**Westinghouse
Astronuclear
Laboratory**

WANL-TME-1928

May, 1969

DATA ITEM T-119

**TWO POSITION ELECTRIC
CONTROL DRUM ACTUATOR**

DEVELOPMENT TEST REPORT

MASTER

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DEVELOPMENT TEST REPORT

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1.0 GENERAL

1.1 INTRODUCTION

This report describes the testing of a two-position electric control drum actuator candidate, Responsyn stepping motor, Model HDUM-30-100-04. This is the same actuator motor and test setup that was used for the proportional electric actuator tests as described in WANL-TME-1921. However, a step input signal was used to obtain the two-position output of the actuator instead of a proportional input signal. The testing was performed at the WANL Mechanisms Laboratory during April 1969.

1.1.1 Type of Report

This report is a final report.

1.1.2 Scope of Test Document

The Test Document is TS:85DA-184-0.

1.1.3 Functional Category of Test

The test is a development test of a candidate reactor component.

1.1.4 Contractor

Westinghouse Astronuclear Laboratory (WANL/14683) under Subcontract NP-1, CY 1969.

1.2 PURPOSE OF TESTS

The purpose of the tests is to obtain performance data on the two-position electric control drum actuator candidate to verify analytical design parameters and to optimize the parameters to obtain the best overall subsystem performance.

The results are required for control system design and analysis and are to be used as a partial input to actuator trade studies. Trade studies will be performed to select a preferred and recommended actuator for the NERVA reactor.

2.0 REFERENCES

2.1 SPECIFICATION

CP 677585 - Control Drum Drive System for NERVA Nuclear Subsystem

2.2 DATA REQUIREMENT SHEET

Wanl Data Requirement Sheet T-119

2.3 SCOPE OF TEST DOCUMENT

TS:85DA-184-0

2.4 TEST REPORT

WANL-TME-1921 - Proportional Electric Actuator, Development Test Report

3.0 TEST ARTICLE CONFIGURATION

3.1 TEST SETUP

The test setup is as shown in Figure 3-1. An overall view of the test setup is shown in Figure 3-2. Description of the components used in the setup are as follows:

3.1.1 Stepping Motor

The stepping motor is a Responsyn Model, HDUM-30-100-04, manufactured by the USM Corporation. The motor is shown in Figure 3-3.

3.1.2 Drive Amplifier

The drive amplifier is a USM Corporation Model HDUM-A-PA30. It is a solid state power amplifier used to drive the stepping motor. This unit is shown in Figure 3-4.

3.1.3 Driver Logic Module

The driver logic module is a USM Corporation Model HDUM-A-MM2. It is a solid state translator for converting input pulses to logical switching of current to the drive amplifier. This module is shown in Figure 3-4.

3.1.4 Pulse Source

The pulse source is a unijunction transistor oscillator circuit as shown in Figure 3-5. It supplies pulse signals to the driver logic module at a rate of 100 pulses per second. This unit is also shown in Figure 3-4.

3.1.5 Control and Feedback Amplifiers

The control and feedback amplifiers are Philbrick Model P85AU operational amplifiers mounted in a Model RP manifold. These amplifiers are shown in Figure 3-6.

3.1.5.1 Feedback Amplifier 1

This is an inverting amplifier with a gain of one and is used as a buffer for the feedback signal.

Figure 3-1. Overall Test Setup Diagram

Figure 3-2. Overall Test Setup

Figure 3-3. Stepping Motor

Figure 3-4. Driver Amplifiers and Pulse Source

Figure 3-5. Pulse Source Schematic

Figure 3-6. Control and Feedback Amplifiers

3.1.5.2 Error Amplifier 2

This is a summing inverting amplifier with a gain of 20 and a noise filtering capacitor. It compares the feedback signal with the input demand signal.

3.1.5.3 Output Amplifier 3

This is an inverting amplifier with an adjustable gain. The gain was set at 5 for the test which results in a total gain of 100 for the error signal.

3.1.5.4 Inverting Amplifier 4

This is an inverting amplifier with a gain of one. It is used to supply the proper polarity signal to the pulse source to obtain both forward and reverse motor operation.

3.1.6 Inertia Load

Two different dummy inertia loads are used for the test, with values of 0.2 in.-lb-sec^2 and 0.4 in.-lb-sec^2 . These dummy loads are shown in Figure 3-7.

3.1.7 Torque Load

A magnetic particle clutch is used as a brake to obtain the desired torque loading. It is an electrically adjustable Lear-Siegler Model 917L magnetic particle clutch. The torque load value was set to 27 in.-lbs. The brake is shown in Figure 3-8.

3.1.8 Feedback Potentiometer

The feedback pot is a Markite conductive plastic, Type 8038. It is energized by a floating D.C. power supply that is tied to ground to obtain a virtual ground at the center of the pot. The output of the supply is adjusted to obtain a feedback pot scaling of 18 degrees/volt. The feedback pot value is $500 \pm 10\%$ ohms, 0.2% linearity, and is shown in Figure 3-8.

3.2 ADDITIONAL TEST EQUIPMENT

The following additional test equipment was used during the test.

Figure 3-7. Inertia Load

Figure 3-8. Torque Load and Feedback Potentiometer

3.2.1 Power Supply

3.2.1.1 + 28 VDC Power Supply

Kepco Model K070-20M (Two units in parallel).

3.2.1.2 +18 VDC Power Supply

Eico Model 1064

3.2.1.4 Feedback Potentiometer Supply

Trygon Model P32-1.5

3.2.1.5 Torque Load Supply

Hyperion Model HY-W1

3.2.2 Oscilloscope

Tektronix Model 502A

3.2.3 Oscilloscope Camera

Polaroid Model C-27

3.2.4 Function Generator

Hewlett-Packard Model 202A

3.2.5 D.C. Ammeter

Triplett 0-50A

4.0 SUMMARY OF TESTS

4.1 TRANSIENT RESPONSE TEST

The transient response tests were conducted by applying a series of input demand signals and measuring the resultant follow-up voltages at the feedback pot wiper arm. The tests were conducted for various conditions of input steps, load inertia, and load torque as listed in Table 4-1.

The test results were recorded with the oscilloscope and camera and are shown in Figure 3 through Figure 8. The scaling of the oscilloscope was as follows: For Tests 1, 3, 5, 7, 9, and 11 the horizontal scale is .2 sec/cm while the vertical scale is 1 volt/cm for the input step and .2 volt/cm for the follow-up position voltage. For Tests 2, 4, 6, 8, 10, and 12 the horizontal scale is 1 sec/cm while the vertical scale is 10 volt/cm for the input step and 2 volts/cm for the follow-up position voltage.

4.2 TORQUE TEST

The torque test was conducted by applying a step input signal and then adjusting the torque load braking current until the motor began to slip. The test was conducted for various values of motor supply voltage as listed in Table 4-2. The motor current and brake current were measured and the maximum torque value was obtained from a calibration curve of the brake. The results are listed in Table 4-2 and plotted in Figure 4-7.

4.3 OTHER TESTS

4.3.1 Critical Failure Test

This test was not performed since the test configuration was the same as that used for the proportional electric control drum actuator tests; hence, repetition of the test would serve no further purpose. Refer to WANL-TME-1921 for details.

4.3.2 Environmental Tests

Low temperature tests and shock and vibration tests were not conducted on the test unit, since it is a stock unit that was not designed to meet these environmental conditions.

TABLE 4-1
TRANSIENT RESPONSE TESTS

Test No.	Step Input V. D. C.	Inertia Load lb-in-sec^2	Torque Load in-lb	T_r sec	T_c sec	T_s sec	Overshoot %
1	1	0	0	0.30	0.32	0.33	2
2	10	0	0	3.2	3.5	3.6	0
3	1	0	27	0.30	0.32	0.33	2
4	10	0	27	3.2	3.5	3.6	0
5	1	.2	0	0.30	0.34	0.36	2
6	10	.2	0	3.2	3.5	3.6	0
7	1	.2	27	0.32	0.34	0.35	0
8	10	.2	27	3.2	3.5	3.6	0
9	1	.4	0	0.32	0.34	0.36	2
10	10	.4	0	3.1	3.5	3.6	0
11	1	.4	27	0.31	0.34	0.36	2
12	10	.4	27	3.2	3.2	3.6	0

T_r = Rise Time = 90% of final value.

T_c = Crossover Time = first crossover of final value.

T_s = Settling Time = within 2% envelope of final value.

Input Amplitude: 10 VDC = 180 degrees motor position.

TEST 1

TEST 1

TEST 2

TEST 2

Figure 4-1. Transient Response Test 1 and 2

TEST 3

TEST 3

TEST 4

TEST 4

Figure 4-2. Transient Response Test 3 and 4

TEST 5

TEST 5

TEST 6

TEST 6

Figure 4-3. Transient Response Test 5 and 6

TEST 7

TEST 7

TEST 8

TEST 8

Figure 4-4. Transient Response Test 7 and 8

TEST 9

TEST 9

TEST 10

TEST 10

Figure 4-5. Transient Response Test 9 and 10

TEST 11

TEST 12

TEST 11

TEST 12

Figure 4-6. Transient Response Test 11 and 12

Figure 4-7. Torque Test

TABLE 4-2
TORQUE TESTS

<u>Test No.</u>	<u>Motor Supply V. D. C.</u>	<u>Motor Current Amps D. C.</u>	<u>Brake Current ma. D. C.</u>	<u>Maximum Torque in-lb</u>
1	28	24.5	50	87
2	24	21.0	40	74
3	20	17.0	30	54
4	16	13.5	23	36
5	12	10.0	13	18
6	8	7.0	5	5
7	4	3.8	0	0

5.0 ANALYSIS OF TESTS

5.1 TRANSIENT RESPONSE TEST

The transient response test results indicate that the response time is proportional to the value of the step input. This is attributable to the velocity limit of the stepping motor. The maximum stepping rate of the stepping motor is 100 steps per second since the pulse rate of the pulse source is 100 pulses per second. This is equivalent to a velocity limit of 45 degrees/second since each step of the motor is .45 degrees. However, the test results as shown in Table 4-1 indicate an apparent rotation of 180 degrees (10 VDC) in 3.6 seconds which is a velocity of 50 degrees/second. This discrepancy implies a probable error in the scaling of the feedback potentiometer of about 1.8 degrees/volt.

The velocity changes from zero to maximum in a time period of one pulse and, likewise, from maximum to zero velocity in the same time period. Therefore, the acceleration and deceleration is 45 degrees/second/.01 second which equals 4500 degrees/second/second.

The observed overshoot was small.

Also, the results indicate that the variation of load inertia and load torque have little effect on the behavior of the system at the test conditions.

5.2 TORQUE TEST

The torque test results indicate that the maximum torque decreases as the supply voltage decreases. This is to be expected since the motor torque is a function of the motor current which, in turn, is a function of the supply voltage.

6.0 CONCLUSIONS

The use of the stepping motor system as a two-position electric control drum actuator appears feasible. However, the response time of the unit, as tested, may be slower than desired. This could be improved by the following:

- 1) Increasing the pulse rate of the pulse source.
- 2) Using a step-up gear train between the motor shaft and output shaft.

Either of these methods would result in a decrease in the maximum output torque. In other words, a trade-off is required between speed of response and the output torque.

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	DOCUMENT NO. WANL-TME-1928	DATE May 1969
ABSTRACT This document describes the testing of a Responsyn stepping motor (Model HDUM-30-100-04) as a two-position electric control drum actuator candidate. A step input signal was used to obtain the two-position output of the actuator. The testing was performed at the WANL Mechanisms Laboratory during April, 1969.		
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