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S8DR ACTUATOR
SECOND INTERIM REPORT

AEC Research and Development Report

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION

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By
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ABSTRACT

High-temperature, radiation-resistant, rotary actuators have been developed for use in the control system of SNAP reactors. These actuators are electromagnetic, variable-reluctance, stepping devices with integral, spring-loaded brakes.

Five actuators were built, and four of these have been tested successfully to date to the environmental and performance requirements of the SNAP 8 Development Reactor (S8DR) Program. These tests are still being conducted; the final results will be reported later.

The five actuators were modifications of the originally designed units, the testing of which has been reported previously. These modifications were made as a result of design-margin tests which were conducted at 1125°F (100°F above maximum design temperature). This report details the results of the design-margin tests, the modifications that were made in the original design, and the proof tests that were conducted on the modified design.

The results of the tests, to date, indicate that the modified actuators should meet all requirements for the S8DR Program.

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I. INTRODUCTION

Future space missions of long duration will require an electrical power source in the kilowatt range. To meet this requirement, Atomics International, under contract to the Atomic Energy Commission, has developed a series of Systems for Nuclear Auxiliary Power (SNAP) reactors. These reactors provide thermal energy which can be converted to electrical power.

The first generation of these reactor systems, designated SNAP 10A, produced over 500,000 w-hr of electrical power in 43 days of uninterrupted space operation. The Advanced Zirconium Hydride Reactor Systems, of which SNAP 8 represents the current hardware generation, have a greater power capability, with resultant higher temperatures.

The SNAP 8 reactor is designed to produce 600 kw of thermal power at 1300°F. The control system for this reactor is similar in concept to the SNAP 10A. The reactors are controlled by regulating the neutron leakage from the reactor core. This regulation is accomplished through the reactor control system by accurate positioning of the beryllium reflectors which surround the reactor core. Upon command from a controller,⁽¹⁾ an electromagnetic actuator drives the reflectors through a gear train.

The control drum actuators are electromagnetic, variable-reluctance, stepping devices with integral, spring-loaded brakes. By its proximity to the reactor core, the actuator is subjected to high operating temperature and fast neutron and gamma irradiation. The operating temperatures of the reactor control components have increased with the increased power ratings of the reactor system. A comprehensive development program has been carried out to produce a highly reliable prototype actuator for the SNAP 8 Reactor System.⁽²⁾ This actuator will be tested under operational environment during the SNAP 8 Development Reactor (S8DR) Test now in progress.

Information on the performance of the S8DR actuator was previously reported in Reference 3. This report extends that data.

Figure 1. Tooth Alignment in Adjacent Stator Poles

II. DESCRIPTION AND PERFORMANCE OF ACTUATOR DESIGN

A. OPERATING PRINCIPLES AND FUNCTIONS

The S8DR actuator is an eight-pole, electromagnetic, variable-reluctance device. Torque is produced from the interaction of magnetic forces between stationary teeth on a fixed pole and notched teeth cut into a cylindrical rotor, as shown in Figure 1. As a pole is energized electrically, the rotor moves to minimize the magnetic flux flow path, producing a small rotary step. As this rotation takes place, the teeth in the adjacent pole are misaligned, by a distance equal to one-half of a tooth width, into position for the next step.

The brake which restrains the rotor between stepping sequences operates on the tractive electromagnetic principle. The armature, which is restrained rotationally, has an attached toothed ring which, when the brake is de-energized, engages a mating disc attached to the rotor. The brake surfaces are coated with a sodium silicate bonded dry film lubricant to prevent adherence.

B. MECHANICAL AND ELECTRICAL DESIGN

The eight equally spaced stator poles are bolted to the stator shell capturing the coil between the shaped pole face and the shell. A nonmagnetic Inconel 600 chip shield fills the space between the poles, and fits into grooves in the endbells. The poles, shell, end bells, and rotor are all constructed from Hiperco 27,^{*} a cobalt-iron high-temperature magnetic alloy. The homogeneous construction is used to minimize the effects of thermal expansion. The actuator rotor turns on bearing surfaces of aluminum oxide in contact with carbon-graphite bushings, for minimum friction torque at operational temperature. The rotational clearance between the rotor and the stator poles is a nominal 0.008 in. The carbon-graphite bushings are sized to be loaded in compression by the end bells for temperatures through 1025°F. Design requirements for the control drum drive, and comparison to other actuators, may be found in Reference 3.

The coils for the S8DR actuator stator were fabricated from 24 AWG Oxalloy 28[†] wire. Oxalloy 28 consists of a copper core, clad with a chrome-iron alloy (Type 410 stainless steel). This cladding material is bonded to the

^{*}Westinghouse Electric Corp.

[†]Sylvania Electric Products, Inc.

Figure 2. Exploded View of Actuator

Figure 3. Actuator After Acceptance Testing

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conductor, and occupies 28% of the wire cross-sectional area. The cladding will not rupture or crack under the most severe bends, providing protection for the copper core. The encapsulant used was AI-1, a phosphoric acid based cement with silica filler, developed by Atomics International. This encapsulant material is completely compatible with the cladding material, in both its liquid and its cured forms. The brake coils were made from the same materials, but employed 20 AWG wire. The actuator contained four phases, with two coils in each phase, connected in parallel.

An exploded view of the S8DR actuator is shown in Figure 2. The unit weighs 15.75 lb, is 8.325 in. long and 4.125 in. in diameter, and employs a 13.8 to 1 stepdown gear to drive the control drums. Figure 3 shows the pinion gear as part of the actuator shaft. It also shows the actuator, complete with lock wiring, as it appears after acceptance testing.

C. PERFORMANCE

The ability of the S8DR actuator to satisfy the program requirements was demonstrated by testing four actuators. These actuators were designated as Dev. 010, Dev. 011, Dev. 013, and Dev. 016. The previous test history on the mechanical parts used is as follows:

<u>Actuator Number</u>	<u>Previous Test Hours</u>
Dev. 010	5,800
Dev. 011	6,310
Dev. 013	5,340
Dev. 016	10,073

Actuators Dev. 010, Dev. 011, and Dev. 013 were tested to the production acceptance test specification after assembly and prior to endurance testing. An additional actuator, Dev. 014, was also fabricated; but it was transferred to the status of a spare actuator for the production actuators. Actuator Dev. 016 was connected with all the phase coil leads brought out external to the housing, so it could be used as a Performance Mapping Unit.

1. Performance Mapping Test

The performance mapping actuator, Dev. 016, was assembled identically to the other actuators, except for the final connection. The coils were connected to low-temperature wiring, and both coil leads of each coil were brought outside the housing. This allowed for testing in the normal arrangement, as well as allowing simulation of the effects of failures in various coils.

Development actuator Dev. 016 produced 70 and 82 oz-in. torque at rated current, depending upon the direction of rotation, when tested with all phase coils energized. Testing was then performed with one coil open, two coils open, three coils open, and four coils open, with various combinations of open coil location. This included adjacent coils being open, as well as coils widely separated being open. The total range of torque values obtained at rated current was 70 to 87 oz-in. No appreciable change of output torque or performance was detected, as long as the current to each phase was kept at a constant 4-amp value.

2. Life Test

Three developmental actuators, Dev. 010, 011, and 013, were placed on a long-term design verification life test at 1125°F. The test sequence for these actuators was:

- 1) 54 thermal cycles
- 2) 1000-hr endurance (includes 12 thermal cycles)
- 3) 1000-hr static dwell
- 4) 3000-hr endurance (includes 36 thermal cycles)
- 5) 1000-hr static dwell
- 6) 4000-hr endurance (includes 82 thermal cycles)
- 7) 2000-hr static dwell
- 8) 16 thermal cycles
- 9) Post-test calibration and inspection

The thermal cycle consists of heating the actuator from ~300°F to 1125°F at the rate of 15°F/min, stabilizing at 1125°F, and then cooling back down to 300°F. On alternate thermal cycles, the actuator is operated at rated input current at the speed of one step (3.6° rotation) every 2.5 sec for 25 min prior to the heatup, and again after temperature stability at 1125°F is achieved. The

25-min operation of the actuator provides the actuator rotation equivalent to that required to drive the S8DR control drum from the Full Out position to the Full In position. The startup cycle test was conducted with 4.0 amp to the phase and 2.0 amp to the brake, up through the 3000-hr endurance phase. Subsequently, the current was increased to 5.4 amp to the phase and 2.2 amp to the brake, to correspond more closely to the output of the actual controller being used to operate the actuator on the S8DR test system.

During the endurance run, the actuator is maintained at 1125°F, except for the two thermal cycles (including 1 startup cycle) which are conducted once per week. In the static dwell phase, the actuator remains undisturbed while being maintained at 1125°F. The minimum current to the brake coil to release the mechanical brake is measured prior to, and after, the dwell period.

The current status of the three actuators is shown on Table 1. The performance of the actuators has been stable and satisfactory throughout the test period, as indicated by the summary of test data listed on Table 2.

TABLE 1
S8DR ACTUATOR DESIGN VERIFICATION TESTING

Test	Completion Dates		
	Actuator S/N		
	Dev 011	Dev 013	Dev 010
Initial 54 Thermal Cycles	12-19-67	1-8-68	1-24-68
1000-hr Endurance at 1125°F	2-13-68	2-19-68	3-12-68
1000-hr Dwell at 1125°F	3-26-68	4-1-68	4-17-68
3000-hr Endurance at 1125°F	8-1-68	8-6-68	8-23-68
Second 1000-hr Dwell at 1125°F	9-16-68	9-18-68	10-7-68
4000-hr Endurance at 1125°F	In test	In test	In test
2000-hr Dwell at 1125°F			
Final 16 Thermal Cycles			
Ambient Test and Inspection			
Test Status to End of Second 1000-hr Dwell			
Total Test Hours	7217	7134	7072
Total Thermal Cycles	105	106	106
Total Startup Cycles	51	50	51

TABLE 2
ACTUATOR PERFORMANCE AT 1125°F

	Actuator S/N	Brake Current		Stepping Current*		Insulation Resistance	
		Pull-in (amp) (min)	Release (amp) (max)	Clock- wise (amp) (min)	Counter- clock- wise (amp) (min)	Brake (M Ω)	Phase (min)
Start of Test	011	1.55	0.35	2.9	2.9	7	300 k Ω
After 1st 1000-hr Dwell		1.80					
After 2nd 1000-hr Dwell		1.62					
Latest Data		1.62	0.34	3.0	2.9	1.6	1.6 M Ω
Start of Test	013	1.44	0.68	3.9	2.8	7.5	5 M Ω
After 1st 1000-hr Dwell		1.56					
After 2nd 1000-hr Dwell		0.94 [†]					
Latest Data		1.54	0.56	2.6	2.6	0.85	4.5 M Ω
Start of Test	010	1.28	0.34	3.0	3.2	10	200 k Ω
After 1st 1000-hr Dwell		1.6					
After 2nd 1000-hr Dwell		1.6					
Latest Data		1.38	0.34	2.5	2.6	1.3	1.6 M Ω

*To step 40 oz-in. load

[†]Brake not fully seated during dwell

III. PERFORMANCE OF ORIGINAL ACTUATOR DESIGN

The actuators described in Section II were modifications of an earlier design.

A. PERFORMANCE AT DESIGN CONDITIONS

The ability of the S8DR actuator, as originally designed, to satisfy the design requirements was demonstrated by testing on multiple developmental units, including long-term operation at design service temperature. A total of 15 developmental S8DR actuators were built and tested in this program. The description of these tests and performance results was reported in Reference 3, and is summarized in Table 3.

TABLE 3
COMPOSITE TEST RESULTS

Actuator S/N	Type of Test	Temperature (°F)	Thermal Cycles	Time (hr)	Revolutions Stepped	Brake Actuations	Load Stepped (oz-in.)
1	Thermal-Vacuum	1025	10	10,373	110	11,000	40
2	Thermal-Vacuum	1025	10	10,373	36	3,600	40
3	Irradiation	1025	6	2,313	25	2,500	40
4	Irradiation	1025	6	2,313	44	4,400	40
5	Scram Kit	900	200	13,100	13,890	1,389,000	40
6	Thermal-Vacuum	1025	6	5,876	21	2,100	120
7	SHOCK AND VIBRATION TEST UNIT						
8	Scram Kit	900	108	11,645	9,460	946,000	40
9	Startup and Thermal Cycle	1025	15	450	500	50,000	40
10	Startup and Thermal Cycle	1025	208	5,800	1,248	124,800	80
11	Startup and Thermal Cycle	1025	208	6,300	1,248	124,200	40
12	Scram Kit	1000	111	5,270	9,890	989,000	40
13	Thermal-Vacuum	1025	7	190	8	800	40
14	Thermal-Vacuum	1025	1	300	5	500	40
15	Thermal-Vacuum	1025	10	5,367	60	6,000	40

B. PERFORMANCE DURING DESIGN-MARGIN TESTING

Design-margin tests, conducted at 1125°F (100°F above maximum design temperature), disclosed the following potential weak points.

Design-margin thermal cycle testing appeared to be the most severe testing mode, ultimately resulting in a conductor failure in a number of the phase coils. The developed defect was a fracture across the conductor, which was generally located in the last turn of the coil near the lead wire. In this region, the conductor is cold worked when the attachment to the lead wire is made. Figure 4 shows a typical break, taken from Actuator S8DS 010D. The fractures were brittle in nature, without evidence of any necking down of the conductor, and there were pits in the surface of the conductor near the fracture. From this visual examination, some relationship between cold work, corrosion, and cracking appeared evident. A number of possible failure mechanisms were postulated and evaluated analytically, using data from a large number of coils produced, not only from the S8DR actuator, but also for position sensors, SRIP* coils, Piqua† coils, and various test coils.

Figure 4. Fracture Across Conductor

*SNAP Reactor Improvement Program, Zirconium Hydride Reactor

†Magnetic jack coils for City of Piqua Reactor

The mechanisms of failure investigated were hydrogen embrittlement, corrosion, stress corrosion cracking, work hardening, etc. None of the calculations or extrapolation of the data for single failure mechanisms predicted the observed brittle failure in the number of cycles in which it occurred. It was thus concluded that the failures were due to a combination of effects, generally referred to as low-cycle fatigue, aggravated by corrosion.

One actuator, S8DR 002D, on a special test with continuously applied ground potential while at 1125°F, failed by flashover. This occurred while the phase coils were attached to a faulty power supply, capable of producing high voltage spikes (~1000 v) during line transient conditions. Investigation of this failure⁽⁴⁾ determined that conductive titanium from the chip shield was being transferred as a film on the adjacent Al_2O_3 bobbin surface, and possibly migrating onto the encapsulant surface. Failure was due to flashover from the coil conductor to the titanium film, resulting in a burnout (local melting) of the conductor.

Although reliability testing, as such, was not performed, an estimate of coil reliability was made, based upon the results of testing at 1025 and 1125°F. Since thermal cycle testing is the most severe testing mode, reliability figures were based upon thermal cycles. It is estimated that the S8DR actuator will see, in service, about 55 thermal cycles. For the same confidence levels, the probability of survival of any one phase coil for 55 thermal cycles is 99.97%, if operated at 1025°F, and 86.5%, if operated at 1125°F.

The conclusion from the results of the design-margin tests was that, although the actuator performs satisfactorily at 1025°F, the <100°F temperature margin was inadequate for the intended application.

IV. DESIGN MODIFICATIONS

To increase the design margin beyond that indicated by the preceding tests, the complete coil design was evaluated to provide the best coil/conductor insulation combination, based upon all available information. All areas of actual, or potential, malfunctions were reviewed for possible improvement. It was decided to maintain the present physical shape, but to wind new coils suitable for higher temperature, based upon the results of coil materials test programs being conducted for the Advanced Zirconium Hydride Reactor Program. The following specific changes to the S8DR actuator, as previously reported,⁽⁵⁾ were made.

A. ENCAPSULANT

The encapsulant used in the original S8DR actuator was SAP II. This was replaced, in the modified S8DR actuators, by AI-1. Both encapsulants were developed by Atomics International, and are phosphoric acid based cements with silica filler. To reduce the corrosive characteristics, the pH of AI-1 has been increased to 3 (the pH of SAP II is <1); and corrosion-inhibiting ingredients, such as calcia, have been added. Tests have shown that the conductor corrosion is significantly less, in AI-1, than in SAP II (See Figure 5).

B. CONDUCTOR

The coils for the original S8DR actuator stator were fabricated from 26 AWG glass-fiber insulated, chrome-plated copper conductors, wound on alumina bobbins. The brake coils were made from the same materials, but employed 24 AWG wire. Coil lead wires were bonded to the coil with the encapsulant.

The chrome plate was very thin (~0.00007 in. thick), and was subject to cracking when the wire was bent. Oxalloy 28 wire was substituted for this conductor. This change in conductor provides increased strength (calculations of the clad wire strength indicate that Oxalloy 28 is at least 50% stronger than the same size copper wire, for temperatures to 1000°F), as well as increased protection from corrosion attack. Figure 6 shows an Oxalloy 28 conductor, after testing to 1225°F for 200 thermal cycles in the reworked S8DR coil configuration.

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a. In SAP II

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b. In AI-1

Figure 5. Comparison of Corrosive Attack on 30 AWG Cr-Cu Wire Immersed in Encapsulants for ~54 hr at Room Temperature

a. Wire Surface as Received (20X)

b. Wire Surface Following Test (20X)

c. Longitudinal Section of Wire (35X)

d. Transverse Section of Wire (100X)

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Figure 6. Oxalloy 28 Conductor After Testing to 1225°F for 200 Thermal Cycles

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Figure 7. Effect of Phase Coil Connection Design on Actuator Reliability

C. PHASE CONNECTION

The S8DR actuator originally contained four phases, with two coils in each phase, connected in series. Any failure in any coil would cause an actuator malfunction. Using the same number of phases and coils, but connecting the phase coils in parallel rather than in series, a failure of both coils of a phase must occur to cause an actuator malfunction, providing one coil produces the required operating torque. Tests performed on an actuator with individual wiring to the coils demonstrated that the torque varied insignificantly with one coil per phase operating, if the total phase current (amp-turns) was maintained constant. The S8DR actuator connection was modified from a series connection in the phases to a parallel connection. The controller was modified to provide current control, rather than voltage control, to maintain constant output current if one coil of any phase open circuited. The increase in the performance reliability of the actuator and S8DR control system, for given single-coil reliability, by the change from series to parallel coil connection is shown in Figure 7. Coil reliability shown is the value calculated for the S8DR actuator coil.

D. CABLE CONNECTIONS

The S8DR actuator was designed with a high-temperature connector half. After the elimination of all sliding contacts, including connectors, on the reflector wiring, this connector half was used as an electrical feedthrough. The cable connections were welded to the external pins, and the lead wires were welded to the interior pins. To reduce welded joints, and thus improve reliability, the cable wires were carried into the actuator as lead wires in the modified S8DR actuator. Figure 8 shows the reworked S8DR actuator, with the cable and cable wires carried into the actuator as lead wires.

E. CHIP SHIELD

The S8DR actuator's chip shield was made from titanium alloy, a material selected for its magnetic properties, coefficient of expansion, and high-temperature characteristics. The unexpected transfer of conducting material from the chip shield onto the coil insulation system, experienced during design-margin testing, could possibly be another limitation to high-temperature

Figure 8. Actuator With
Cable and Cable Wires
Carried in as Lead
Wires

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Figure 9. Finish Lead
Configuration

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operation. In the modified S8DR actuator, the chip shield material was changed to Inconel 600, a material with suitable expansion characteristics and low vapor pressure at the expected operational temperature.

F. COIL FINISH LEAD

In the original S8DR actuator design, the coils were terminated to a finish lead which was protected from the coil conductors by a mica spacer. The point where the coil conductor crossed over the edge of the mica spacer was a point of potential stress rise, promoting failure. The design was modified to bring the coil conductor around the end of the mica spacer, avoiding stress risers, and placing the joint to the finish lead over the start lead. Both lead joints remain separated from the coil body by the mica separator at the side of the coil. The details of the coil lead routing are shown in Figure 9.

Figure 10. Distorted Stator Coils in
Test Bed No. 001 After 203 Thermal
Cycles to 1225°F

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Figure 11. Stator Coils (Left, as manufactured; center and right, after
203 thermal cycles to 1225°F)

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V. DESIGN-MODIFICATION PROOF TEST

To demonstrate the high-temperature performance of the modified S8DS actuator coils, proof tests were conducted on three test bed actuators.⁽⁶⁾ Each test bed was a complete field and brake assembly, containing eight stator coils and a brake coil wound with Oxalloy 28 wire encapsulated in AI-1 cement. Rotational elements (rotor and brake disk) were left out, since they would not affect coil evaluation. The test program consisted of subjecting each test bed to 203 thermal cycles at a different temperature. The temperatures selected were 1025, 1125, and 1225°F.

Test Bed No. 001 was thermal cycled to 1225°F 203 times. At the end of the test, there was no evidence of failure in any of the nine coils. Trouble was experienced, however, with the brake coil. Due to excessive clamping pressure of the cable feedthrough, the cable insulation broke down after the 72nd thermal cycle. In repairing this defect, a screw of excessive length was used in the clamp. This screw caused a ground to the coil during the 118th thermal cycle, causing delays in testing. Both problems were corrected in the final design. Post-test examination of Test Bed 001 revealed that the coil wire on the rectangular bobbins in the stator had elongated, causing a change in resistance of ~14%. This elongation produced a noticeable visual distortion of the coils (see Figures 10 and 11). The Oxalloy 28 conductor, however, was in good mechanical condition following this test (Figure 6). This and other tests indicate a thermal ratcheting action existing within the wire.⁽⁷⁾ The practical effect of this ratchet action is to increase coil size and conductor resistance.

Test Beds No. 002 and 003 were thermal cycled to 1125 and 1025°F 203 times respectively. As with No. 001, there were no coil failures or malfunctions. Test Bed No. 002 experienced a resistance increase of 3.3%, while Test Bed No. 003 had a negligible resistance change (Table 4). No visual change in the coils of Test Beds No. 002 and 003 could be detected. Metallurgical and visual examination of the conductors tested to 1225, 1125, or 1025°F showed no detrimental effects due to testing, other than the elongation in Test Bed No. 001. Some irregularity of the conductor surface of the 1225°F test also appeared. Other tests performed seem to confirm that growth does not affect the conductor, except for change in length and resistance. No failures of Oxalloy 28 wire as a conductor have been recorded in the test program to date.

TABLE 4
SUMMARY OF TEST-BED PERFORMANCE
(203 Thermal Cycles)

Coil Fabrication	Performance Characteristic	Test Bed No.		
		001	002	003
Brake Coil: 370 turns AWG 22 Oxalloy 28 wire, AI-1 encapsulant	Maximum Temperature (°F)	1225	1125	1025
Phase Coil: 65 turns AWG 24 Oxalloy 28 wire, AI-1 encapsulant	Minimum Temperature (°F)	390	330	290
Average phase coil conductor resistance, hot (Ω)	Start of Test	2.60	2.41	2.29
	End of Test	2.97	2.49	2.29
	Increase (%)	14.0	3.3	0.0
Lowest phase coil insulation resistance, hot	Start of Test	66 k Ω	140 k Ω	1 M Ω
	End of Test	30 k Ω	120 k Ω	350 k Ω
Brake coil conductor resistance, hot (Ω)	Start of Test	16.7	15.8	14.6
	End of Test	17.9	16.0	14.6
	Increase (%)	7.2	1.3	0.0
Brake coil insulation resistance, hot	Start of Test	70 k Ω	5 M Ω	40 M Ω
	End of Test	0.1 Ω	1.7 M Ω	45 M Ω

One unit, Test Bed No. 002, with seven phase coils and the brake coil, was selected for continued testing. A stator coil of this unit had been removed for the metallurgical examination. As of 10-8-68, this unit had completed 245 additional thermal cycles to 1125°F and 8211 hr of testing (448 total cycles) without significant change in coil performance. Testing on this unit continues.

Based upon the very satisfactory performance of the test beds, it was decided to rework selected developmental and production S8DR actuators to incorporate all the design improvements described. The developmental and production actuators were disassembled and rebuilt concurrently. A total of five developmental actuators were reworked for the design verification test program. The results of this test program are detailed in Section II-C.

Seven actuators of the original design, built and acceptance tested for the S8DR Test System, were also disassembled and reworked to the modified design. Subsequent to the reacceptance testing, six units were installed on the Reflector Assembly for the S8DR Test System. During reflector assembly, one actuator was inadvertently damaged mechanically. Thereafter, Dev. 014 unit was designated as a spare actuator for the S8DR Test System. The six actuators on the S8DR Test System operated satisfactory during the checkout and acceptance test of the Reflector Assembly. The actuators are continuing to perform well within requirements during the early phase of the S8DR Test System operations.

VI. FUTURE TESTING

The developmental test program will continue until 12,000 hr of testing have been completed. At that time, several units will be disassembled and inspected to determine the effect of the testing on the actuators. One or more of the actuators will be continued in testing to 20,000 hr, depending upon the results of the inspection and test.

VII. SUMMARY

The modifications made to the S8DR actuators to increase reliability appear to have achieved that purpose. With over 50% of the design verification tests completed, no evidence of change in performance has been detected. It is expected that the test will be completed without incident. The increased design margin provided by the stronger, more corrosion-resistant conductor, with a less active encapsulant, should be adequate to ensure reliable actuator operation throughout the S8DR System Test.

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