# FINAL REPORT

# REACTION WHEEL ASSEMBLY

JANUARY 1976

Contract No. NAS 8-31385

Prepared For

George C. Marshall Space Flight Center

Marshall Space Flight Center

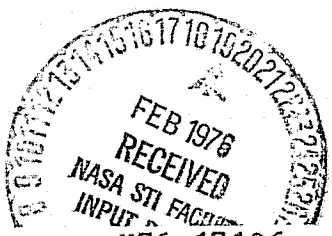
Alabama 35812

Prepared By

Satellite Programs Department

Sperry Flight Systems

Phoenix, Arizona




(NASA-CR-144168) REACTION WHEEL ASSEMBLY Final Report (Sperry Phoenix Co.) 16 p HC $3.50 CSCL 22B

N76-17186

Unclas
G3/18 13602

Project Engineer C. G. Sutter
C. G. Sutter

Program Manager J. R. Dohogne
J. R. Dohogne

## I. INTRODUCTION

This document is the final report for Contract Number NAS 8-31385, and is submitted to fulfill Paragraph 2 of the Reports Requirements, Exhibit "B" to that contract. The program consisted of the fabrication of three Reaction Wheels with associated drive and system monitoring electronics with brushless dc spin motors. They are intended for use on the MSFC Teleoperator Simulator. These reaction wheels were a modification of the existing Sperry Model 15 design incorporating the dc motor and drive electronic circuits from another Sperry design along with a speed pickoff which operates down to zero speed.

In order to execute the program within the required period it was necessary to make use of existing hardware. The first unit was built using an existing prototype wheel which had previously been used at Sperry to test various design concepts. Although the performance of this wheel is identical to the other two, the external appearance is somewhat different because of attachment points which had been machined into the housing.

The following sections provide a summary of the work accomplished and the equipment performance.

## II. PROGRAM STATUS

The program was authorized on 18 June 1975 for a six month period. The following equipment and documentation were shipped to MSFC.

| Equipment | Shipped |
|---|---|
| Reaction Wheel S/N 5100001 | Nov. 1975 |
| Reaction Wheel S/N 5100002 | Jan. 1976 |
| Reaction Wheel S/N 5100003 | Jan. 1976 |

| Documentation | Shipped |
|---|---|
| Progress Reports | 6 reports - 1 per month |
| Drawings | Oct. 1975 |
| Test Procedure | Sept. 1975 |
| Operation Manual | Oct. 1975 |
| Test Report | 3 reports - 1 w/each unit |
| Final Report | Jan. 1976 |

The completion of program milestones is shown on the bar chart, Figure 1.

## III. EQUIPMENT PERFORMANCE

The performance and characteristics of the units are shown in the Table I which follows. Complete test results are contained in the Test Reports for each unit which have been submitted under separate cover. The principal measurements and calculations were done with English Units and the values converted to SI units for Table I.

The comments below explain the performance values listed for each unit.

Weight - Minor differences occur because of machined part tolerances.

Rotor Unbalance - Typical balance requirements for this size wheel are 3.6 gm-cm (0.05 oz-in) static and 100 gm-cm$^2$ (0.5 oz-in$^2$) dynamic.

Rotor Inertia - Variations are due to machining tolerances and weight removal for balancing.

Angular Momentum - Calculated from rotor inertia.

Insulation Resistance - Variations occur due to wire routing and part cleanliness.

REACTION WHEEL ASSEMBLY SCHEDULE

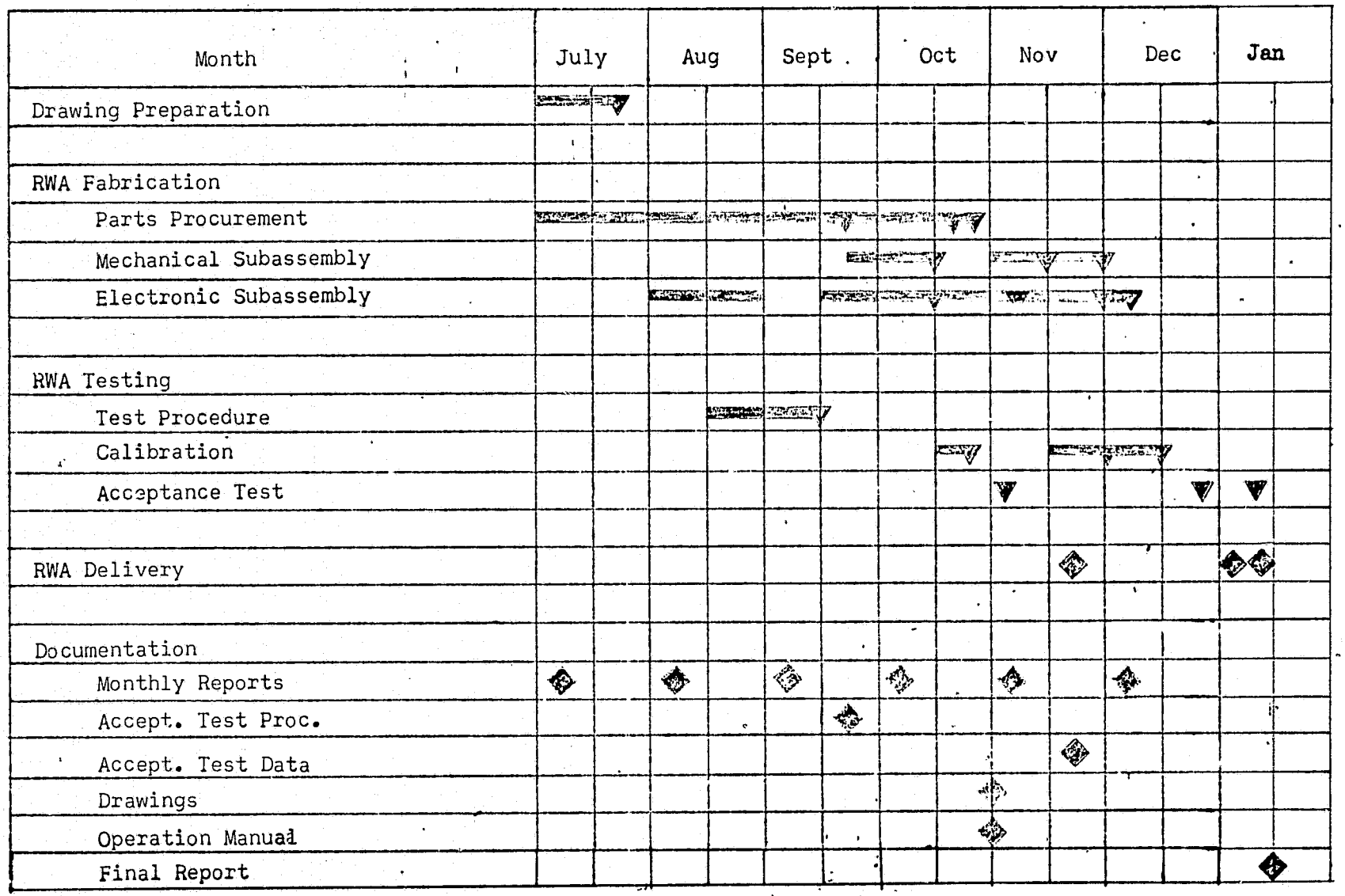
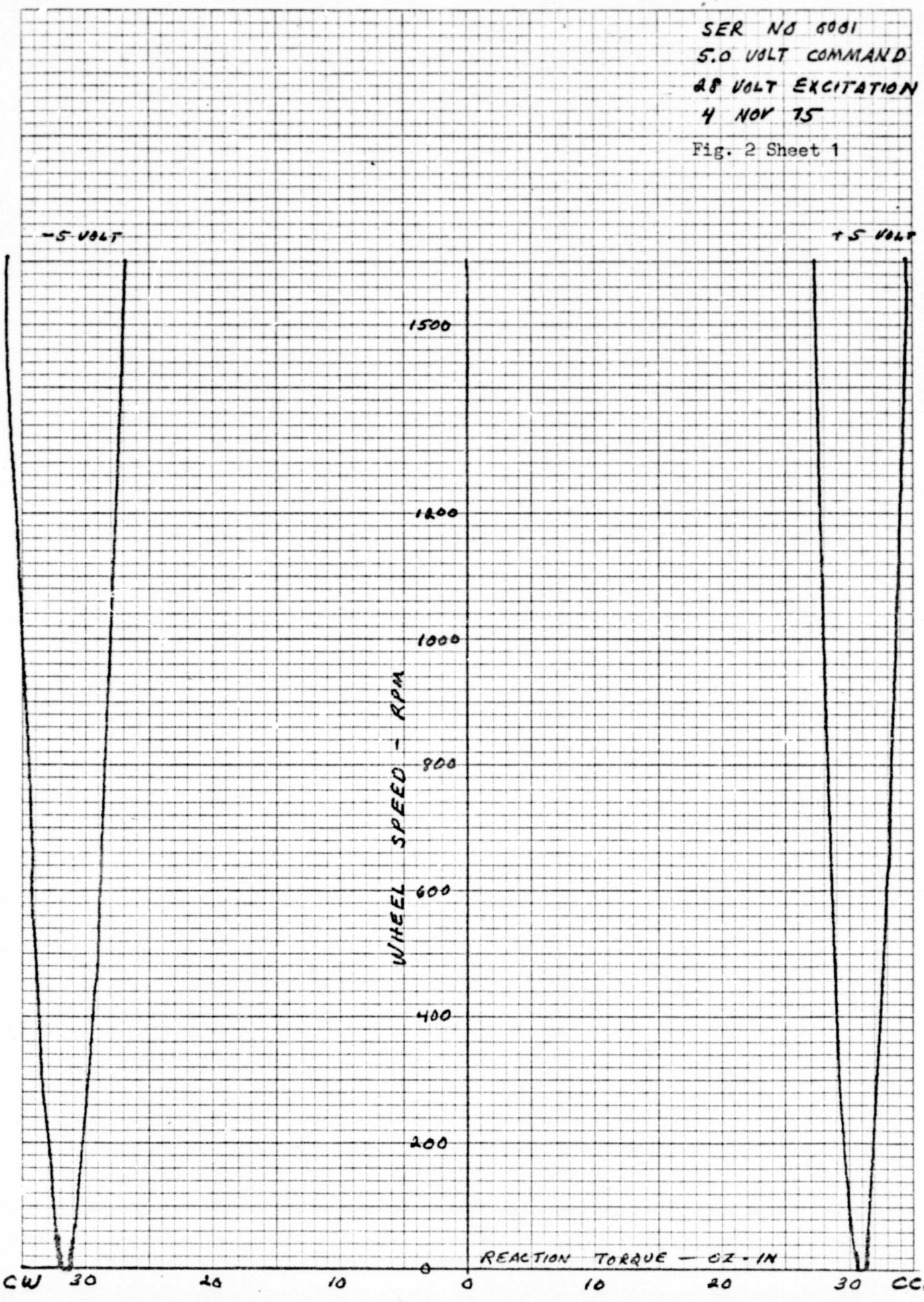


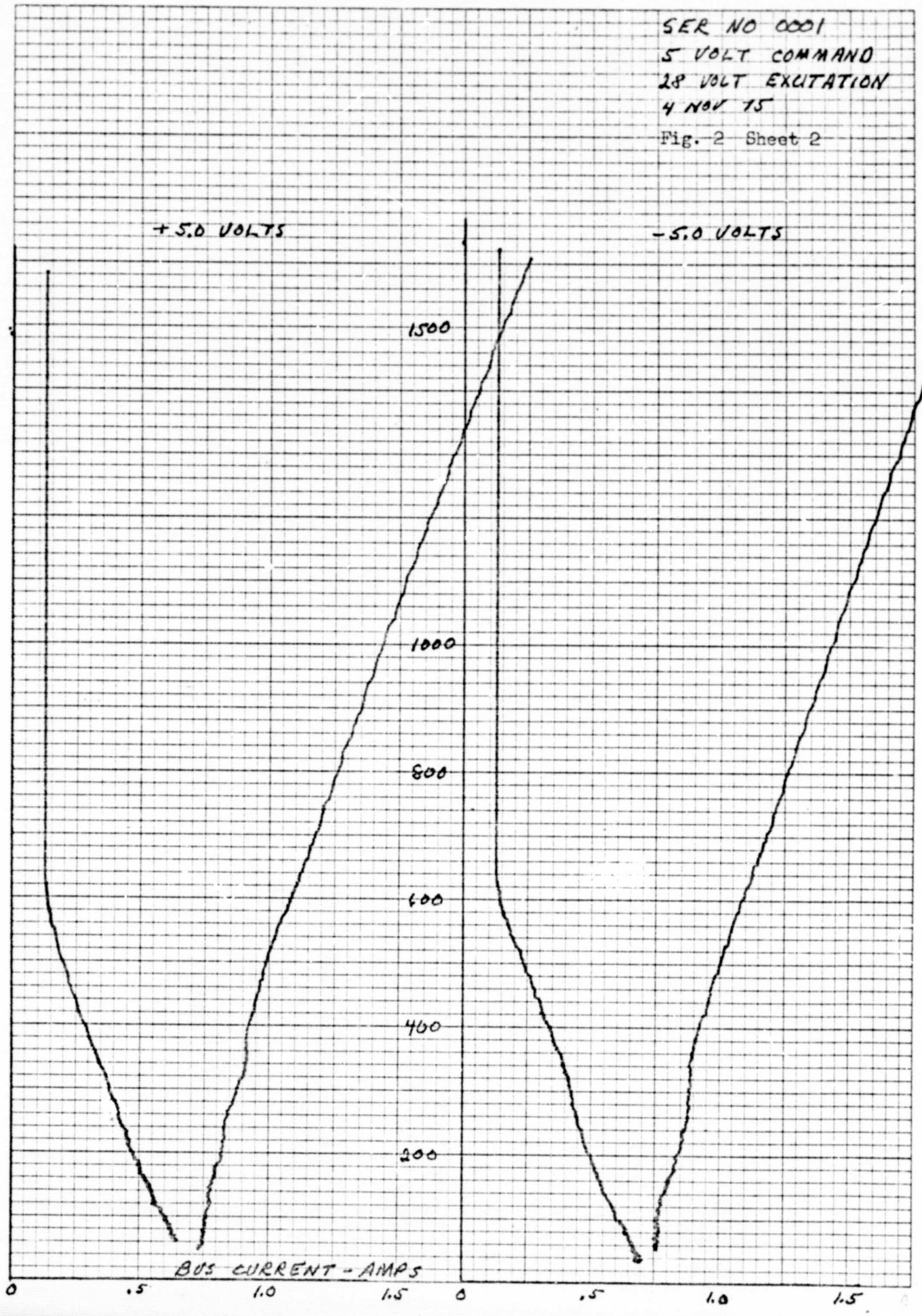

Figure 1

SER NO 6001
5.0 VOLT COMMAND
28 VOLT EXCITATION
4 NOV 75

Fig. 2 Sheet 1

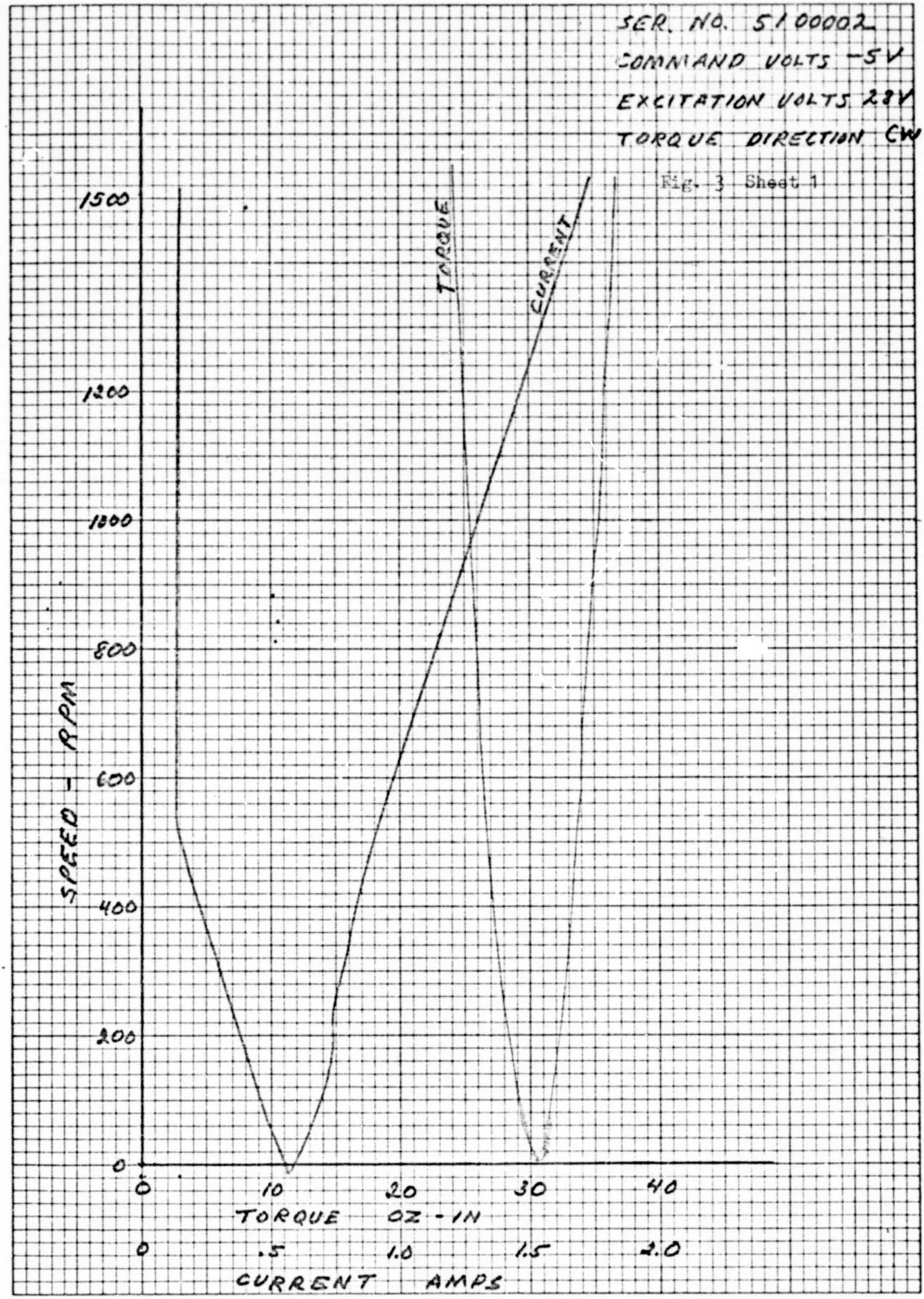


SER NO 0001
5 VOLT COMMAND
28 VOLT EXCITATION
4 NOV 75
Fig. 2 Sheet 2



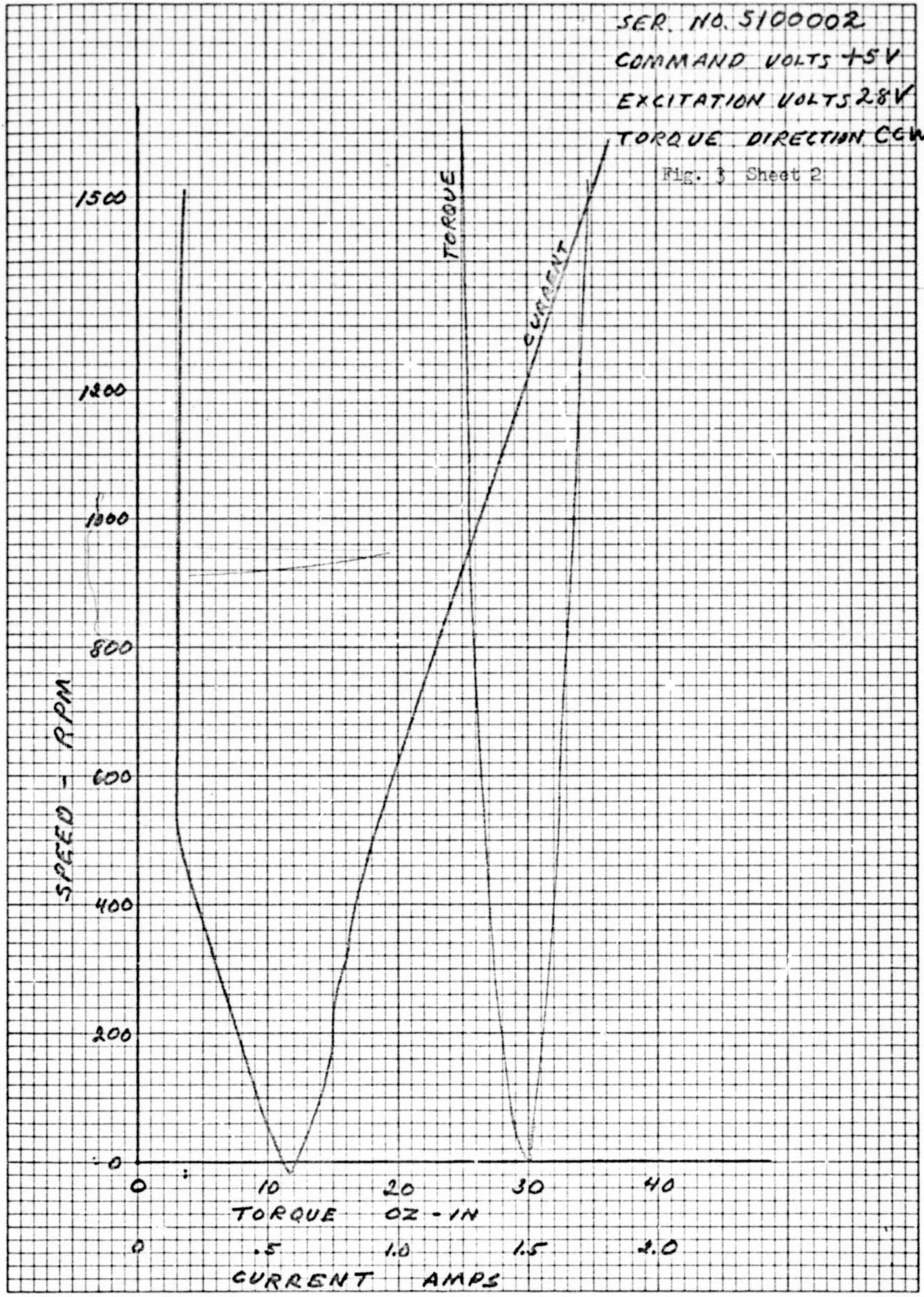
SER. NO. 5100002
COMMAND VOLTS -5V
EXCITATION VOLTS 28V
TORQUE DIRECTION CW

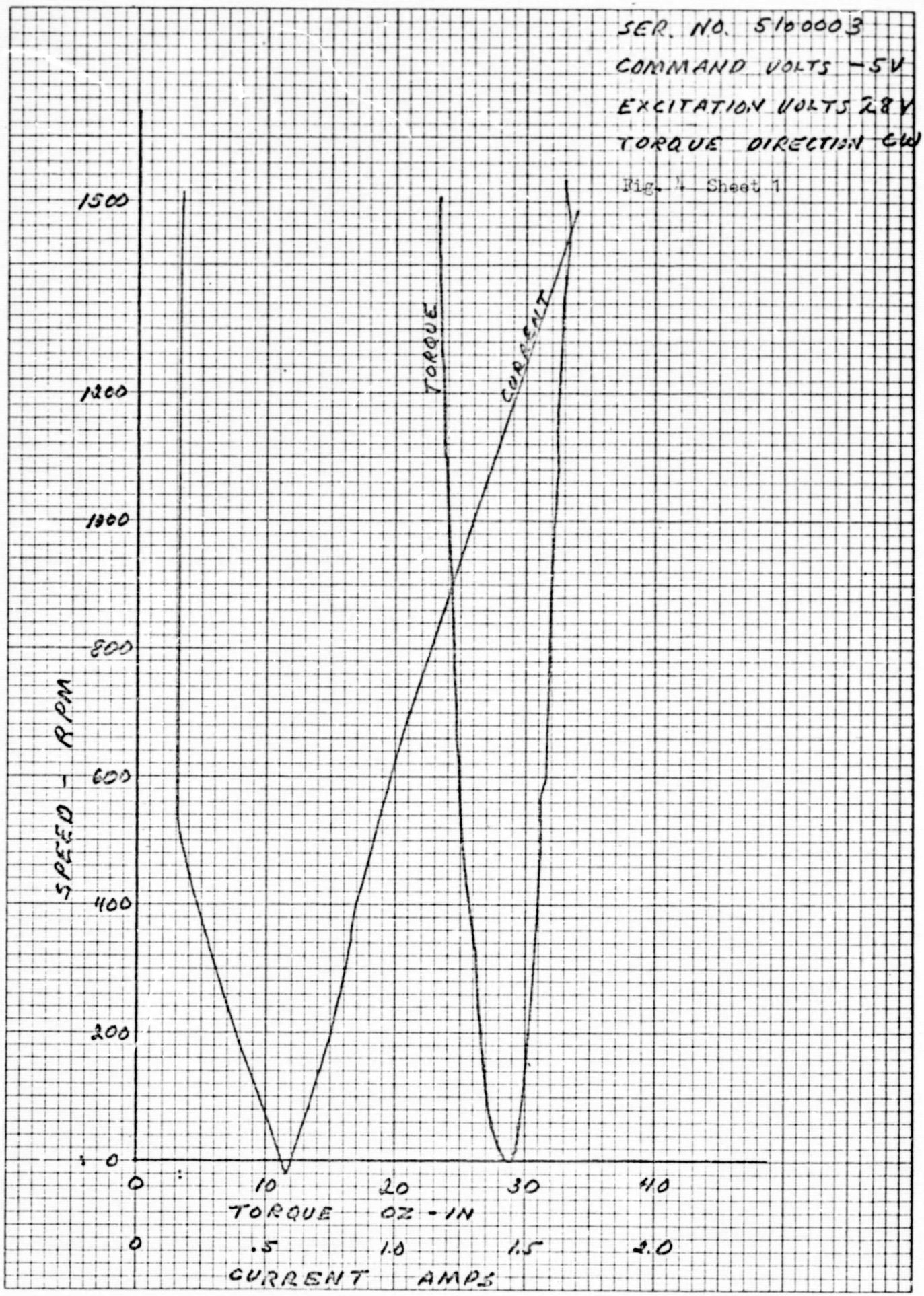
Fig. 3 Sheet 1

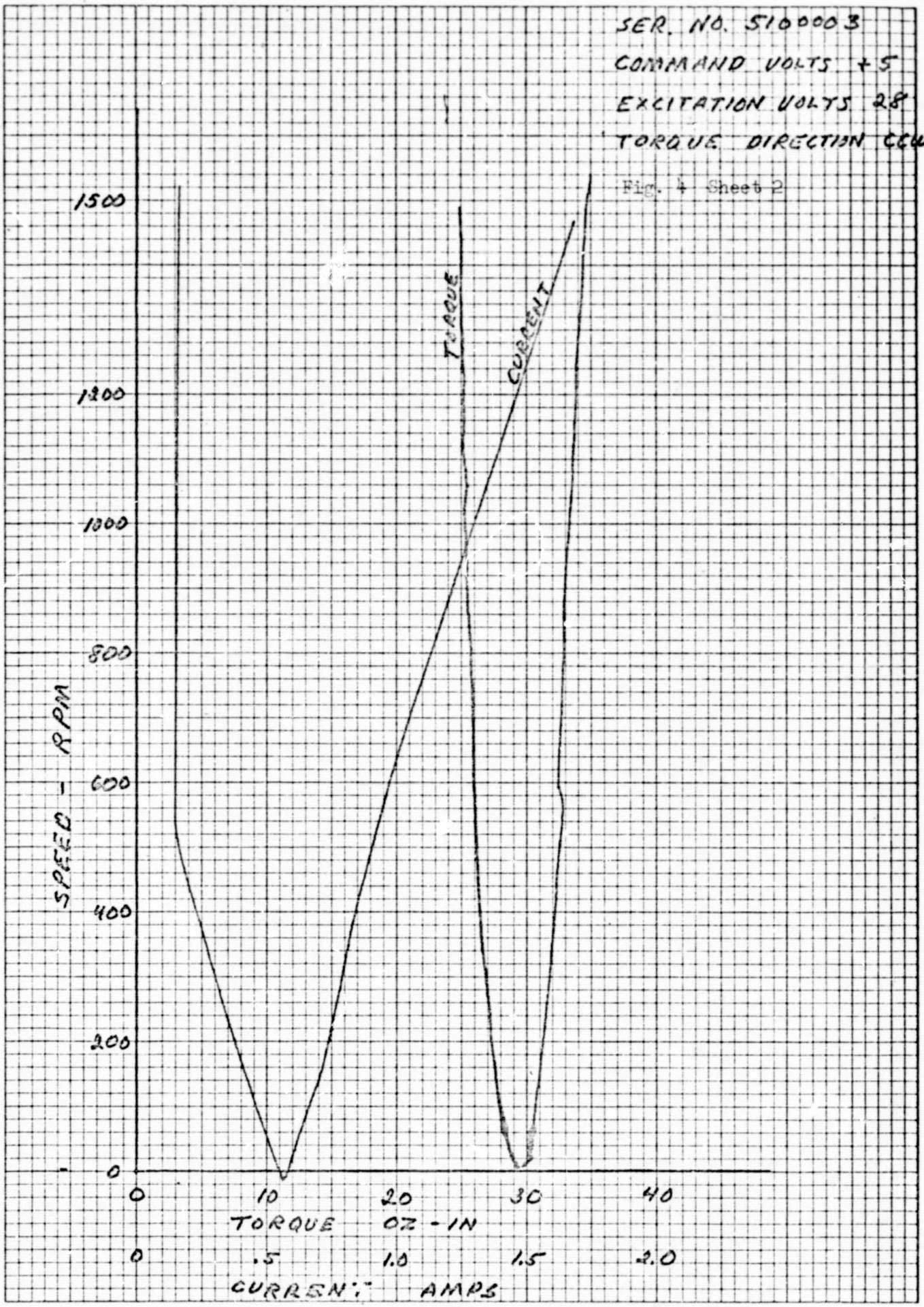


SER. NO. 5100002
COMMAND VOLTS +5V
EXCITATION VOLTS 28V
TORQUE DIRECTION CCW

Fig. 3 Sheet 2








EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

Pressure Rise Rate - Rate for S/N 5100001 was lower because additional effort was expended in cleaning and outgassing to solve a high pressure rise rate problem. The problem was found to be covers over the motor windings which prevented effective cleaning but were not a good enough seal to prevent outgassing. These covers were vented to solve the problem.

Tach Pulse Height - Value is determined by standard TTL circuit perofrmance.

Direction Signal - Vlaue is determined by standard TTL circuit performance.

Output Torque - Typical performance is shown on the curves of Figures 2, 3 and 4. Additional curves for 2.5 and 5.0 volt commands and 24, 28 and 32 volt excitation are included in the Test Reports. The curves for S/N 51000001 (Fig. 2) have a different format because a two channel recorder was not available at the time of test.

Constant Speed Power - Minor variations are caused by part and calibration tolerances.

Torque Time Constant - Variations caused by part tolerances and measurement errors.

Drag Torque - Both bearing drag and motor drag torques are included in the value given. Bearing drag varies because of differences in lubricant amount and location. Motor drag variations occur because the motor drive electronics are attempting to maintain zero current but zero offsets and other errors allow some motor current to flow.

Breakout Torque - Variations occur because of motor torque ripple and accuracy of electronics calibration. The test results given were obtained by gradually increasing command voltage until the rotor continued to turn. In Figures 5 and 6 a triangle shaped command voltage was applied while recording the reaction torque output. The

TABLE I

REACTION WHEEL PERFORMANCE CHARACTERISTICS

| Parameter | Units | Requirement | S/N 5100001 | S/N 5100002 | S/N 5100003 |
|---|---|---|---|---|---|
| Weight | newton<br>(pounds) | | 92.79<br>(20.86) | 93.76<br>(21.08) | 93.85<br>(21.1) |
| Rotor Unbalance | | | | | |
| Static | gm-cm<br>(oz-in) | | 0.79<br>(0.011) | 0.61<br>(0.0085) | 0.60<br>(0.0083) |
| Dynamic | $gm-cm^2$<br>$(oz-in^2)$ | | 1.10<br>(0.006) | 7.50<br>(0.041) | 1.10<br>(0.006) |
| Rotor Inertia | $Kg-m^2$<br>$(ft-lb-sec^2)$ | | 0.0734<br>(0.0541) | 0.0724<br>(0.0535) | 0.0734<br>(0.0541) |
| Angular Momentum at 157.08 rad/sec (1500 rpm) | n-m-s<br>(ft-lb-sec) | 11.4<br>(8.4) | 11.52<br>(8.498) | 11.39<br>(8.404) | 11.52<br>(8.498) |
| Insulation Resistance | megohms | | 13,000 | 200,000 | 25,000 |
| Pressure Rise Rate | $n/m^2/sec$<br>(micron/day) | | 0<br>(0) | $7.8x10^{-8}$<br>(2) | $1.95x10^{-8}$<br>(.05) |
| Tach Pulse Height | volts | | 3.4 | 3.4 | 3.7 |
| Direction Signal CW | volts | | 0.078 | 0.097 | 0.099 |
| Direction Signal CCW | volts | | 3.89 | 3.9 | 4.1 |
| Output Torque | n-m<br>(oz-in) | 0.21<br>(30) | Fig. 2 | Fig. 3 | Fig. 4 |
| Constant Speed Power | | | | | |
| 0 RPM 28 v | watts | | 4.5 | 5.13 | 4.48 |
| 1500 RPM 28 v | watts | | 9.5 | 10.03 | 9.8 |

REACTION WHEEL PERFORMANCE CHARACTERISTICS (Continued)

| Parameter | Units | Requirement | S/N 5100001 | S/N 51000002 | S/N 5100003 |
|---|---|---|---|---|---|
| Torque Time Constant | sec | | 0.1 | 0.11 | 0.08 |
| Drag Torque | n-m<br>(oz-in) | | 0.021<br>(3.0) | 0.030<br>(4.25) | 0.028<br>(4.0) |
| Breakout Torque | n-m<br>(oz-in) | | 0.0079<br>(1.12) | 0.0095<br>(1.35) | 0.014<br>(1.99) |

Figure 5

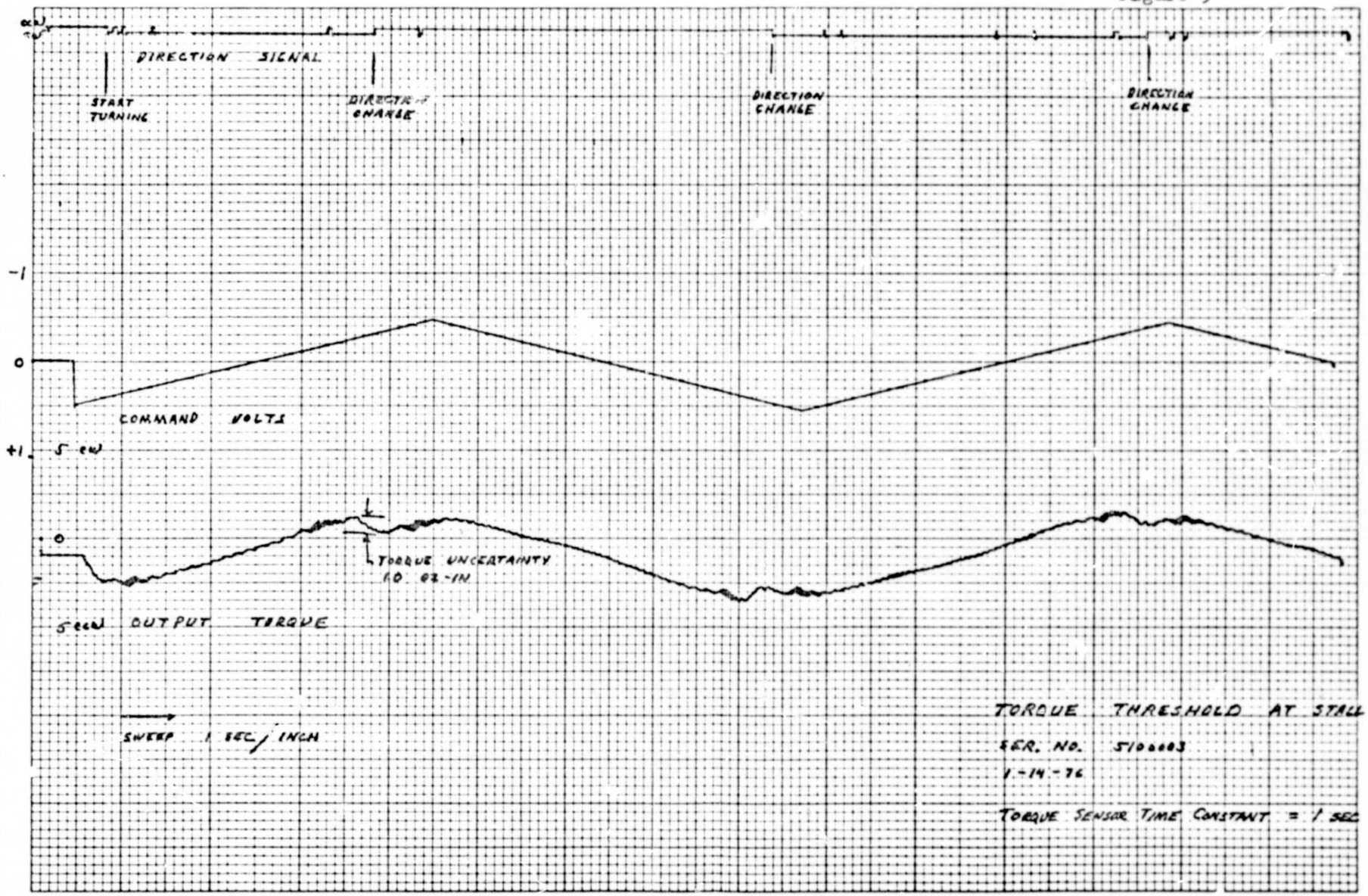
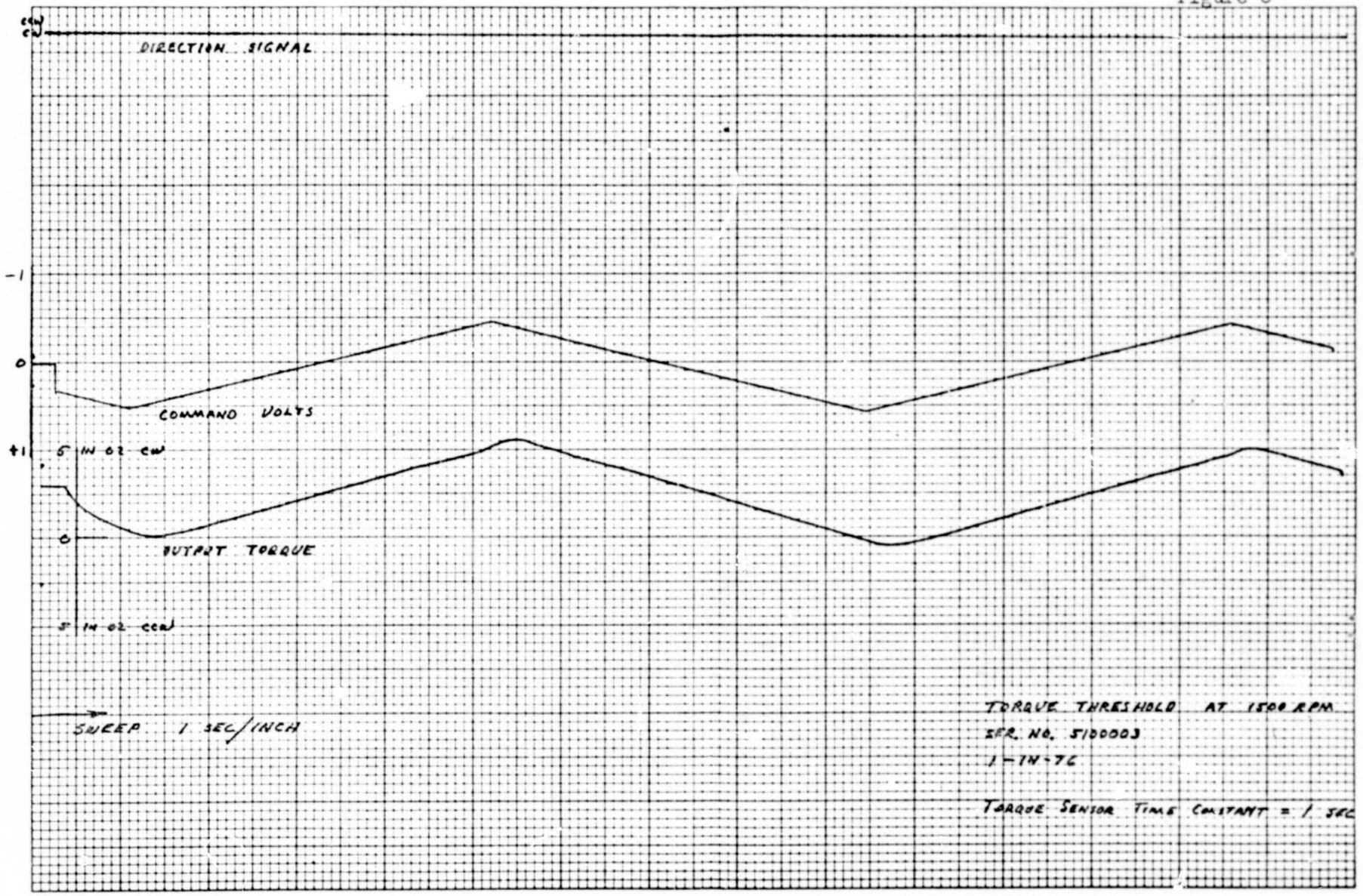

DIRECTION SIGNAL
START TURNING
DIRECTION CHANGE
DIRECTION CHANGE
DIRECTION CHANGE
-1
0
COMMAND VOLTS
+1
5 CW
0
TORQUE UNCERTAINTY
1.0 OZ-IN
5 CCW OUTPUT TORQUE
SWEEP 1 SEC / INCH
TORQUE THRESHOLD AT STALL
SER. NO. 5100603
1-14-76
TORQUE SENSOR TIME CONSTANT = 1 SEC

Figure 6


CCW
CW
DIRECTION SIGNAL
-1
0
COMMAND VOLTS
+1
5 IN OZ CW
0
OUTPUT TORQUE
5 IN OZ CCW
SWEEP 1 SEC/INCH
TORQUE THRESHOLD AT 1500 RPM
SER. NO. 5100003
1-7N-76
TORQUE SENSOR TIME CONSTANT = 1 SEC
EUGENE DIETZGEN CO.
MADE IN U.S.A.
NO. 3400R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

results show somewhat better threshold at stall and there is probably no error at 1500 rpm when the torque fixture lag is taken into account.

## IV. RECOMMENDATIONS AND CONCLUSIONS

The three Reaction Wheels provided met all of the performance requirements of the contract. Minor improvements to the test procedure in the areas of torque threshold and response time could be made if better accuracy is required.

Maintenance should be on an "as required" basis and it is recommended that the units be returned to the factory if any malfunctions occur.