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Reactor Division

EGCR CONTROL-ROD-DRIVE
ENDURANCE TEST

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Abstract

To assure reliable operation of reactor control-rod drives, it is necessary that they be thoroughly tested in an environment similar to that of the reactor in which they are to be used. A rod-drive mechanism purchased for use in the Experimental Gas-Cooled Reactor was subjected to an endurance test under simulated reactor environmental conditions except for neutron radiation. The drive mechanism with a control rod attached was operated through numerous cycles of each of the mechanism's normal operating functions. It is concluded that the rod drive meets the performance requirements of the design specifications and is satisfactory for use in the EGCR.

Introduction

The control-rod drives for the EGCR were designed by the Allis-Chalmers Manufacturing Company and manufactured by the General Electric Company. A prototype model of the drive mechanism was performance tested by General Electric in air and by Oak Ridge National Laboratory in a simulated reactor environment. The results of these tests and a description of the facility are given in previously issued reports.^{1,2,3}

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¹N. J. Biglieri, Prototype Control Rod Drive Test, Interim Report No. 48, General Electric Company, dated June 22, 1964.

²W. F. Ferguson and E. Storto, A High Temperature Environmental Test Facility and Test Program for the EGCR Control Rod Drive, USAEC Report ORNL-TM-855, March 1965, Oak Ridge National Laboratory.

³W. F. Ferguson, EGCR Control Rod Drive Environmental Test, USAEC Report ORNL-TM-1026, June 1965, Oak Ridge National Laboratory.

The testing program for the production drive was designed to prove endurance performance of a production model drive mechanism operating under simulated reactor environmental conditions. The test was performed in accordance with requirements specified by ORNL and approved by the EGCR design team.⁴ The program required that the mechanism be operated through 130 full insertion-withdrawal cycles; 2000 insertion-withdrawal cycles over four inches of rod travel; and 1400 scram cycles.

Testing

General

The rod-drive mechanism, General Electric Serial No. 2, was received on March 17, 1965, at which time it was visually inspected to assure that there was no apparent shipping damage. Assembly of the unit in the test facility was completed on March 19, 1965. Prior to start of testing in the helium environment, the drive was operated in air and operating features as presented in Table 1 were checked. All preliminary testing proved to be satisfactory, except that the lower limit switch was unstable in operation as it was reset with the rod driving in the withdraw direction.

Throughout testing, under simulated reactor conditions, the environment within the test vessel was controlled with regard to coolant gas pressure, inlet temperature, flow through the mechanism, and purity. Table 2 shows the desired operating level for these parameters; highest, lowest, and average values for each parameter during operation; and other significant data pertaining to the environmental conditions. During the test - except for gas analysis - data were recorded six times daily to assure that these conditions did not vary appreciably. To assure that coolant gas impurities were within the tolerances permitted, a sample was

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⁴G. C. Robinson, Jr. and G. D. Whitman, EGCR Control Rod and Drive Endurance Test, Revision 2, February 16, 1965. (Unpublished)

Table 1. Summary of Preliminary Tests

Item	Function Checked	Remarks
Limit Switches	Position setting	All switches were set within design tolerances.
Retarder Switches	Position setting	All switches were set within design tolerances.
Manual Drive (before closure was installed)	Torque required to move cable drum with 5-lb wt attached to cable.	Torque required to withdraw cable was 27-in.-lb. Torque required to insert cable was 12-in.-lb.
Manual Drive (with closure installed)	Torque required to move cable drum with 5-lb wt attached to cable.	Torque required to withdraw was 250-in.-lb.
Drive Motor	Meggered winding and lead resistance.	AØ 200 megohms BØ 200 megohms CØ 200 megohms
Drive Motor	Measured winding and lead resistance.	A-B Phase 16.4 ohms B-C Phase 19.4 ohms C-B Phase 20.6 ohms AØ Neutral 8.2 ohms BØ Neutral 9.9 ohms CØ Neutral 12.4 ohms
Drive Motor	Motor rotation	Had to reverse power supply leads to achieve correct rotation.
Clutch	Operating current	1.35 amps at 29.2 volts.
Drive Motor	Running current	1.78 amps at 205 volts.
Slack Cable Switch	Operation	Switch operated properly.
Locking Mechanism	Operation	Locking mechanism operated satisfactorily and also operated indicating lights as specified.

Table 2. Summary of Environmental Data

	Desired Operating Level	Actual ^(a)		
		High	Low	Average
Coolant Gas				
Helium (% by vol.)	-	99.930	99.162	99.674
H ₂ O (% by vol.)	0.0200	0.0369	0.0090	0.0211
O ₂ (% by vol.)	Low as practical	0.0030	0.0001	0.0018
Coolant Gas Inlet Temp. (°F)	125	130.0	110.0	126.3
Coolant Gas Flow (lb/hr)	125	129.6	123.6	125.7
Coolant Gas Pressure (psig)	290	297.5	265.5	289.2
Core Bottom Temp. (°F)	525	-	-	550.
Core Mid-Plane (°F)	700	-	-	680.
Core Top (°F)	800	-	-	785.

^(a)Data presented is highest, lowest, and average for the entire test period.

withdrawn from the coolant system each day - Monday through Friday - and analyzed using mass spectrometry.

Testing was performed in a simulated control rod channel with the graphite bowed one inch off-center and having a one-half inch tilt from top to bottom.

Full Insertion-Withdrawal Test

One hundred and thirty full insertion-withdrawal cycles were performed with the mechanism operating under simulated environmental conditions. During the course of this test, the rod was observed for smoothness and uniformity of operation throughout its range of travel. Drive motor current and voltage were observed and recorded. Rod speed was determined and the various indicating lights were observed for proper operation. All rod drive functions tested appeared to be normal except for the lower limit switch. Drive motor current was 1.78 amps at 205 volts. Rod speed

was measured to be 2.14 to 2.16 in./min during both withdrawal and insertion operation. Figure 1 is a reproduction of a portion of the position recorder chart showing rod position during movement of the rod through one complete insertion-withdrawal cycle.

Four-Inch Insertion-Withdrawal Test

The mechanism was operated through 2014 four-inch insertion-withdrawal cycles. Each cycle consisted of insertion for four inches; one minute hold; withdrawal for four inches; and one minute hold. During this operation, performance of the mechanism was observed in the same manner as for the full insertion-withdrawal operation. Performance under this test condition was normal. Figure 2 shows a portion of the position recorder chart as the mechanism was being cycled over the 4-in. of travel.

Slack Cable Switch

Four incidents involving a jammed control rod or broken drive cable were simulated to prove operability of the slack cable switch in helium. Switch operation on each occasion was satisfactory.

Scram Test

The testing specifications required that 50 scrams each be initiated from rod elevations of 1-ft, 3-ft, 6-ft, 9-ft, 12-ft, and 14-ft. In addition, it was required that 100 scrams be performed from the fully withdrawn position and 1000 scrams be performed at low rod elevations. Each scram was performed with the necessary scram switching action provided automatically by control circuitry built into the magnetic tape system. The sequence of switching was as follows:

- A. The rod was withdrawn to approximately two inches past the specified rod elevation.
- B. The rod was reversed and inserted to the specified elevation, at which point it was stopped.
- C. After a 30 second time delay, switching action necessary to scram the rod was initiated.

Total scram time, rod elevation, and scram clutch response time were measured for each scram by the magnetic tape system. Scram curves of rod position, acceleration, and velocity vs. time, were plotted as required by the testing specification. Figures 3 through 8 show rod position vs. time of scrams from elevations of 1-ft, 3-ft, 6-ft, 9-ft, and 14-ft (fully withdrawn). Figures 9 and 10 show acceleration vs. time, and figures 11 and 12 show velocity vs. time for scrams from the fully withdrawn position and from 144-in. above the fully inserted position. Table 3 shows a summary of data taken from all scrams where the scram data was processed. Scram clutch response time was measured for each scram performed by the magnetic tape system, and, as a check, was also measured using an electronic counter. As a spot check, a direct writing oscillograph was also used during several scrams for measurement of response time. The clutch response time ranged from 37 to 40 msec, with no increase beyond this range during testing. (Scram clutch response time is defined as the elapsed time between the opening of the scram relay contact and the first detected rod movement.)

Idle Time Scram Test

The idle time scram test consisted of pulling the rod to the fully withdrawn position and holding it with the clutch at that point for four weeks without any rod movement whatsoever. Following the four weeks of idle time, the rod was scrammed from the fully withdrawn position and three times from low elevations. The clutch response times for these scrams were 38-40 msec.

Hot vs. Cold Scram Test

Subsequent to the completion of required testing, it was verbally suggested by the EGCR team that at least one scram be performed with the simulated reactor core heated to 1050-1100°F. In order to heat the core to this temperature, it was necessary to reduce the coolant flow through the mechanism and control rod to approximately 75% of the normal required flow (this flow was adequate to maintain 125°F temperature within drive motor housing). A temperature of 1080°F at the top of the core was achieved, and one scram from a fully withdrawn position was performed

Table 3. Summary of Scram Data

Scram ^a Number	Scram Height (in.)	Velocity at 6-ft (fps)	Velocity at 2.5-ft (fps)	Velocity at 1.5-ft (fps)	Velocity at 4-in. (fps)	Maximum Deceler- ation (G's)
2001	10.53	-	-	-	.36	.60
2048	10.53	-	-	-	.28	.53
2055	36.63	-	2.10	1.23	.36	.56
2094	36.63	-	2.16	1.30	.27	.59
2125	72.63	1.94	1.30	1.23	.29	.58
2146	73.44	2.05	1.34	1.29	.32	.61
2154	108.63	9.88	1.18	1.17	.23	2.08
2181	169.83	16.18	1.16	1.17	.22	2.89
2195	142.83	13.98	1.13	1.06	.22	2.49
2240	108.63	9.99	1.19	1.11	.26	1.85
2260	169.83	16.30	1.19	1.21	.25	3.06
2270	144.63	14.13	1.15	1.13	.24	2.44
2290	144.63	14.09	1.12	1.11	.23	2.44
2305	3.33	-	-	-	-	.69
2401	22.23	-	-	2.17	.31	.75
2525	3.33	-	-	-	-	.69
2606	22.23	-	-	2.18	.31	.76
2650	22.23	-	-	2.28	.32	.77
2775	11.43	-	-	-	.29	.60
2810	169.83	15.93	1.23	1.16	.26	2.83
2875	11.43	-	-	-	.28	.65
2972	169.83	16.19	1.18	1.17	.22	2.88
3095	16.83	-	-	-	.33	.87
3150	16.83	-	-	-	.25	.87
3248	16.83	-	-	-	.33	.99
3350	22.23	-	-	2.32	.32	.76
3423	169.83	16.87	1.27	1.32	.25	3.09
3427	170.73	16.53	1.24	1.31	.28	2.85
3428	169.83	16.56	1.23	1.28	.24	2.95

^aFirst scram was numbered 2000 to avoid confusion with previous test data. For scram No. 3427, the top of core was heated to 1080°F. Temperature of core was 250°F for scram No. 3428.

under these conditions. Following this scram, the flow was increased to the normal 125 lb/hr and the heat within the simulated core was reduced to permit the core to cool overnight. With the core temperature at approximately 250°F, another scram was performed from a fully withdrawn position. Scram time to one foot above bottom limit of rod travel was identical for these two conditions. The scram curves showing rod position vs. time for these scrams are shown by Figures 13 and 14.

Oil-Leakage

Prior to installing the drive mechanism into the test vessel, the planetary gear oil housing was filled by adding 11 cc's of oil. During disassembly of the mechanism following the completion of the test, the oil housing was drained with 6 cc's of oil being removed. Although no evidence of oil leakage around the vent line or in the oil drip pan existed, there was an apparent loss of 5 cc's of oil during test operation.

Abnormal Conditions Observed

During operation, the only abnormal condition observed was erratic operation of the lower limit switch. As the rod was inserted, the lower limit switch always operated satisfactorily. When the rod was being withdrawn, the limit switch was erratic in operation as the switch contacts opened to de-energize the lower limit light. This caused the lower limit indicating light to flash on and off for approximately 15-sec as the switch actuator was riding over the ramp portion of its actuating cam.

Summary and Conclusions

During the course of testing, the rod drive mechanism was in helium for 84 days. The drive motor was operated for 1018 hours in a simulated reactor environment and four hours in air, for a total operating time of 1022 hours. A summary of testing is presented in Table 4. The performance of the mechanism was entirely satisfactory and in all cases met or exceeded

the specified design requirements.^{5,6} This conclusion is substantiated by data presented in Table 5.

Acknowledgements

The author gratefully acknowledges the support of G. D. Weaver for his assistance with the performance of testing and the correlation of test data. Appreciation is also expressed to R. F. Hyland, J. W. Reynolds, and C. D. Martin for their assistance with the data handling system and the processing of test data.

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⁵Allis-Chalmers Manufacturing Company, Experimental Gas-Cooled Reactor, Control Rod Drive Mechanism, Specification RD-2, April 26, 1961.

⁶Allis-Chalmers Manufacturing Company, Experimental Gas-Cooled Reactor, Control Rod Drive Mechanism Prototype and Acceptance Test, Specification RD-6, February 27, 1961.

Table 4. Summary of Test Operations

Test	Completed During Shakedown	Completed Under Conditions
4-in. Insertion-Withdrawals	18	2014
Full Insertion-Withdrawals	1	130
Slack Cable Switch	6	4
Scrams		
Low Elevation	188	1025
12-in. Elevation	-	50
36-in. Elevation	-	50
72-in. Elevation	-	50
108-in. Elevation	-	50
144-in. Elevation	-	50
170-in. Elevation	-	153

Table 5. Comparison of Design Requirements to Test Data^a

Parameter	Design Requirement ⁵	Test Performance
Scram Clutch Response Time	< 100 msec	37-40 msec
Scram Time to 6-ft above Crash Stop	1 1/2 sec	< 1 sec
Scram Time to 1-ft above Crash Stop	8 1/2 sec	< 4 sec
Total Scram Time	23 1/2 sec	< 8 1/2 sec
Rod Deceleration	4 g (max)	2.83 - 3.09 g
Control Rod Speed		
Insert-Normal Operation	1.8 in./min (min.)	2.14-2.16 in./min
Withdraw-Normal Operation	1.8 in./min (min.)	2.14-2.16 in./min

^aScram data shown for rod fully withdrawn.

⁵Specification RD-2, p. 9.

EGCR ROD DROP NUMBER 2001 DATE 04-13-65
POSITION VERSUS TIME

Figure 3. Scram Rod EL.

Figure 4. Scram Rod Elevation - 3-ft.

0 9.0 10

Figure 6. Scram Rod Elevation - 9-ft.

8.0

9.0

10

EGCR RO

Figure 8. Scram Rod Elevation - 14-ft.

8.0

9.0

10