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# CALIBRATION OF LINEAR INDUCTION MOTOR USING GSFC MARK VI TORQUEMETER

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MAY 1970

GSFC
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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CALIBRATION OF LINEAR INDUCTION

MOTOR USING GSFC MARK VI

TORQUEMETER

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# CALIBRATION OF LINEAR INDUCTION MOTOR USING GSFC MARK VI TORQUEMETER

## PROJECT STATUS

The ATS-III antenna drive system has been successfully load tested using the Linear Induction Motor, the calibration of which is described in this report.

## AUTHORIZATION

Test and Evaluation Charge No. 325-630-11-29-02

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## SUMMARY

A linear induction motor was required to apply known torques to a spacecraft antenna drive system. A calibration was made of this induction motor which yielded torque as a function of antenna angular velocity and motor voltage.

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# CALIBRATION OF LINEAR INDUCTION MOTOR USING GSFC MARK VI TORQUEMETER

## INTRODUCTION

The ATS III mechanically despun antenna system has exhibited irregularities in the spin rate in orbit. As a part of an investigation to determine the cause of this behavior it was decided to subject a duplicate antenna system to known torques at a number of rotational rates, including standstill. It was also decided that this braking effort should not involve physical contact such as friction loading.

At the suggestion of Abe Kampinski of GSFC it was decided to explore the possibility of using some sort of eddy current brake. This was found to be feasible and a linear induction motor (LIM) was selected. It was calibrated using the GSFC Mark VI Torquemeter.

## PURPOSE

The objective of the work described herein was first to design an appropriate braking system and then to calibrate it so that known torques could be applied to the antenna system at any desired speed within its range of operation.

## DESIGN OF BRAKE

The specifications for the braking system were as follows:

- Must produce 20 to 30 ounce inches of torque at all speeds from standstill to 150 RPM.
- Must have no physical contact with the antenna system.
- Must add as little as possible to the moment of inertia of the antenna system.
- Must be capable of being readily switched on and off for pulsed operation.

Since it was required that torque be produced at standstill, a linear induction motor was selected to be used in conjunction with a thin disk of aluminum alloy attached to the rotatable portion of the antenna and its drive system. The linear induction motor (LIM) has three separate windings and is energized with three phase 60 hz power so as to produce a resultant moving magnetic field. This permits relative motion between the magnetic field and conducting disk even at standstill, resulting in the required zero speed torque.

The LIM selected has the trade name "Semotor" and was manufactured by the Trombetta Solenoid Corporation of Milwaukee, Wisconsin. The particular model used is part number AX-218. Although designed for 550 volt three phase service, it was found that the motor could produce the desired torque even when down rated to 220 volts three phase.

The LIM was used in conjunction with a 17"O.D. × 0.04" thick disk made of AISI - 1100 aluminum alloy. The 0.04" thickness was considered the minimum that was practical consistent with the rigidity necessary for use with the LIM.

CALIBRATING OF BRAKE

Calibrating was accomplished using the apparatus shown in Figure 1. In this arrangement, the disk and driving motor are mounted on the Mark VI torquemeter. The LIM is separately supported and positioned so that the disk may

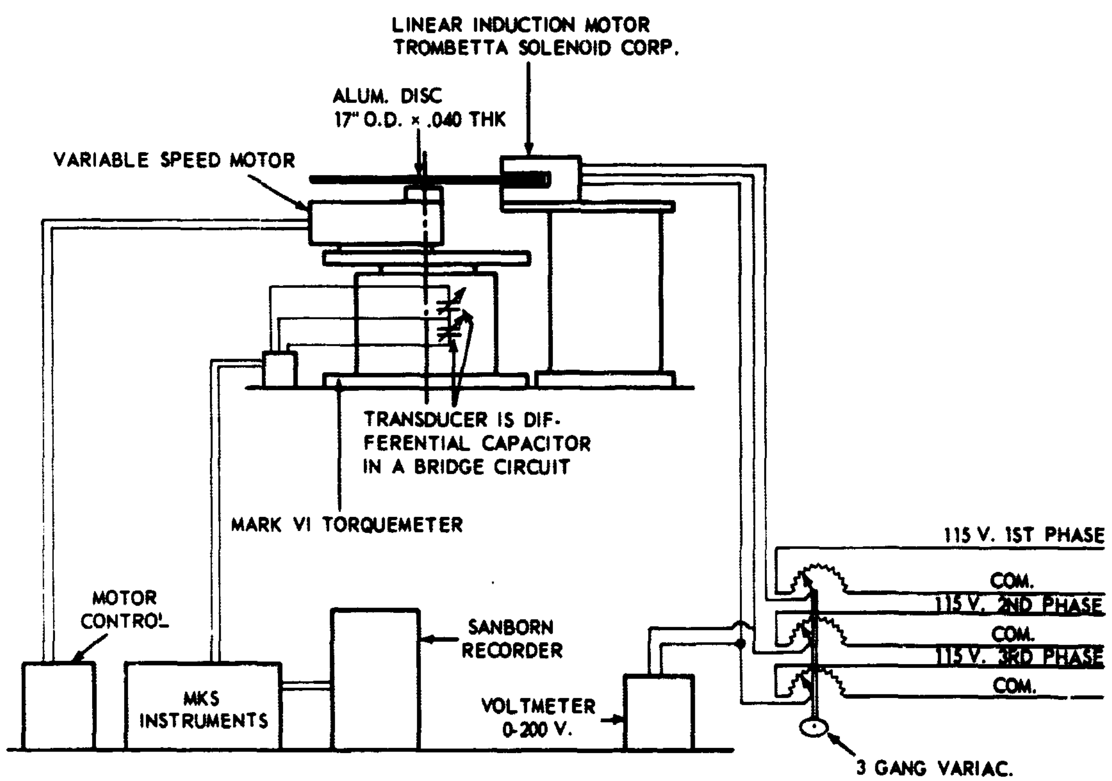


Figure 1. LIM Calibration

rotate within the "C" slot without rubbing. Three phase 60 cycle power is supplied to the LIM using the triply ganged variac. The actual voltage to the LIM is measured by the Simpson meter. The disk drive motor is powered through a controller so as to provide a variable speed up to 170 RPM in either direction of rotation. As voltage is applied to the LIM, an eddy current torque is generated. The polarity of voltage to the LIM is selected so that this torque opposes the motion of the disk. The torque is transmitted from disk to drive motor and ultimately to the torquemeter itself. The torquemeter contains a differential capacitor transducer which forms part of an ac bridge circuit. The application of a torque alters the balance of this circuit and the resulting amplified and conditioned signal is fed to a 2 channel Sanborn for recording. The electrical circuitry involved in the calibration is shown in the schematic, Figure 1.

Calibration of the torquemeter itself was accomplished by applying a known weight to one arm of a bellcrank. The geometry is such that a torque of 17.86 ounce inches was thus applied to the rotatable element of the torquemeter. The remarkable versatility of the Mark VI Torquemeter is evident when one considers that it is normally used to measure torques in the neighborhood of 100 dyne centimeters or roughly one ten thousandth of the requirement of the present application.

## CALIBRATION RESULTS

A typical torque trace taken during the LIM calibration is shown in Figure 2. The data extracted from these traces are shown in Table 1.

Examination of the data shows the torque to be proportional to the square of the LIM voltage at any given speed so that

$$L = KV^2 \times 10^{-4} \qquad (1)$$

where

L = Torque in ounce inches

V = LIM Voltage

K = Calibration Constant

It is also evident that K is a linear function of disk speed; this relationship has been expressed graphically in Figure 3. Thus, if it is desired to apply a given

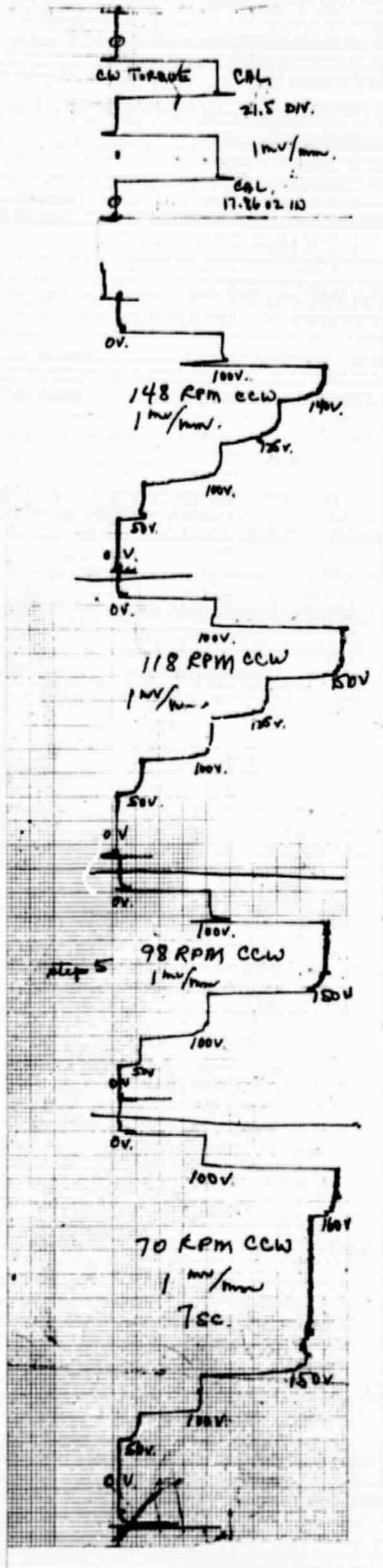


Figure 2. LIM Calibration Typical Torque Record

## Semotor Calibration

### 17" O.A × .04" Aluminum Alloy Recor

| CCW Rotation, Calibration = 0.83 oz.in./Div | | | | | | CW Rotation, Calibration = $\frac{17.86}{16.3}$ = 1.1 oz.in./Div | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Voltage | RPM | Defl. | Oz-In | K × $10^4$ | K Average | Voltage | RPM | Defl. | Oz-In | K × $10^4$ | K Average |
| 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | | |
| 50 | 0 | 3 | 2.5 | | | 50 | 0 | 3 | 3.3 | | |
| 100 | 0 | 13.5 | 11.2 | 11.2 | | 100 | 0 | 11 | 12.1 | 12.1 | |
| 150 | 0 | 31 | 25.8 | 11.5 | 11.5 | 150 | 0 | 23.5 | 25.8 | 11.5 | 11.9 |
| 180 | 0 | 46.5 | 38.6 | 11.9 | | 200 | 0 | 44.5 | 49 | 12.2 | |
| 50 | 46 | 4.5 | 3.7 | | | 50 | 46 | 3.5 | 3.8 | | |
| 100 | 46 | 16.5 | 13.7 | 13.7 | | 100 | 46 | 13 | 14.3 | 14.3 | |
| 150 | 46 | 36 | 29.9 | 13.3 | 13.7 | 150 | 46 | 27.5 | [illegible] | 13.4 | 14.1 |
| 170 | 46 | 49 | 40.7 | 14.1 | | 190 | 46 | 48 | [illegible] | 14.6 | |
| 50 | 70 | 4.5 | 3.7 | | | 50 | 70 | 3.5 | 3.8 | | |
| 100 | 70 | 17 | 14.1 | 14.1 | | 100 | 70 | 13.5 | 14.9 | 14.9 | |
| 150 | 70 | 40.5 | 33.7 | 15.0 | 14.7 | 150 | 70 | 29.5 | 32.5 | 14.4 | 14.8 |
| 160 | 70 | 46 | 38.2 | 14.9 | | 180 | 70 | 44.5 | 49 | 15.1 | |
| 50 | 98 | 4.5 | 3.7 | | | 50 | 92 | 3.5 | 3.8 | | |
| 100 | 98 | 19.5 | 16.2 | 16.2 | 16.3 | 100 | 92 | 14.5 | 16 | 16 | |
| 150 | 98 | 44.5 | 37 | 16.5 | | 150 | 92 | 31.5 | 34.6 | 15.4 | 16.8 |
| | | | | | | 170 | 92 | 42 | 46.2 | 16 | |
| 50 | 118 | 5 | 4.2 | | | 50 | 120 | 4 | 4.4 | | |
| 100 | 118 | 20.5 | 17 | 17 | | 100 | 120 | 15 | 16.5 | 16.5 | |
| 125 | 118 | 31.5 | 26.2 | 16.8 | 17.2 | 150 | 120 | 34.5 | 37.9 | 16.8 | 16.8 |
| 150 | 118 | 48 | 39.9 | 17.7 | | 160 | 120 | 40 | 44 | 17.2 | |
| 50 | 148 | 5.5 | 4.6 | | | 50 | 144 | 4 | 4.4 | | |
| 100 | 148 | 22 | 18.3 | 18.3 | | 100 | 144 | 16 | 17.6 | 17.6 | |
| 125 | 148 | 34.5 | 28.7 | 18.3 | 18.4 | 150 | 144 | 37 | 40.7 | 17.3 | 17.9 |
| 140 | 148 | 44 | 36.6 | 18.7 | | 160 | 144 | 44 | 48.4 | 18.9 | |

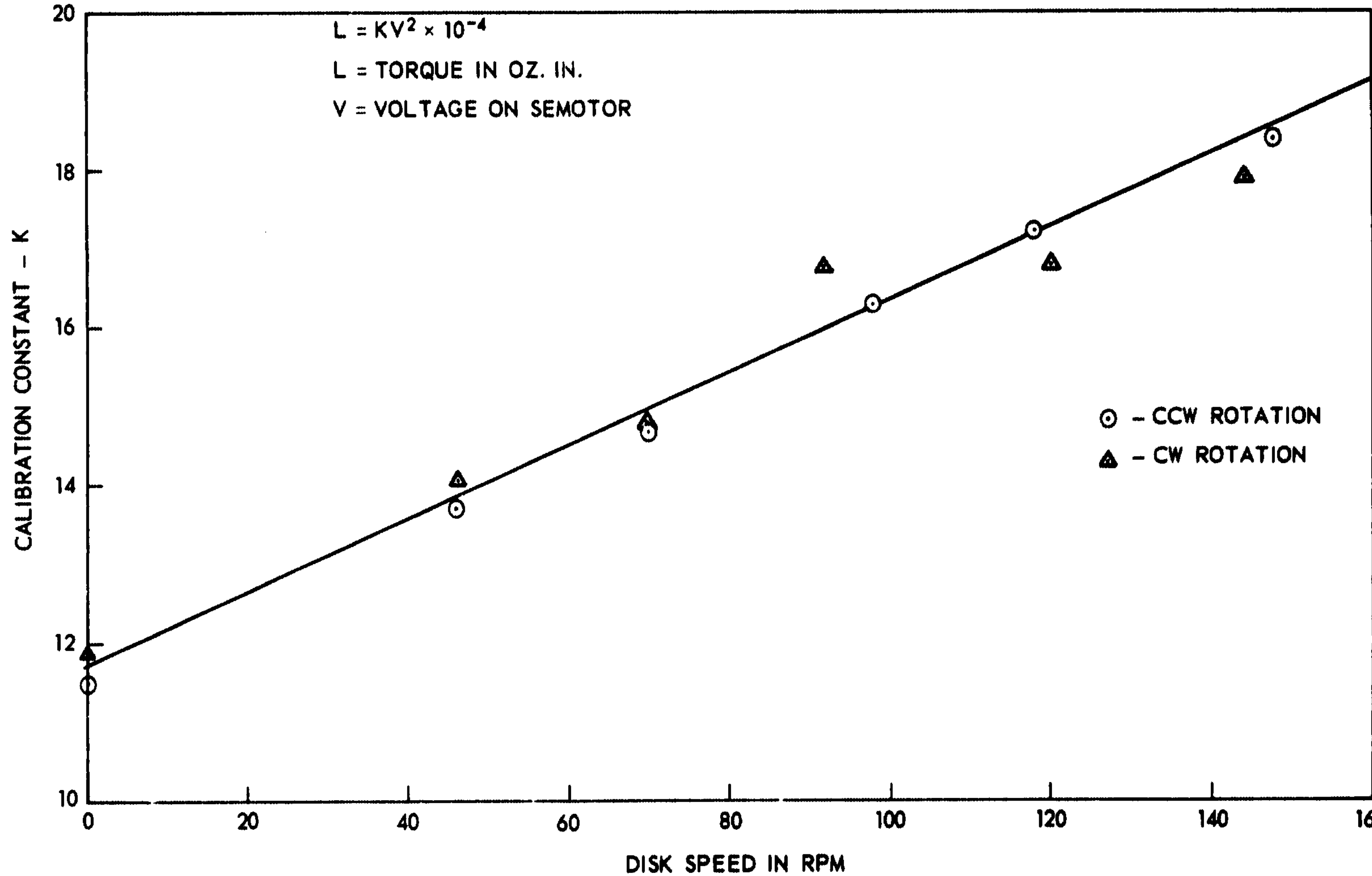


Figure 3. SEMOTOR Calibration 17" O.D. × 0.04" RECOR

torque at some specific RPM, one may enter Figure 3 and obtain the value for K, then solve for the required voltage from Equation (1).

## CONCLUSION

A successful calibration of the LIM eddy current braking device was obtained using the Mark VI Torquemeter. The calibration shows that the LIM selected is more than adequate to apply the specified torque level at all the operational speeds with the voltage available from a 3 phase 110 volt source. The LIM has been successfully used to load test the ATS III antenna drive system. A photograph of this test arrangement is shown in Figure 4.

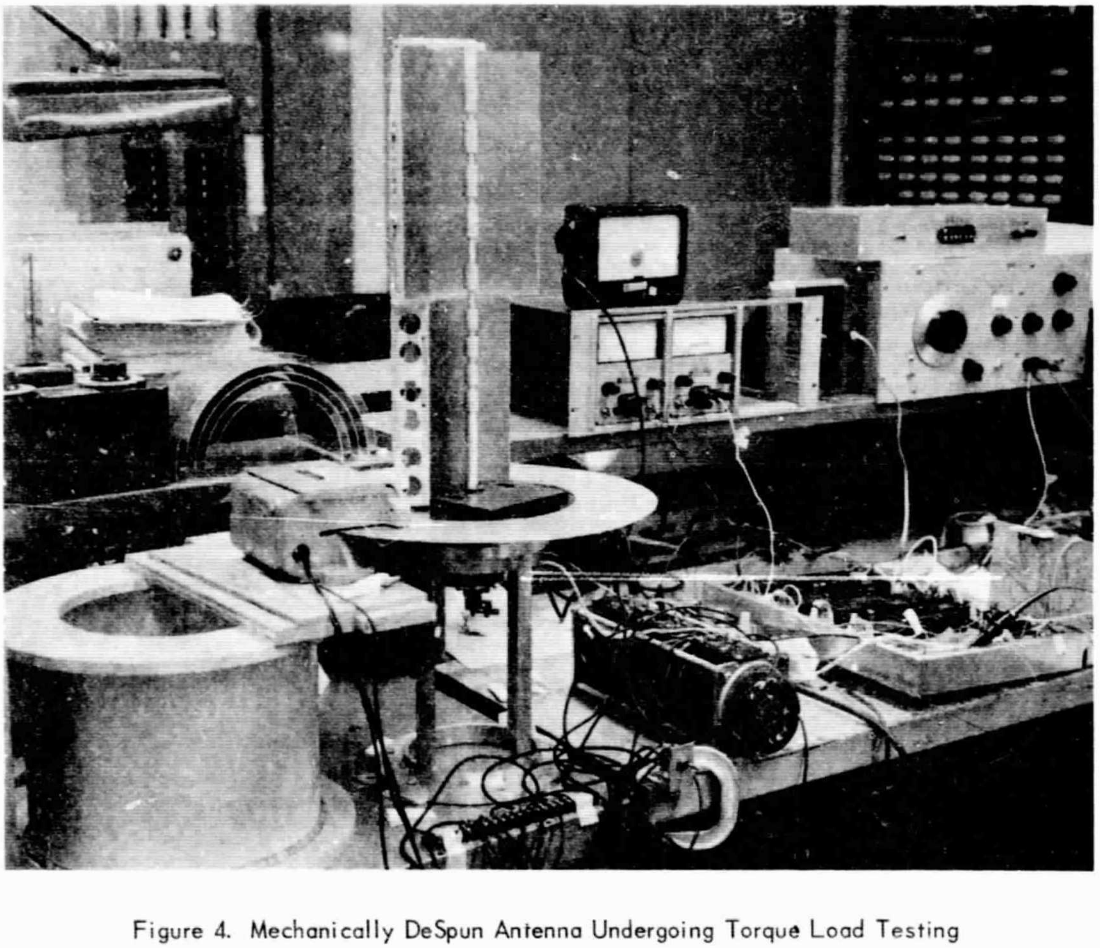

Figure 4. Mechanically DeSpun Antenna Undergoing Torque Load Testing