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WANL-TME-981
September 1964

Westinghouse
Astronuclear Laboratory

SUMMARY REPORT

REACTOR ASSEMBLY AXIAL VIBRATION TESTS
(Title Unclassified)

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REACTOR ASSEMBLY AXIAL VIBRATION TESTS
(Title Unclassified)

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1. SUMMARY

The reactor assembly axial test series, described in this report, was the second series of tests designed to determine the ability of the NRX-A reactor to withstand external vibratory loads.

A complete reactor, including outer reflector and simulated pressure vessel was mechanically vibrated. Vibratory forces were applied first at the nozzle flange and then at the pressure vessel flange. The tests were useful in investigating the dynamic interactions of the components, with all boundary conditions properly represented.

Vibration up to 2.0 g's was applied to the reactor over the entire frequency band from 10 to 2000 cps. The input force level was limited to less than 11,000 lbs. These environmental restraints were chosen as representing values that would not be exceeded during the NRX-A2 "hot flow" tests. Summary of environment and cycles accumulated during reactor assembly test are shown in Table 1.

One of the main objectives of the test was to determine the important resonances of the reactor components. The major resonances encountered are explained in this report.

Chattering of the control drums due to bearing clearances was also very evident. Tests were performed to confirm that the bearings were responsible for the harmonics on the accelerometer signals. The chatter was present, but greatly reduced in magnitude, when a simulated flow preload was imposed on the dome end thrust bearing.

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The bearings on each end of the control drums were replaced by solid rings. The resulting clamping of the drum produced a clean signal which permitted more accurate determination of system resonances.

2. INTRODUCTION

One of the primary concerns, as the test program evolved, was to describe major component motions and to anticipate information needed in evaluating NRX-A2 hot test data.

Each major reactor component was instrumented with accelerometers. These were (1) Core, (2) Inner Reflector, (3) Core Support Plate, (4) Outer Reflector and (5) Pressure Vessel.

Other transducers were monitored to confirm that low stress levels, found in the previous core assembly tests, still existed.

Other objectives were:

- (1) To determine if design problem areas existed.
- (2) To determine resonant and anti-resonant frequencies.
- (3) To determine the feasibility of studying the complex mass-spring system by using an analog computer model.

Vibratory forces were initially applied to the reactor at the nozzle flange position, since nozzle vibration is one of the most probable excitation forces in ground static tests. In this case, it was necessary to suspend the reactor with the dome end up, so that the vibration exciters could drive the reactor at the nozzle flange. This test is shown in Figure 1.

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FIGURE 1

NOZZLE EXCITATION

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In the latter phase, in which excitation was applied to the pressure vessel directly at the dome end flange position, the reactor was mounted with the dome end down. This test is shown in Figure 2.

3. CONCLUSIONS

The reactor assembly test results, coupled with those of the core assembly tests, have increased the knowledge and confidence in the NRX-A design with respect to the expected vibratory environment.

Some of the more detailed conclusions revealed by the tests were:

1. The natural frequency of the core support plate mass acted on by the spring rate of the core support cone and tie rods is 500 cps.
2. The resonant frequency of the outer reflector - core support plate combination acted on by the spring rate of the dome end support ring is 200 cps. A high input impedance and an outer reflector amplification of 4 to 1 occurred during the pressure vessel excitation test at 200 cps. These results are in agreement with past analog computer studies.
3. An amplification of the control drum axial vibration due to clearances and thrust bearing stiffness occur in the frequency band from 100 to 200 cps. Other control drum responses are indicated at approximately 350, 450, 900 and 1300 cps.
4. The first tie rod lateral natural frequency, at ambient conditions, is 22 cps. Higher tie rod frequencies are expected

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FIGURE 2

PRESSURE VESSEL EXCITATION (DOME END DOWN)

in the NRX-A2 test due to core pressure drop and thermal effects.

5. System resonances were found at 170 and 400 cps. At 400 cps, the pressure vessel and outer reflector motions are 180 degrees out of phase. The dome end support ring flexibility acting between these two masses is the major cause of this resonance. At the 170 cps resonance, the core plus inner reflector are 180 degrees out of phase with the core support plate, outer reflector and pressure vessel. The tie rod flexibility is the determining spring rate of this resonant system.
6. The highest system input impedances occurred at 50 and 70 cps for the axial vibration tests. All reactor components moved in phase with one another and with a magnification over that of the input. These high impedances are partially due to the simulated nozzle flange stiffness and can be expected to increase somewhat with the stiffer actual pressure vessel.
7. Axial control drum bearing chatter is severe without a pressure drop preload on the thrust bearings.
8. Axial control drum bearing chatter is greatly reduced with the pressure drop preload. Lateral chatter still occurred due to radial bearing clearances.
9. Some of the major resonances and component stress levels which occurred in the core assembly vibration tests were again found in the reactor assembly vibration tests.

10. The motions of the major components as studied on the analog computer, very closely duplicated motions observed in the laboratory tests of the reactor.
11. All visible components were undamaged at the completion of the test series, and there were no other indications of excessive wear such as generation of significant quantities of dust.

Prior to testing, data was made available indicating the simulated pressure vessel configuration was more flexible than the actual pressure vessel flange. An analog comparison of the response characteristics shows a slight frequency shift where the maximum accelerations occur.

4. TEST SPECIMEN

In the reactor assembly vibration series described here, the complete reactor in a simulated pressure vessel was utilized. These tests used the core of the core assembly vibration tests. Eight coated clusters were located at selected positions. In order to up grade the core assembly to include banding, the filler strips were modified. The original inner reflector was replaced with one that had been impregnated. The seal segments were also replaced. The reactor as tested consisted of the core assembly, aluminum barrel, outer reflector with control drums, and simulated pressure vessel.

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The major subassemblies are tabulated below:

Parts list	710J301
Reactor assembly	709J516
Core	710J359
Inner reflector	710J328
Aluminum barrel	710J327
Outer reflector	709J705
Simulated pressure vessel	NT 700115
Dome end support ring	709J511
Core support ring	710J355
Core support plate	909E316

5. TEST EQUIPMENT

Three 10,000 lb. vibration exciters were used to sinusoidally excite the reactor at two positions. In both conditions the reactor was suspended from low frequency mounts as seen in Figures 3 and 4. Figure 3 shows the reactor in the dome end up attitude. The three vibrators drove the test assembly at the nozzle flange through a stiff conical fixture. The control accelerometer was located directly above the mating surfaces of the fixture and nozzle flange, inside the nozzle extension adapter.

In the second position for test, three vibration exciters were used to drive the pressure vessel at the dome end as shown in Figure 4. This loading simulated external vibrations of the reactor, such as those induced by shipment or motions of test car components.

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FIGURE 3

AXIAL NOZZLE FLANGE EXCITATION
REACTOR ASSEMBLY TEST SERIES

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FIGURE 4

AXIAL PRESSURE VESSEL EXCITATION
REACTOR ASSEMBLY TEST SERIES

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6. RESULTS

In the reactor assembly axial vibration series, sweep and dwell tests were performed over the frequency band of 10 to 200 cps. The maximum input acceleration was limited to 2 g's. Incremental g level sweeps indicated a definite non-linear effect. Not only did modes of motion change with g level but also with location of excitation.

The summary table, Figure 5, describes the motions of the major reactor components. In general, it was noticed that for the dome end excitation of the pressure vessel all components remained in phase below the frequency of maximum impedance and out of phase with the control above this frequency. During the nozzle flange excitation a definite phase shift was exhibited at the various component resonant frequencies. Therefore, the location of the exciting force is important in determining motion modes.

The impedance curves shown in Figures 6 and 7 reflect the motions of the components. Figure 6 shows the high impedance at 70 cps for the nozzle excitation. At 170 cps the outer reflector-pressure vessel-core support plate combination become out of phase with the input acceleration, resulting in an increasing mechanical impedance. The system resonance at 375 cps is reflected by a sharp reduction in the mechanical impedance value. The increase in impedance at approximately 400 cps was due to the pressure vessel moving out of phase with that of the control.

Excitation at the dome end of the pressure vessel shows a slightly different impedance curve, Figure 7. The maximum impedance occurred at

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Legend

PV =	Simulated Pressure Vessel	IR =	Inner Reflector (control during nozzle excitation)
OR =	Outer Reflector	CSC =	Core Support Cone
C =	Core	DESR =	Dome End Support Ring
SP =	Core Support Plate	TR =	Tie Rods

Component Combination	Frequency Band				Significant Events		
	In Phase with Control	Out of Phase with Control	C-SP Out of Phase with Control and PV-OR	PV-OR Out of Phase with Control and C-SP	Frequency	Location of Excitation	Occurrence
Pressure Vessel (PV) Outer Reflector (OR)	10-66	—	—	—	70	Nozzle	High system impedance
	—	75-170	—	—	170	Nozzle	Component resonance between C-SP and OR-PV on CSC
	170-280	—	170-280	—	—	Nozzle	—
	—	280-400*	—	375-400	400	Nozzle	Component resonance between OR and PV on DESR
	400*-500**	—	—	—	—	Nozzle	—
	—	500**-900	—	500-700	—	Nozzle	—
	900-1100	—	900-1100	—	—	Nozzle	—
	10-30	—	—	—	22	Dome End	Component resonance of TR
	—	52-2000	—	—	50	Dome End	High system impedance
	—	—	—	—	170	Dome End	Component resonance between OR-PV-SP and C-IR on TR
Core (C) Core Support Plate (SP)	10-66	—	—	—	200	Dome End	Component resonance between SP-OR and DESR
	—	75-375	—	—	500	Dome End	Component resonance between SP and DESR on CSC-TR
	375-700	—	—	—	—	Nozzle	—
	—	700-1100	—	—	375	Nozzle	System resonance due to drive cone

* OR in Phase with Control and Out of Phase with PV at 400 cps.
 ** PV in Phase with Control and Out of Phase with OR at 500 cps.

FIGURE 5

MAJOR COMPONENT MOTION STUDY

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FIGURE 6
IMPEDANCE CURVE FOR NOZZLE EXCITATION
(0.3G SWEEP)

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FIGURE 7

IMPEDANCE CURVE FOR DOME END EXCITATION
(0.3G SWEEP)

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50 cps. A major resonance, as in the nozzle excitation, was recorded at 170 cps. High impedances were at 200 and 500 cps. These frequencies revealed a resonance of the core support plate and outer reflector at 200 cps. The 500 cps impedance change was due to the core support plate resonance.

Typical wave shapes are sampled in Figures 8 through 13. Magnitudes and phasing are also shown.

Low stress levels noted during the previous core assembly tests were still evident as seen in Table 2. .

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FIGURE 8

COMPONENT MOTIONS AT 62 CPS. MAXIMUM SYSTEM IMPEDANCE OCCURRED AT APPROXIMATELY 50 CPS. (DOME END EXCITATION)

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FIGURE 9

COMPONENT MOTIONS AT 79 CPS. MAXIMUM SYSTEM IMPEDANCE OCCURRED AT APPROXIMATELY 70 CPS. (NOZZLE EXCITATION)

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FIGURE 10

COMPONENT RESONANCE AT 170 CPS BETWEEN OR-PV-SP AND C-IR ON TR
 (DOME END EXCITATION)

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FIGURE 11

COMPONENT RESONANCE AT 200 CPS BETWEEN SP-OR AND DESR
 (DOME END EXCITATION)

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FIGURE 12

OUTER REFLECTOR RESONANCE AT 400 CPS
(NOZZLE EXCITATION)

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FIGURE 13

DOME END VIBRATION EXCITING NATURAL FREQUENCY
 OF CORE SUPPORT PLATE AT 501 CPS

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Location of Excitation		Nozzle End	Dome End	Reactor Assembly Series
Input Acceleration or Force Control	Frequencies Band (cps)	Accumulated Cycles in Thousands	Accumulated Cycles in Thousands	Total Cycles in Thousands
0.3 g	10 to 2000	2,627	304	2,931
0.6 g	10 to 2000	1,283	215	1,498
1.0 g	10 to 2000	1,481	140	1,621
2.0 g	160 to 2000	560	156	716
750 lb. (1.6 g max.)	10 to 460	---	67	67
1500 lb. (1.4 g max.)	10 to 300	---	44	44
3000 lb. (1.3 g max.)	10 to 96	---	14	14
4500 lb. (1.5 g max.)	10 to 92	---	12	12
Total Cycles in Thousands		5,951	952	6,903

TABLE 1
SUMMARY OF APPLIED ENVIRONMENT

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Component	Maximum Strains Monitored	
	Frequency (cps)	Values (μ "/")
2H5 Fuel Element	all	<25
3E3 Fuel Element	all	<45
1E4 Tie Rod	99	14.3
	400	15
	500	13.2
2H5 Tie Rod	24	100
	49	95
	60	180
	104	150
Tie Bolt	104	50
	all others	<20
Core Support Ring (Axial)	62	38
	74	45
	79	60
	121	45
	all others	<15
	(Circumferential)	
	all	<30
Dome End Support Ring	65	50
	89	60
Bolt (I.D. Core Support Ring)	63	40
	74	40
Bolt (O.D. Core Support Ring)	all	<10

TABLE 2
 SUMMARY OF COMPONENT STRAINS

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