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Westinghouse Astronuclear Laboratory

Report on the Results of Qualification

Testing of Re-Designed Pneumatic

Actuator Shut-Off Valves

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Report on the Results of Qualification
Testing of Re-Designed Pneumatic
Actuator Shut-Off Valves

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PREFACE

The XE-1 pneumatic actuators which were delivered to NTO for installation in the XE-1 test reactor were subjected to a rework. The rework was required to increase lock pin clearance and thus remove a potential failure area from actuator lock mechanisms. The entire operation was accomplished at NTO by WANL personnel from July 23 through August 2, 1967. As a precautionary measure taken during this rework all actuator electrical components mounted in the immediate vicinity of the rework area were tested to detect any damage or faulty wiring which might have occurred. By virtue of this check it was found that one actuator lock shut off valve solenoid had a low coil resistance value of 125 ohms. The correct coil resistance should be 190 to 220 ohms. This unit was then rejected and returned to WANL. The entire rework history and details are reported in WANL Trip Report, WANL-TR-5698, dated August 8, 1967.

Investigations by WANL, General Electric, and the shut off valve manufacturer Wright Components Incorporated, into the solenoid coil design disclosed that 1) the failure occurred due to the coil electrically shorting internally, 2) the coil was prone to this shorting due to the ceramic wire insulation which was used and the manner in which the coil was wound dry on the solenoid spindle without interlayer bonding. As a direct result of the investigation into the valve failure it was decided to redesign the shut off valve solenoid. The redesign jointly agreed on was to use PYRE-ML¹ enameled wire in lieu of the former brittle ceramic coated wire. The enameled wire was to be wound while being wetted with PYRE-ML¹ varnish so as to totally encapsulate each winding and finally the entire coil. The subject of this report is the Qualification Test Results of these redesigned configuration of shut off valves.

1. Manufactured by E. I. DuPont DeNemours and Co., Inc.

Introduction:

A series of environmental tests was conducted on three (3) pneumatic actuator shut off valves (Serial No's. 76, 77, and 78) which were built to a specified valve re-design configuration. These re-designed units were fabricated at the Wright Components Incorporated plant in Clifton Springs, New York under Westinghouse Purchase Order 88357 with design surveillance of General Electric Corporation and Westinghouse Electric Corporation. The one major portion of the shut off valve which was re-designed was the solenoid coil and all remaining portions of the valve remain unchanged.

Purpose of Test:

The qualification test was conducted as a series of environmental tests to demonstrate the ability of the new valve design to withstand the anticipated XE test environments. A WANL Test Procedure, T-711893, entitled "Qualification Test Specification and Procedure" was issued and is the document to which the subject of this report was tested. The radiation qualification tests are being performed in a separate test series using the same re-designed shut off valves. The radiation test series is an integral portion of the NRX-A6 Side by Side Test and the XE-1 Lewis Laboratory Pneumatic Actuator Irradiation tests. In addition, re-designed valves have been installed in the XE-1 series actuator and will provide further operational test data for XE-2 input.

Summary:

Each of the three (3) shut off valves tested performed satisfactorily during

all environmental tests. The valves completed all of the performance tests as outlined in T-711893. After exposure and operation in each of the test environments the valves successfully passed the General Electric valve acceptance test.¹ The test results showed that all tested valves were well within the acceptable operating limits as specified for acceptance.

During the vibration and shock test phases no harmful vibration resonances were detected in the valve solenoid. Although no valve resonances were detected the valves were further tested by dwelling for a period of 10 minutes at the worst detected actuator housing resonance. No valve failures occurred as a result of this test.

After life testing to 500 cycles of "on" - "off" operation a randomly selected valve (S/N 77) was tested to an additional 5000 cycles over and above the previous life test cycling. The General Electric valve acceptance test (TP-0004-00-B) was performed after each 1000 cycles. The valve successfully passed these acceptance tests after each 1000 cycle operation including the 5000th cycle.

The same test valve, S/N 77, was then tested above and beyond the qualification tests to determine the valves ability to operate below 140°R. This test was performed at a temperature of 40°R to 43°R by submersion in LH₂. While at this temperature the valve was cycled on and off 100 times and achieved successful shut off and opening against 200 psig of helium each time. After 100 cycles the shut off valve was "soaked" for a 30 minute period in the LH₂ bath while in a condition of full open with 200 psig helium gas flow. After this "soak" period the valve was successfully operated for 10 cycles.

1. "Shut Off Valve Acceptance Test", TP-0004-00-B, General Electric Space Power and Propulsion Section dated February 15, 1967.

Test Results:

The first objective which was to be accomplished was to establish acceptable criteria which could be used as base line data. Once base line data was established then it would be possible to test each valve by subjecting the valve to each test environment and then repeating the same "base line" data test after each environment exposure. Acceptance would be based upon all valves successfully completing the base line criteria after exposure to the environment. A document was issued defining all of the above, WANL T-711893, "Qualification Test Specification and Procedure, Re-Design Lock Solenoid Valve, XE Series Pneumatic Actuator", dated September 1967. In this document the General Electric shut off valve acceptance test, TP-0004-00-B, was selected to be used as the base line criteria. It followed then that the success of each valve would be based upon the ability to meet the G.E. acceptance test performed after exposure to each environment. As a matter of explanation, the G.E. acceptance test is that test performed by General Electric to ascertain that each valve meets the design requirements with limits imposed to each requirement. The base line data, as originally taken, is listed in Table I. The gas media employed for the base line test was helium gas as opposed to nitrogen gas as specified in the G.E. acceptance test. Helium was used as it best approximates hydrogen which is the final operating media in the XE reactor. In addition, the actuator ergo the valve are tested prior to and during XE using helium. At a later point of the qualification test the gas media was changed to nitrogen to use for a comparison of operation on both gases.

After obtaining base line data the test valves were subjected to the shock and vibration environments as defined in T-711893. During this test no valve resonances were observed, however, as a test precaution 10 minute dwells were

accomplished at 250 HZ and 1500 HZ which were resonances observed in the test fixture. The data taken and recorded during vibration and shock is listed in Table II. The relationship between Sweep numbers as used in Table II and the specified test as defined in T-711893 are as follows:

Sweep 1	Force parallel to output shaft of actuator. Valve de-energized. Sweep 5 to 2000 to 5 HZ. Refer to plane X.
Sweep 2	Repeat of Sweep 1 with valve energized.
Dwell	10 minute dwells at observed resonances.
Sweep 3	Force applied perpendicular to output shaft of actuator. Valve de-energized. Sweep of 5 - 500 - 5 HZ. Refer to plane Y.
Sweep 4	Not accomplished. Due to geometry of the valve coil Sweep 4 and Sweep 6 are the same and would be repeats.
Sweep 5	Rotate actuator 90° on axis from plane Y and refer to new plane as Z. Sweep 5 - 500 - 5 HZ with valve de-energized.
Sweep 6	Repeated Sweep 5 with valve energized.

It was observed that planes Y and Z were symmetrical and the vibration in these planes were repeats of each other. Due to this fact the test of Sweep 4 was not conducted and Sweep 6 shall be used as data.

After completion of the exposure to the vibration environment the valves were individually tested to repeat the base line data. Each valve successfully completed this phase and the results are listed in Table I.

The next required environment to which the valves were tested as defined in T-711893 is a mechanical shock load of $\pm 6g$ for a .01 second duration in all three planes. After 3 pulses at each shock level the valve coil resistance was measured and recorded. No coil failed during this test. The shock levels and test data are listed in Table III.

The post-shock test was performed on each valve and each valve successfully completed this phase of the test. The results are posted in Table I.

The required low temperature, high temperature and thermal cycling test was performed as defined by WANL T-711893. The valve solenoid coil resistance was measured at each extreme temperature level and the valve was intermittently operated during cycling. No valve coil failed during this test either by reason of resistance readings indicating a shorted coil or by failure of the valve plunger to operate "open" and "closed". The test results listed in Table IV are the resistance and temperatures as recorded for each valve. Immediately following this test each valve was subjected to the required base line test. The results are listed in Table I as "Post Thermal" data. All valves successfully completed this phase.

The final acceptance criteria to which the valves were to be subjected as a portion of this test is "Life Cycling". The objective of this phase of the test was to subject each valve to 500 on-off cycles with gas pressure applied to the valve. After each 100 cycles the valve solenoid coil resistance value was measured and recorded to determine if coil failure had occurred. Each valve successfully completed the 500 cycles and the test data is listed in Table V.

As the final test performed all valves were subjected to the base line data test (G.E. Acceptance Test) using nitrogen gas as the final media. This was used in lieu of helium gas because the G.E. test limits are based upon nitrogen

media. All valves successfully completed this final phase of the test. The test results are listed as "Post Life" in Table I.

In addition to the specified qualification tests which were performed it was deemed highly desirable to obtain test information in regards to extended life capacity and operation at temperatures below 140°R.

In order to obtain this desired test data a randomly selected valve, serial number 77, was further tested after completing the qualification test. The first phase of extended testing was to repeat the life 500 cycle test to 5000 cycles over and above the original 500 cycles. After each 1000 cycles of operation the valve "base line" data was repeated. The base line data results are listed in Table VI. In addition, the final 5000 cycles data is recorded in Table I for easy comparison to data of the qualification test. From this comparison it is obvious that no degradation of the unit has occurred in over 5800 known and recorded cycles of operation.

Operation of this same valve, Serial Number 77, at liquid hydrogen temperatures was accomplished per Test Request No. 106. The shut off valve was cooled to a temperature of 40°R to 43°R by means of submersion in LH₂. The valve was operated during cooldown, operated 100 times at minimum temperatures and then operated 10 times after a 30 minute soak at minimum temperature.

The valve operated successfully during all phases of the test. Functional seating of the valve was monitored and the normal full open and full closed positions were constantly attained.

The test was conducted in the following manner. The valve to be tested was mounted on an actuator housing and suspended approximately two (2) inches above the bottom of a sealed liquid helium rated dewar. The desired test temperatures were achieved by the introduction of LH₂ into the dewar resulting in

complete submergence of the valve and actuator housing. The valve was operated using GH_e regulated at 200 psig. The GH_e attained temperatures ranging from 40°R to 140°R during the test.

The test data was recorded by means of redundant Cu-Con thermocouples attached to the valve mounting screws. The valve solenoid coil current was measured directly with a milliammeter while the coil resistance was measured by means of a wheatstone bridge. The valve seating and opening capability was determined by observation of the pressure bleed off rate as indicated by the drive line pressure gage with the drive line solenoid valve closed. The first phase of the test was to flow valve drive gas pre-chilled to 140°R through the valve. When the valve attained 400°R then the LH_2 fill commenced. During cooldown operational checks of the valve were made. When valve temperatures of 43°R were attained the valve was checked as follows:

1. De-energize the shut off valve (S/N 77) solenoid and measure the coil resistance.
2. Close the GH_e as supplied to the valve and observe the downstream supply line for a bleed-off rate.
3. Energize the shut off valve and measure and record the solenoid current while monitoring the supply line for rapid pressure loss.
4. Open the GH_e supply valve and maintain flow until the next cycle.

After the 100 cycles of test were achieved a 30 minute "soak" period was performed with the shut off valve energized and full flow through the valve maintained. At the end of the soak period a check of the test dewar disclosed that the test article was still submerged in approximately 85 liters of LH_2 . The valve drive gas was then passing through 2.5 feet of LH_2 prior to entering the

actuator housing and is assumed to be almost at LH₂ temperature. During the soak period 40°R temperatures were measured at the valve. In terminating the soak period several measurement cycles were performed and a series of ten (10) on-off cycles were accomplished.

After proper warm up and disassembly of the test setup the valve was removed, installed in the base line test fixture, and the valve acceptance test was performed for comparison to the prior base line data. This final base line data is recorded in Table I. The test performance data is recorded in Table VII.

Conclusions:

All valves which were tested successfully completed all phases of the tests which were intended to demonstrate qualification for XE application. On the basis of this successful demonstration the re-designed version of the pneumatic actuator shut off valve is considered qualified for XE application for all environments tested. Although it is not the intent of this test to determine qualification of the valves in a radiation environment, the results of the NRX-A6 side by side test, although qualitative, indicate that no damage occurred to the lock solenoid shut off valve under the doses received in this test. Lock operation was normal before, during, and after the A-6 reactor run.

	Insulation Resistance (Meg Ω)	Coil Resistance (Ω)	Leakage De-Energized scc/min	Leakage Energized scc/min	Pull-In Voltage (volts)	Drop-Out Voltage (volts)	Steady State Output Pressure (psig)	Steady State Output Voltage (volts)	Operation Time (Seconds)	Time Media	Valve Serial Number
Base Line	200	211	882	1100	10.5	4.5	199	28	.018	He	78
Post Vibration	8.5K	212	900	119	10.7	4.5	202	28	.023	He	78
Post Shock	25K	212.7	900	490	11.3	4.8	200	28	.025	He	78
Post Thermal	37K	214	500	199	11.1	4.5	199	28	.052	N ₂	78
Post Life	37K	214.7	650	75	11.1	4.5	200	28	.052	N ₂	78
Base Line	1.3K	212.8	660	95	9.8	4.0	200	28	.020	He	77
Post Vibration	40K	213.1	142	102	9.7	4.0	197	28	.027	He	77
Post Shock	30K	213.5	110	106	10.3	4.0	196	28	.032	He	77
Post Thermal	360	214.3	128	35	10.5	4.0	200	28	.060	N ₂	77
Post Life	4K	214.9	120	70	10.5	4.0	199	28	.060	N ₂	77
Post 5000 Cycles	50K	214.9	272	20	10.5	3.8	204	28	.040	N ₂	77
Post Cryogenic	120K	213.1	11.8	8.5	10.5	3.9	200	28	.032	N ₂	77
Base Line	7K	211.7	250	495	10.1	4.0	198	28	.022	He	76
Post Vibration	40K	211.8	60	55.5	10.4	3.8	198	28	.030	He	76
Post Shock	160K	212.6	200	80	10.3	3.8	203	28	.023	He	76
Post Thermal	60K	212.3	200	1.2	10.1	3.7	205	28	.025	He	76
Post Life	70K	212.7	200	68	10.5	3.3	203	28	.045	N ₂	76

QUALIFICATION TEST DATA

TABLE I

	Valve #76 Resistance (ohms)	Valve #77 Resistance (ohms)	Valve #78 Resistance (ohms)	Plane
Sweep 1	211.6	211.8	209.5	X
Sweep 2	213.2	211.9	210.4	X
Dwell	212.9	212.9	210.6	X
Sweep 3	210.4	211.5	210.4	Y
Sweep 4	No	Data	Available	Y
Sweep 5	212.2	213.3	210.2	Z
Sweep 6	211.8	213.1	210.9	Z

No Resonance Detected in Planes Y and Z.

Note: Refer to Figures 1 and 2 for load levels.

VIBRATION TEST
COIL RESISTANCE DATA

TABLE II

<u>Shock Plane</u>	<u>Shock Level*</u>	<u>Valve S/N</u>	<u>Resistance</u>
Axial (Z)	+6g	76	210 ohms
Axial	-6g	76	210 ohms
Axial	+6g	77	209.1 ohms
Axial	-6g	77	209.1 ohms
Axial	+6g	78	212 ohms
Axial	-6g	78	212 ohms
Radial (Y)	+6g	76	209.8 ohms
Radial	-6g	76	210 ohms
Radial	+6g	77	209 ohms
Radial	-6g	77	211 ohms
Radial	+6g	78	211.9 ohms
Radial	-6g	78	211.9 ohms
Radial (Z)	+6g	76	210.9 ohms
Radial	-6g	76	210.9 ohms
Radial	+6g	77	209.4 ohms
Radial	-6g	77	209.4 ohms
Radial	+6g	78	212.3 ohms
Radial	-6g	78	212.3 ohms

* Each of the listed shock levels were produced for a total of
three (3) pulses in all directions for each valve.

MECHANICAL SHOCK TEST

COIL RESISTANCE DATA

TABLE III

Valve #76

Cycle #	1	2	3	4	5	6	7	8	9	10
Temp. (°R)	140	150	150	150	150	150	150	150	140	140
Resistance (Ω)	95	97	100	96.4	101	95	96	97	94.6	94.8
Temp. (°R)	685	690	685	700	700	700	700	700	690	690
Resistance (Ω)	254.9	256.7	256	254	263	260	250	250	251	251

Valve #77

Cycle #	1	2	3	4	5	6	7	8	9	10
Temp. (°R)	140	140	140	140	140	140	140	140	140	140
Resistance (Ω)	97	97	97	97	97	97	97	96.7	96.7	97
Temp. (°R)	690	695	690	690	690	685	690	682	685	685
Resistance (Ω)	258	291	288	266	262	270	259	259	259	250

Valve #78

Cycle #	1	2	3	4	5	6	7	8	9	10
Temp. (°R)	140	140	140	140	140	140	140	140	140	140
Resistance (Ω)	93	94	96	96	95	96	95	95	94	96
Temp. (°R)	690	690	690	690	690	690	690	690	690	690
Resistance (Ω)	250	250	254	253	254	253	254	253	250	250

THERMAL CYCLING TEST DATATABLE IV

	No. of Cycles	0	100	200	300	400	500
S/N 77*	Coil Resistance (Ω)	216	217	218	217.7	217.9	214.9
S/N 78**	Coil Resistance (Ω)	212.3	212.7	214.6	215.3	216.1	214.7
S/N 76*	Coil Resistance (Ω)	212.8	215.1	215.8	216.3	216.7	216.2

* 200 $\pm$ 5 psig of helium gas applied

** 200 $\pm$ 5 psig of nitrogen gas applied

LIFE CYCLE TEST RESULTS

TABLE V

	Insulation Resistance (Meg Ohm)	Coil Resistance (Ohm)	Leakage De-Energized scc/min	Pull-In Voltage (Volts)	Drop-Out Voltage (Volts)	Steady State Output Pressure (psig)	Steady State Output Voltage (Volts)	Operation Time (Seconds)
1000 Cycles	38K	215.7	300	40	3.9	203	28	.070
2050 Cycles	20K	217.9	498	30	3.8	204	28	.050
3122 Cycles	50K	213	400	55	3.8	204	28	.045
4229 Cycles	20K	213.6	322	20	3.8	204	28	.040
5300 Cycles	50K	214.9	272	20	3.8	204	28	.040

Valve Serial No. 77

Nitrogen Gas

BASE LINE DATA - EXTENDED LIFE TEST

Table VI

Cycle No.	Current (ma)	Resistance (ohms)	Temperature (°R)	Time (min.)
1	138	202	498	Setup
2	136	207	500	0
3	138	206	500	6.5
4	139	204	497	18
5	139	203	497	20
6	141	197	470	25
7	151	185	430	30
8	162	176	404	34
9	198	-	306	36
10	223	127	265	37
11	266	106	180	39
12	302	94	126	41
13	335	83	63	44
14	340	81	60	46
15	340	81	60	49
16	342	78	43	51.5
17	342	78	43	55
18	342	78	43	57
19-34	Cycle on-off without taking measurements			
35	342	78	43	61
36-44	Cycle on-off without taking measurements			
45	342	78	43	63
46-54	Cycle on-off without taking measurements			
55	342	78	43	65
56-64	Cycle on-off without taking measurements			
65	342	78	43	66.5
66-74	Cycle on-off without taking measurements			
75	341	78	43	67.5
76-84	Cycle on-off without taking measurements			
85	341	78	43	69
86-94	Cycle on-off without taking measurements			
95	341	78	43	71
96-104	Cycle on-off without taking measurements			
105	340	78+	43	72.5
106-114	Cycle on-off without taking measurements			
115	340	78+	43	74
116	340	78	40	102
117	340	78	40	104
118-127	Cycle on-off without taking measurements			
128	340	78	40	106

Cryogenic Test DataTable VII

Figure 1

Vibration Levels Tested To In Plane X

Figure II

Vibration Levels Tested To In Planes Y and Z