type operation, and as such, the hydrogen facilities will consist essentially of a gas storage tank, process piping with appropriate flow control valves and a discharge or vent stack.
- 5.4 Test Parameters - The test will be activated in two stages. The first stage will have instrumentation limited to visual (camera) observations and sound (microphone pickups). This instrumentation is the minimum required to evaluate core stability. A second phase using a fully instrumented core as described in Section 5.5 will follow phase one. The second phase tests will follow the reactor start-up schedule and will be carried to nominal design, hydrogen flows. These tests will be followed with a more rapid step function pressure build-up. Succeeding tests will be based on selected, fueled cores and the test conditions will be dictated by previous results.

Test conditions utilizing hydrogen will include:

5.4.1	Gas Temperatures	140 to 540°R
5.4.2	Gas Pressures	0 to 700 psig
5.4.3	Gas Flow Rate	0.0 to 2 lbs/sec

The length of the test will be determined by the capacity of the gas storage facility. For ambient temperature runs at a mass flow rate of 2 lbs/sec. the test duration will be in the order of thirty seconds. When the gas is cooled to liquid nitrogen temperatures, the testing time will be extended to approximately 120 seconds.

- 5.5 Instrumentation and Data Acquisition - The proto-type test core will be instrumented with tri-axial accelerometers, linear displacement gauges, microphones, pressure transducers and thermocouples. It is planned to locate the displacement gauges between clusters and between the outer clusters and inner reflector. Frequency calibrated pressure transducers will be located at various positions including the gas inlet, the dome end support plenum, the nozzle end support plate plenum and the core discharge or nozzle plenum. In addition, high pressure microphones will be placed in the gas inlet and discharge area. This instrumentation should provide information concerning core vibration, core movement in relation to the inner reflector and clusters, pressure fluctuations in the test fluid at various positions and acoustic effects in the hydrogen stream. In addition, high speed photographic techniques will be utilized to visually determine the behavior of the bottom support blocks and this information will be correlated with the data as determined by the previously cited instrumentation.

The data acquisition system includes two 14 channel tape decks and one 24 channel high speed oscillograph recorder for visual analysis. The amplifiers feeding the tape recorder and oscillograph have dual output capability so that data will be recorded simultaneously.

6. ANALYSIS AND DATA UTILIZATION:

The data from the flow vibration tests will be evaluated to determine core vibration behavior with respect to various lateral support and seal constraints, core models, and flow environments. Required information includes:

- 6.1 What vibration frequencies are obtainable under given flow conditions.
- 6.2 What restraints will eliminate them.
- 6.3 What type of damping can limit the amplitude.
- 6.4 What are the basic flow dynamics which will yield an insight into the mechanisms of exciting these vibrations.

The flow vibration test results will be correlated and compared to information obtained from full scale reactor hot and cold tests as well as the full scale plugged core test, G 3.

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TEST SPECIFICATION
G 3 - PLUGGED CORE FLOW TESTS

Revision No: 1
Date: 7/14/63

1. TEST NUMBER: G 3
2. TEST TITLE: PLUGGED CORE FLOW TESTS
3. PURPOSE:

The effectiveness of the reactor lateral support system as a means of suppressing or eliminating flow induced cluster instabilities must be established. The entire core cluster suspension system comprises a complicated flow system which combines spring load components with flow passages, each capable of flutter. Complex resonance conditions incapable of predictions and analysis can result. A test of the entire interaction of all the component parts without the outer reflector must be made. In order to accomplish such a test, at reasonable flow rates, the core heat transfer passages, that is, the 19 holes per fuel element and the cooling passages in the graphite reflector will be plugged with dummy orifices so that only leakage flow occurs. In this way, the adequacy of the lateral support system for dampening out flow induced vibrations in the clusters of the fuel elements can be established in the presence of the leakage flow through the core and past the seal system.

4. REQUIRED DESIGN DATA:
 - 4.1 Determine the adequacy of the lateral support system in inhibiting flow induced vibrations which arise due to leakage through the core.
 - 4.2 Determine the regions of core stability with respect to pressures in the lateral support, seal system.

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Approved: E. H. Zula

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- 4.3 Determine the hydrogen leakage flows and pressure drops through the lateral support, seal system, and through the core.
5. TEST PLAN:
 - 5.1 Description - A typical core including the lateral support seal system will be mounted in a pressure vessel and all the orifices (normally containing passage diameters ranging from 0.0225 to 0.070 inches) will be replaced with completely plugged orifices. Cooling passages in the graphite barrel will also be plugged. In this way only the leakage flow rather than the main propellant flow will pass through the experimental assembly. This unit will be subjected to various pressure flow envelopes to determine the conditions which result in induced vibrations. Pressure drops in the lateral seal system and leakage flow through the seals and core will also be studied.
 - 5.2 Components Under Test - Complete core including:
 - Fuel Elements and Clusters
 - Top Support Plate
 - Graphite Barrel and Support System
 - 5.3 Experimental Set-Up - The test unit will consist of a complete core, including the lateral support system available from ND-207, enclosed in a pressure vessel. The holes in the elements and in the graphite reflector will be plugged and gas flows will be employed which simulate as a minimum the pressure drop across the core. The lateral support seal system will be designed in such a manner that the pressure distribution in the lateral seal cavities can be varied externally without disassembly. The test unit will be designed so that three hydrogen flow streams will be measured, the in flow to the inner reflector, the dome bleed from the top of the core, and the seal and core leakage from the bottom of the reactor. Figure 1 is a schematic of flow streams showing the measured flow quantities. Pressures in the areas surrounding the support plungers of the lateral support seal system will be measured in a manner

FIGURE 1. MINIMAL REQUIRED FLOW SCHEMATIC

FIGURE 2. PRESSURE PROBES IN THE LATERAL SUPPORT SEAL SYSTEM

similar to that shown in Figure 2. The pressures between elements will be measured by a scheme as shown in Figure 3. Vibration measurements will be obtained through use of accelerometers and displacement gauges, and a camera will be employed for observation of the bottom of the core. The unit will also employ high pressure microphones to study acoustic effects, and system pressure and temperature data will also be gathered continuously during testing.

- 5.4 Test Parameters - The initial tests will be made using nitrogen at low pressures. These tests will be essentially shake-down tests to evaluate equipment and instrumentation performances. Upon completion of the nitrogen tests, hydrogen flow testing will be initiated. Pressure drops across the core will duplicate nominal operating conditions. By maintaining the same pressure drops as in the actual reactor at lower pressures, mass flow rates will decrease thereby increasing the available test time. Figure 4 indicates the flow rates necessary to maintain design point pressure drops for various operating pressures and temperatures compared to the nominal 1 lb/sec at 738 psia and 129° R estimated as the flow in the area between the graphite reflector and the aluminum barrel. Low temperature tests will be conducted with initial reactor temperature conditions approximated by precooling the inner reflector area with liquid and gaseous nitrogen before the flow of cold hydrogen is initiated. Test conditions utilizing hydrogen will include:

5.4.1	Gas Temperature	140 to 540°R
5.4.2	Gas Pressure	15 to 750 psia
5.4.3	Gas Flow Rate	0.01 to 4 lb/sec (initial estimated value is 1.0 lb/sec)

The length of the tests will be determined by the capacity of the gas storage facility. For high pressure, cold gas temperature runs at mass flow rates up to 4.0 lb/sec, the test duration will be about 40 seconds, at lower flows the testing time will be extended.

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G 3

FIGURE 3. MEASUREMENT OF PRESSURES BETWEEN FUEL ELEMENTS

FIGURE 4. MASS FLOW OF HYDROGEN REQUIRED FOR PRESSURE DROP OF 193 PSI BETWEEN REFLECTOR INLET AND CORE OUTLET AT DESIGN CONDITIONS

5.5 Instrumentation and Data Acquisition - Orifice type flow meters will measure hydrogen quantities. Pressure transducers and pressure gauges will be used to measure pressures in the seal and support system, in the core, and in the pressure vessel surrounding the core. Temperatures will be measured with thermocouples. Displacement gauges and tri-axial accelerometers will be mounted on the core clusters to measure the vibration effects which occur. High pressure microphones will be employed to study acoustic effects. A high speed camera will also be used to observe the core during flow tests. A total of 26 FM tape channels will be available in the high flow hydrogen test cell located at Waltz Mills. Multiplexing equipment will provide the capability of obtaining up to 106 simultaneous measurements during a test.

6. ANALYSIS AND DATA UTILIZATION:

6.1 The behavior of a single fuel element with air flowing through the heat transfer passages was evaluated and externally induced mechanical vibrations were damped out by increasing the flow through the passages. Additional tests of a single element with flow of air and hydrogen around or through the elements will be performed prior to the 7 cluster tests in A 11. Once it is established that the behavior of the fuel elements and clusters is substantially the same whether plugged or unplugged, the major effort will be concentrated on the correlation and interrelation between 7 cluster plug flow and full scale plugged core flow data. The data obtainable in the series of plugged core flow tests will provide information on:

- 6.1.1 The vibration frequencies which occur due to leakage through the plugged core.
- 6.1.2 The effectiveness of the lateral seal and support system in damping out the induced vibrations.

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~~Atomic Energy Act 1954~~

- 6.1.3 The flows through the major passages with the core plugged.
- 6.1.4 The effect of varying the pressure distribution in the seals on damping out induced vibrations.

The data obtained will be correlated with the results of the 7 cluster tests in A 11 and the NRX-A1 cold flow tests.

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~~Atomic Energy Act 1954~~