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Lockheed Electronics Company

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

INDUSTRIAL TECHNOLOGY DIVISION

EDISON, NEW JERSEY

QUARTERLY REPORT

for

SPACECRAFT ENDLESS LOOP RECORDER

for the period

1 January, 1965 - 1 April, 1965

CONTRACT NAS5-3914

Prepared by

LOCKHEED ELECTRONICS COMPANY

Industrial Technology Division

Edison, New Jersey

for

GODDARD SPACE FLIGHT CENTER

Greenbelt, Maryland

24893

SUMMARY

This report has been prepared and is submitted in fulfillment of Section II (Deliverable Items), Item 5 of Contract NAS5-3914. Included herein is a detailed discussion of the program activity for the period 1 January, 1965 to 1 April, 1965.

During this period, program effort has been concentrated in the following areas:

1. Completed the design of the speed servo with substitute motor.
2. Received and tested brushless dc motor.
3. Fabricated all mechanical parts, applied non-corrosive finish, and assembled prototype transport.

Author

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INTRODUCTION

This report has been prepared and is submitted in fulfillment of Section II, Item 5 of Contract NAS5-3914. Included herein is the project activity for the period 1 January, 1965 to 1 April, 1965.

It is the objective of this program to design, develop, fabricate, test, and deliver a 1000' compact endless loop magnetic recorder which utilizes 1/2" wide tape. The tape shall contain 5 tracks which will enable recording and reproducing a signal in the frequency range of 20 KC to 130 KC at a tape speed of 33 ips.

The recorder system is divided into the following major areas:

- Phase Lock Servo
- Transport
- Brushless DC Motor
- Magnetic Heads

An analysis of the activity in each of these areas is included in separate sections of this report.

Significant achievements during this period include:

a. Received and tested the brushless dc motor.

b. Completed the design of the reel holding device.

c. Completed the design of the speed servo with the substitute motor.

d. Initiated preliminary tests of the speed servo and the brushless dc motor.

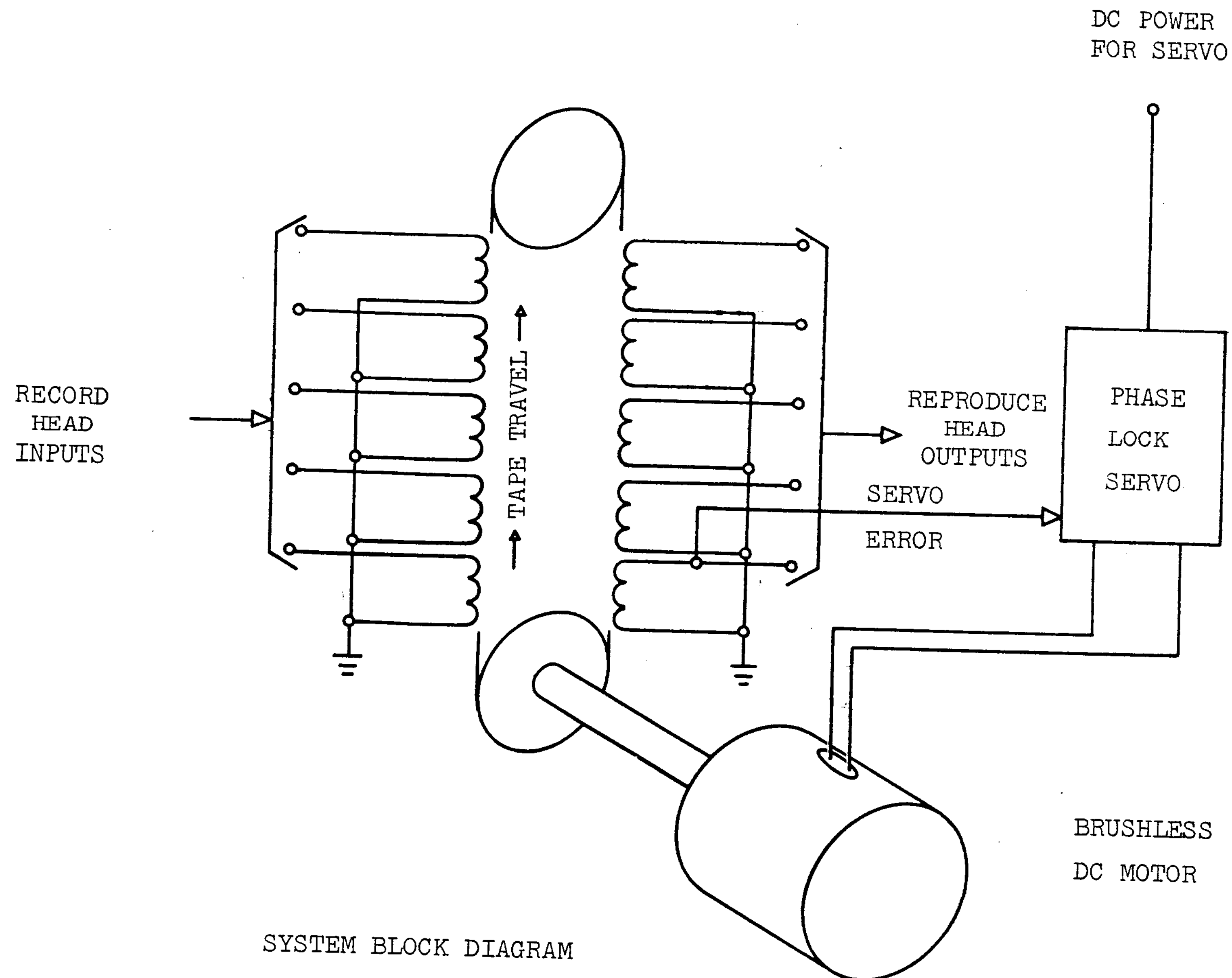
e. Prepared and submitted final test plan for NASA approval.

SYSTEM

The System Block Diagram, Figure 1, represents the current system design.

Tests of a breadboard system, consisting of a breadboard servo, substitute motor, and experimental transport were made. Satisfactory flutter levels were obtained while servoing from the pickup and the tape; however, because of the breadboard configuration of the unit, no absolute values of flutter were measured. These measurements will be deferred until the prototype unit is integrated with the final servo and the brushless dc motor.

A double-acting reel holding device driven by pulse actuation, has been incorporated in the design. This device will be used to hold the reel and tape stable during vibration and will improve the start-stop characteristics of the recorder. In conjunction with the reel holding device, refinements have been made to the cone rollers, which make it possible to accelerate and decelerate even more effectively.



SYSTEM BLOCK DIAGRAM

FIGURE 1

PHASE LOCK SERVO

As the design of the motor drive portion of the speed servo progressed, it became apparent that the power saved by chopping the current to the drive motor would be more than offset by the circuit complexities introduced. Seventeen volts dc is needed to operate the brushless dc motor at the drive speed required.

Assuming a power supply of 24 vdc, a voltage drop of 7 volts, under quiescent conditions, would result across the control transistor. This voltage is less than 1/2 of that required by the drive motor. Since the same current flows through the drive motor and the control transistor, the power dissipation ratio will be the same as the voltage ratio (2:1). If chopped 24 volts is used to control the speed of the drive motor, the power loss in the control transistor would be reduced to the amount encountered in a saturated transistor, which is approximately 1/10th of the voltage consumed by the motor. The power savings in the control transistor is offset by a rise in power necessary to satisfy the impedance requirements for reliable gate control switch operation.

The deciding factor, then, must be in the area of reliability. It is felt that the combined complexity of the blocking oscillator, the level detector amplifier, the gate controlled rectifier and associated commutation circuitry, and the motor drive filter exceed that of the conventional dc amplifier of the type commonly used in speed control servos. Since the failure history of the dc amplifier is known, having been employed in LEC recorders for years, it has been decided to use the dc amplifier in place of the chopper drive for the motor. A schematic diagram and functional block diagram for the revised speed servo appear as figures 2 and 3, respectively.

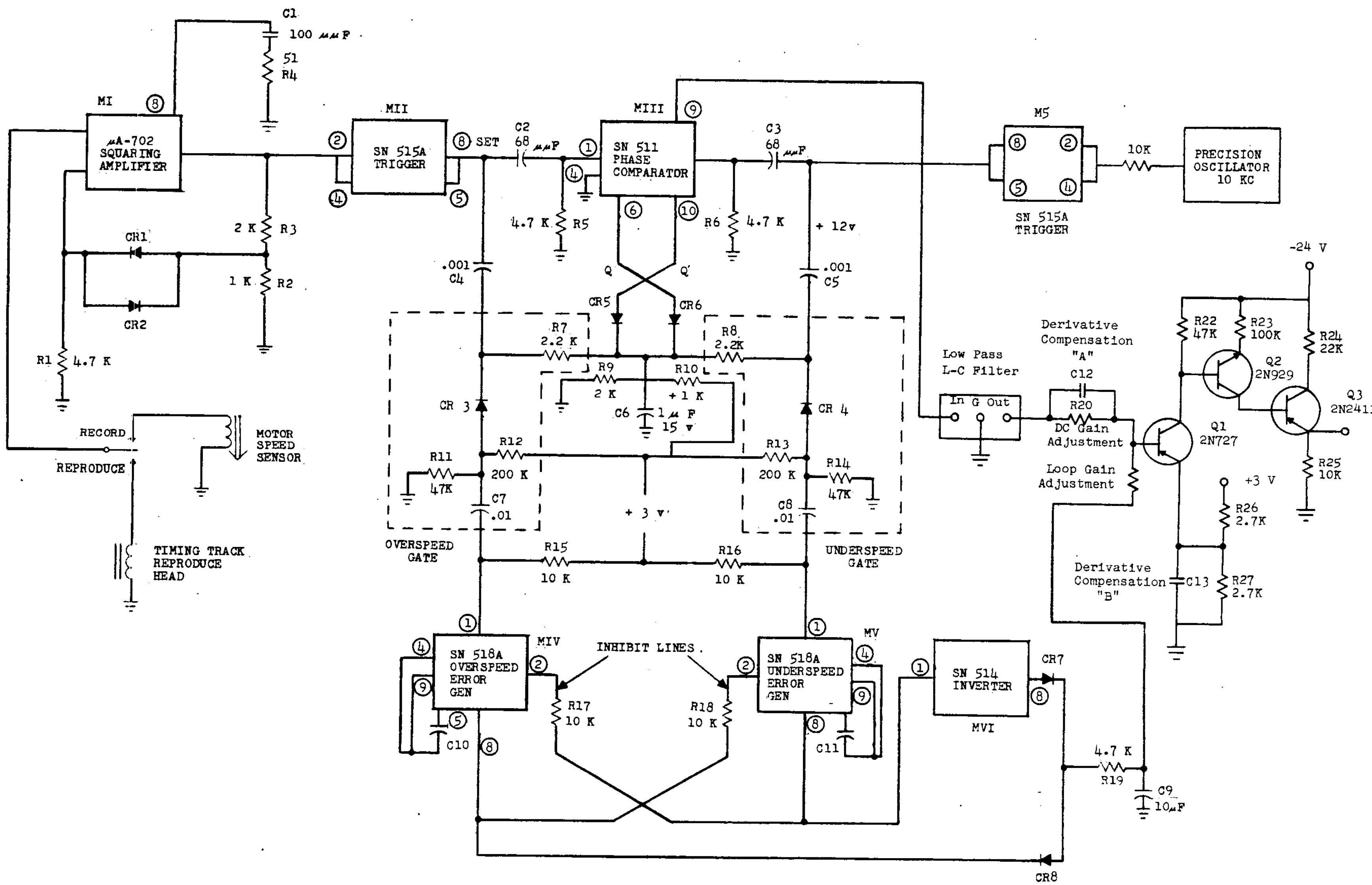


FIGURE 2

SCHEMATIC DIAGRAM, DC AMPLIFIER

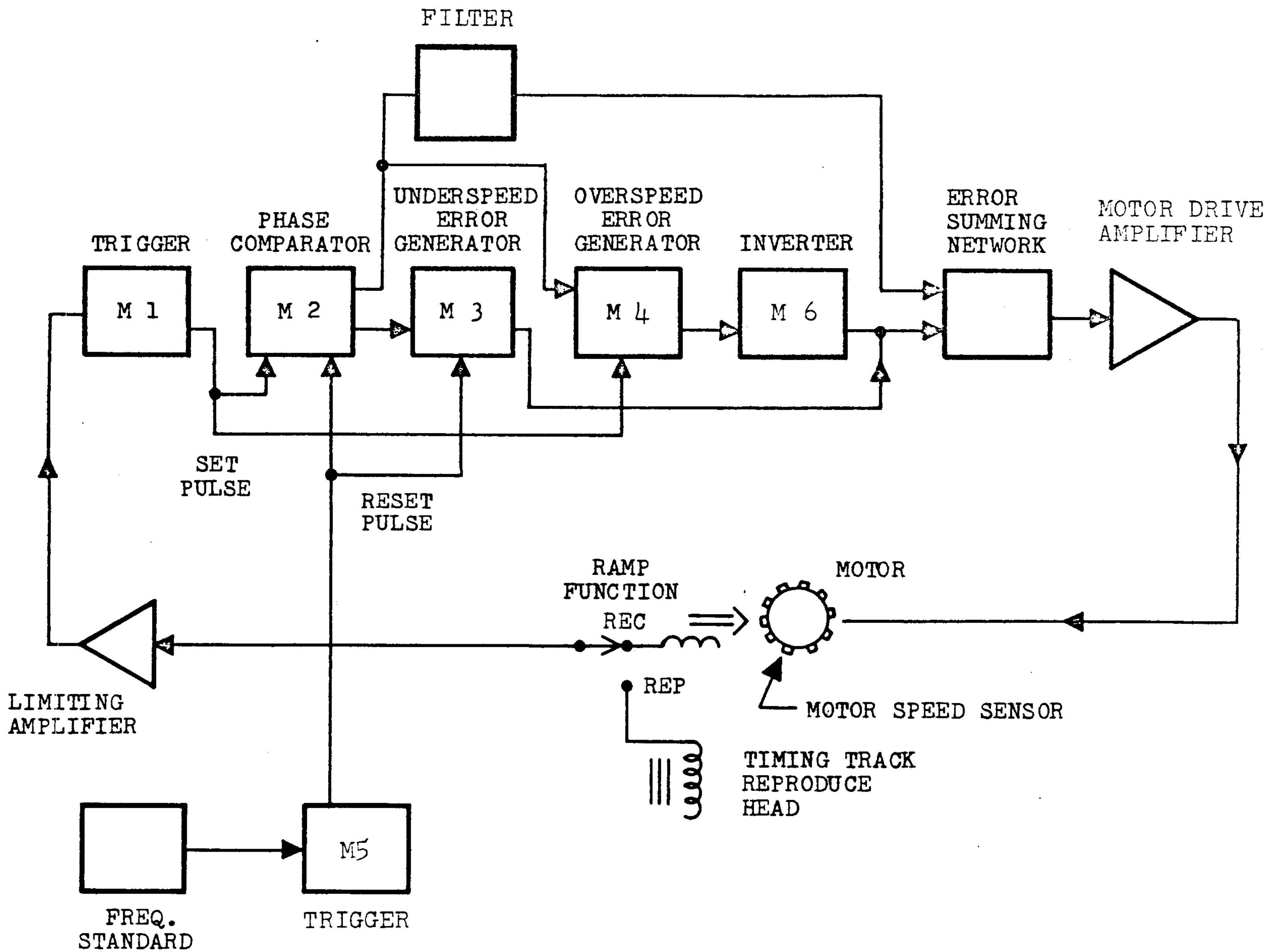


FIGURE 3

FUNCTIONAL BLOCK DIAGRAM

TRANSPORT

After initial testing of three reels having cone angles of 11°, 17°, and 25°, and using cylindrical and/or cone shaped guides to negotiate tape exit, the most successful operation occurred while using the 11° reel and an 11° coned roller. After satisfactory guidance from the reel to the cone, it became apparent that additional guiding from the cone roller to the entrance guide would be necessary due to the angular approach of tape to the last guide. Several methods were attempted until satisfactory results were obtained by the use of a cylindrical roller mounted on a universal joint. The roller, thusly mounted, made it possible to easily change the angle of approach during testing.

Further refinements included the use of flanged rotary guides situated near the side plates to ensure tape captivity during all operating modes. Once the cartridge and drive system were operating satisfactorily, the next step was to select the proper roller for tape insertion into the tape pack. After extensive testing with cylindrical rollers on simple and complex angles, one large cylindrical roller on a simple angle was selected as an optimum design.

Preliminary methods for providing fast start-stop capabilities were studied and a design that utilizes two linear stroke solenoids and a toggle mechanism was selected for optimum performance. The design criteria included tape holding and reel stoppage during vibration plus fast stop-time to eliminate reel coasting after shut-off command. A prototype model has been fabricated and the solenoids have been ordered. Environmental testing awaits the receipt of these parts.

BRUSHLESS DC MOTOR

The brushless dc motor was received and its characteristics are displayed in figures 4 through 6; some of which are summarized as follows:

Motor Speed - 2100 rpm (nominal)

Torque - At an operating voltage of -17 volts dc and a speed of 2100 rpm the available torque is 0.4 in-oz. Comparable measurements made on the 1200' 1/4" unit indicated a need of 0.23 in-oz. This provides a safety factor of better than 1.7.

Number of Commutating points - Five commutating points were finally decided upon with excellent results being obtained. This decision was based on: a. The minimum number of commutating points of three, would increase cogging and overall coefficient of fluctuation. b. Excessive points would decrease reliability and increase complexity because of the additional switching transistors and circuitry.

Efficiency - Originally, it had been specified that a minimum of 55% @ 2 watts input would be required. Actual measurements show the efficiency to be 65% which exceeds the design goal by 5%.

Mechanical Construction - The case outline of the motor is shown in figure 7. Construction is similar to the LEC 113 modular hysteresis synchronous motor which is used in many spacecraft recorder programs.

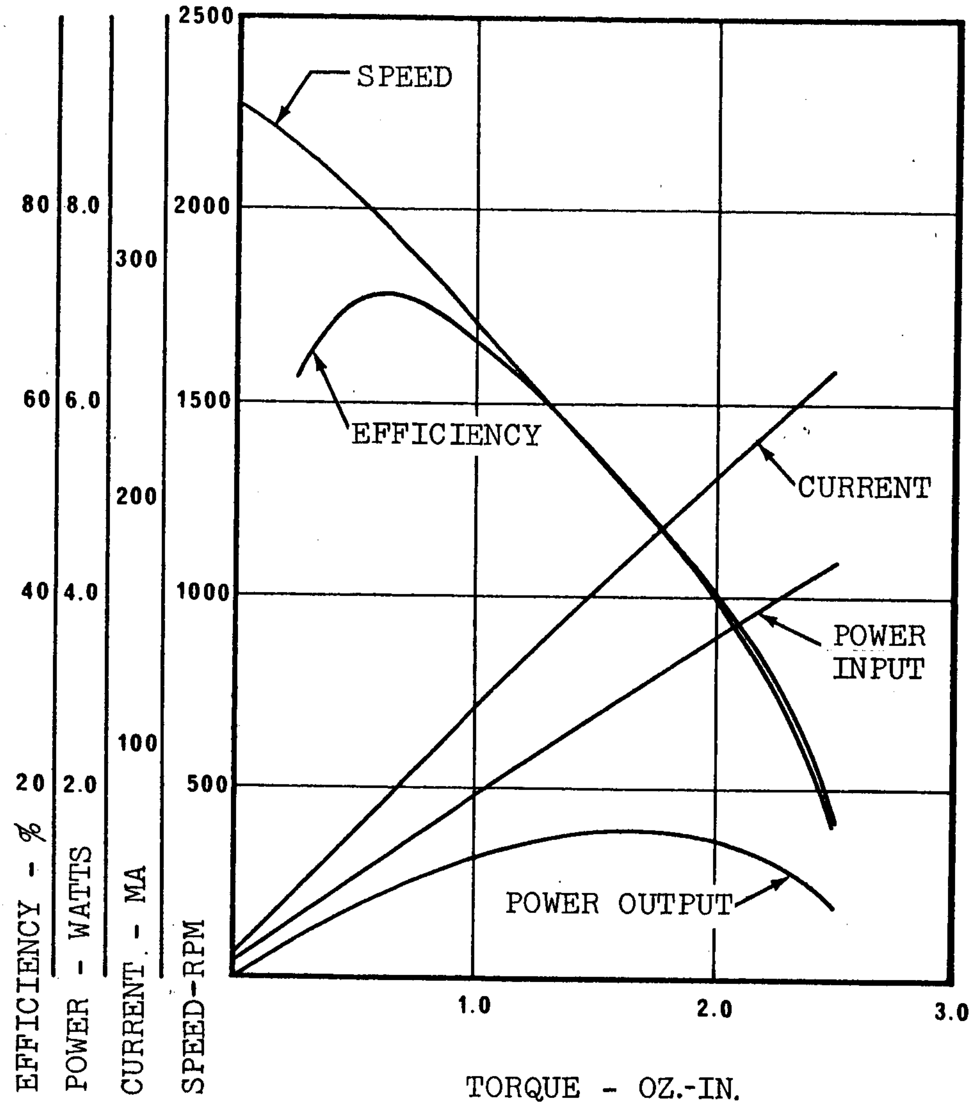


FIGURE 4

BRUSHLESS DC MOTOR CHARACTERISTICS AT 17 VOLTS DC INPUT

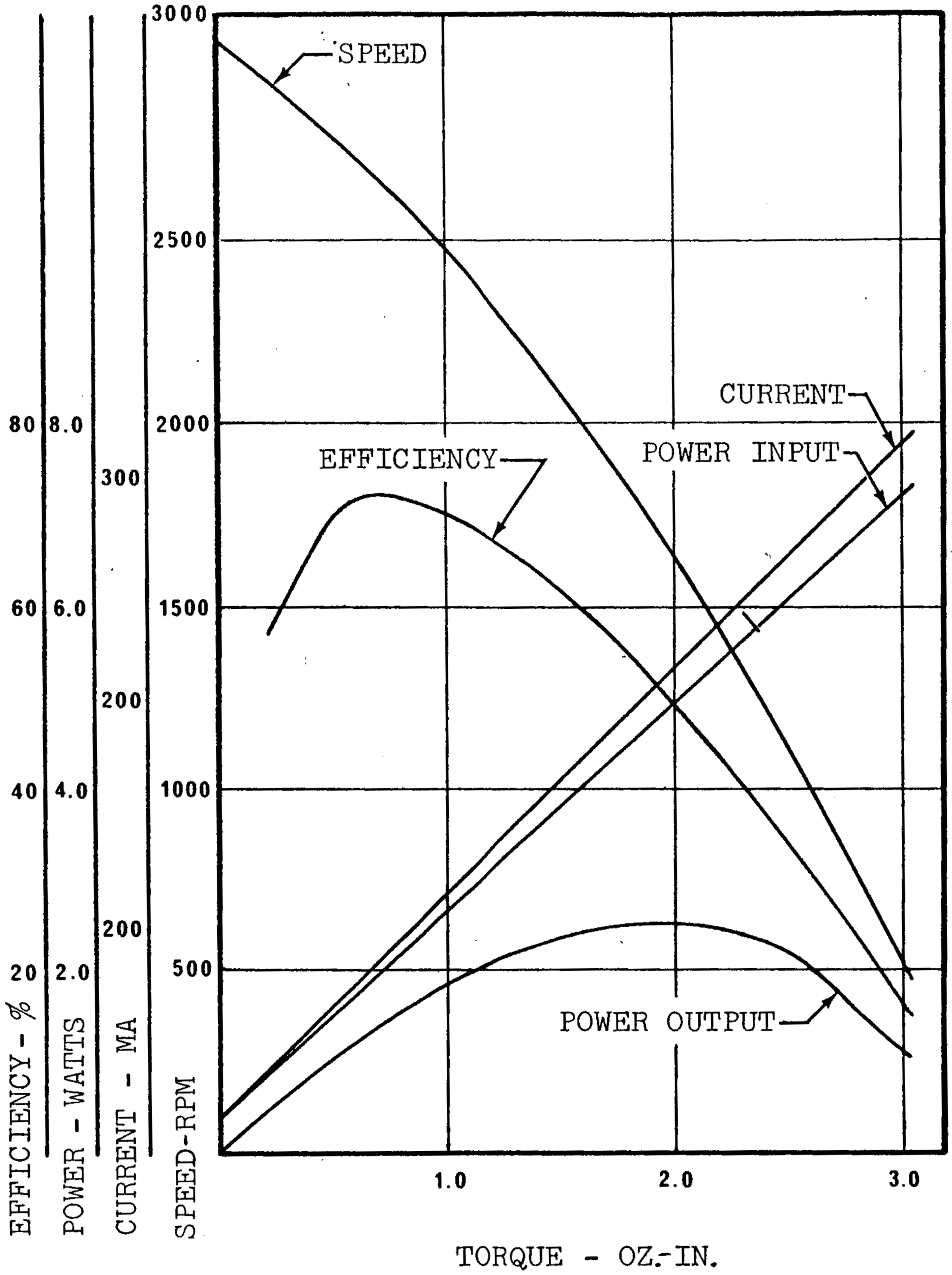


FIGURE 5

BRUSHLESS DC MOTOR CHARACTERISTICS AT 23 VOLTS DC INPUT

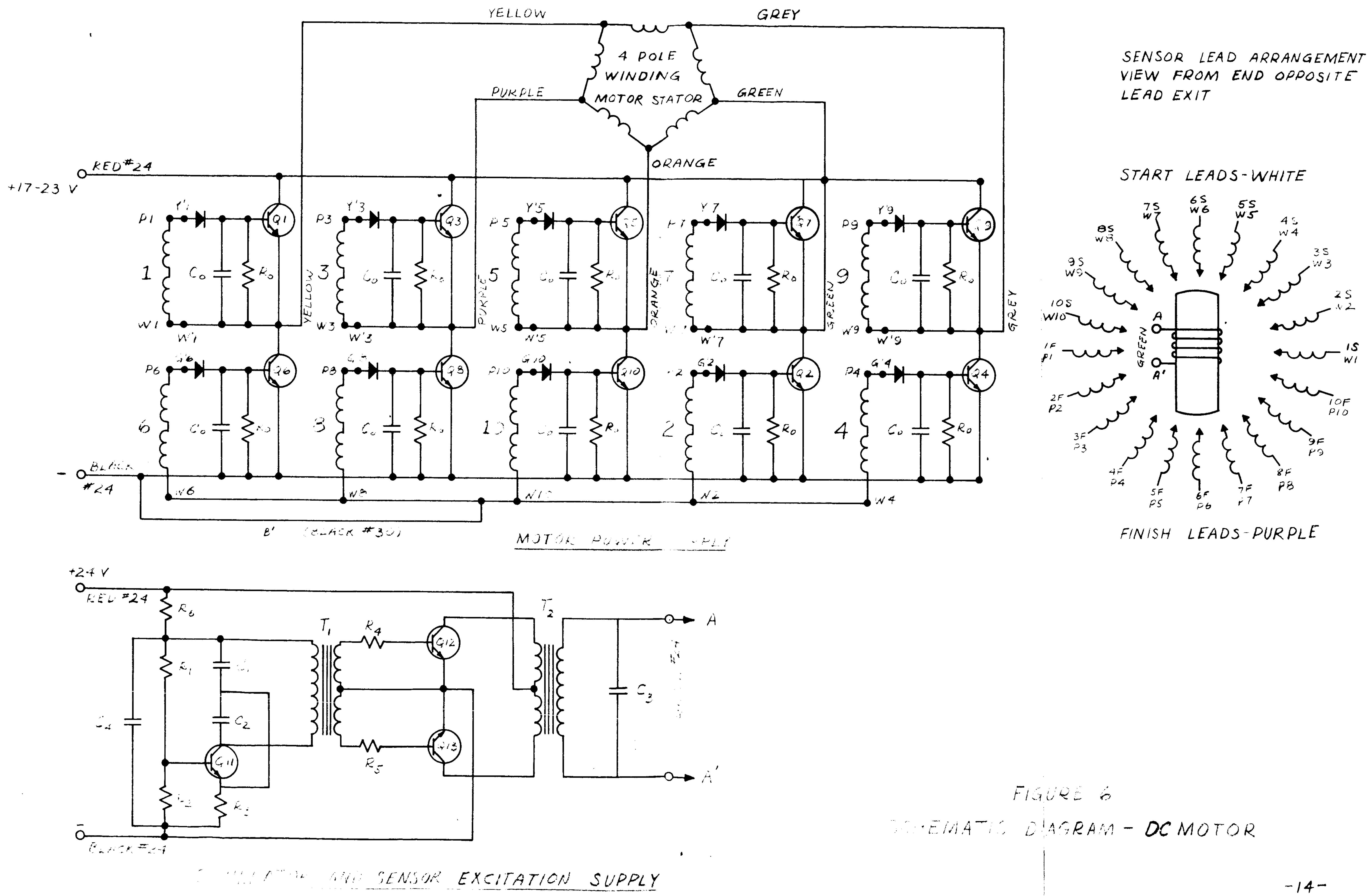
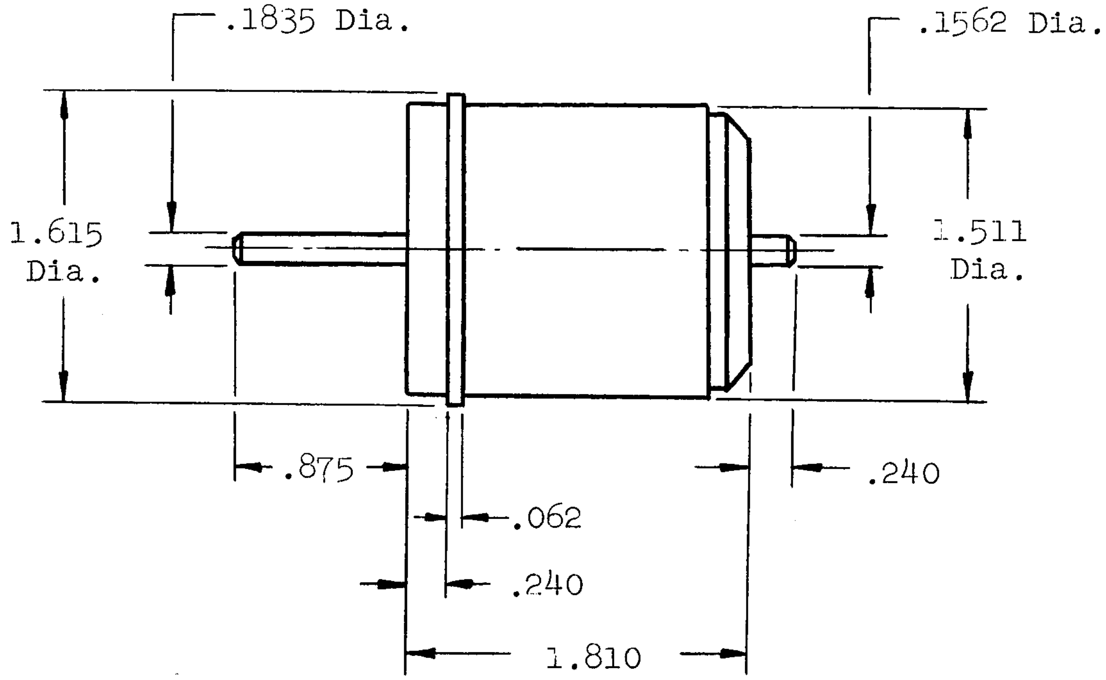


FIGURE 6

SCHEMATIC DIAGRAM - DC MOTOR



OUTLINE -

BRUSHLESS DC MOTOR

FIGURE 7

MAGNETIC HEADS

Listed below are the magnetic head parameters as received from the vendor:

Record Head - providing 5 in-line tracks on 1/2" tape:

Track Width	.050"
Track Spacing	.110" Center to Center
Gap length	.0003"
Average Inductance @ 1 KC	6.36 MH
Average Resistance	12.2 ohms

Playback Head - providing 5 in-line tracks on 1/2" tape:

Track Width	.040"
Track Spacing	.110" Center to Center
Gap length	80 μ inches
Average Inductance @ 1 KC	40 MH
Average Resistance	57 ohms

ANTICIPATED PROGRAM

The program schedule has been updated as shown in figure 8. The remaining major milestones, which are yet to be completed, have been carefully evaluated and represent the present schedule.

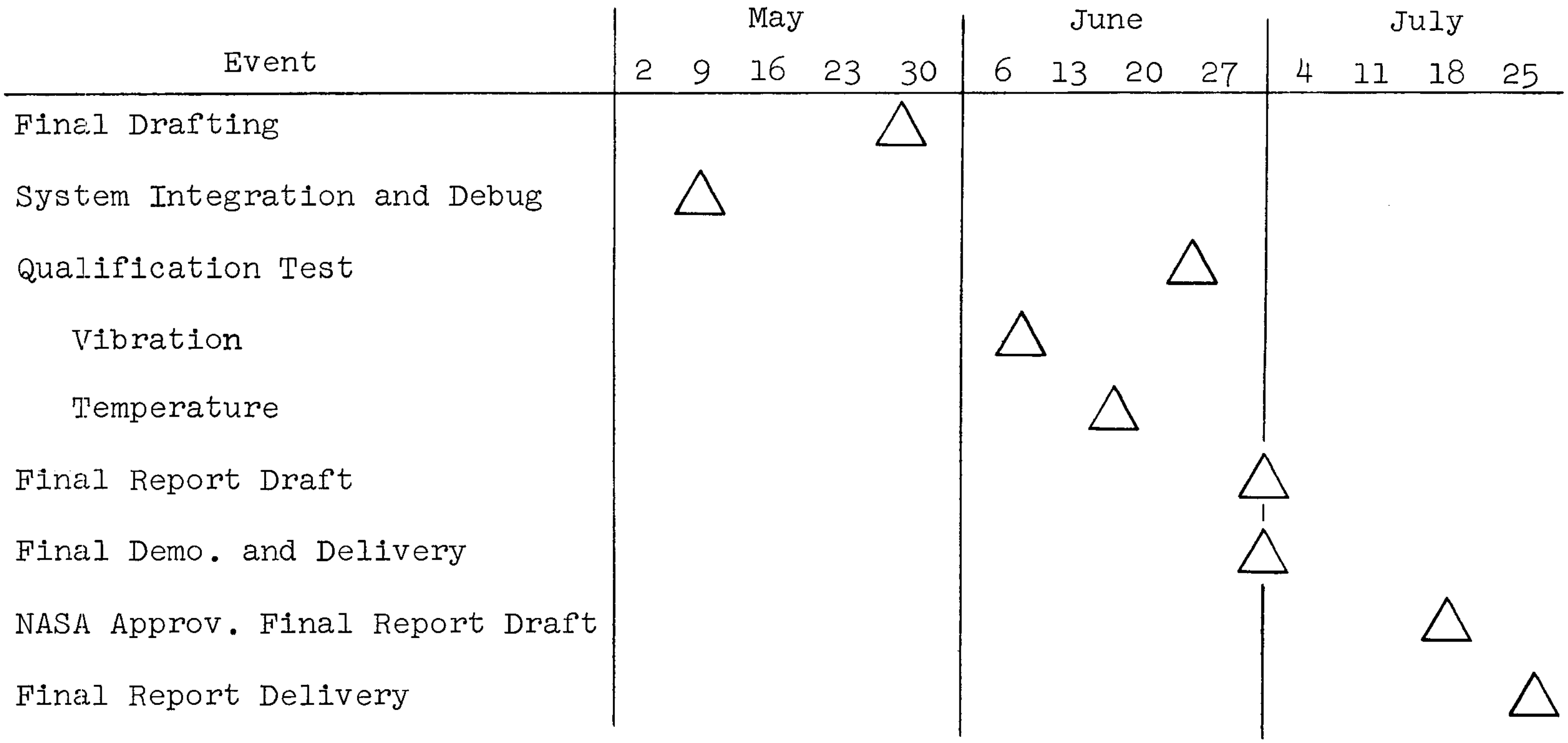
A summary of the anticipated program is as follows:

1. Complete assembly, debug, and prepare unit for testing.
2. Design and conduct tests on the momentum compensation system.
3. Complete drawings.
4. Conduct vibration tests.
5. Conduct thermal tests.
6. Final demonstration and delivery.
7. Prepare final report.

FIGURE 8

PRODUCTION SCHEDULE - NIMBUS 1000', 1/2" COMPACT

CONTRACT NAS5-3914



Dates indicate completion of event.