MAGTROL
DYNAMOMETER/X-Y CONTROLLER

MODEL 4619

INSTRUCTION AND REFERENCE MANUAL

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1.0 INTRODUCTION

1.1 UNPACKING All shipments leaving our plant are adequately packed and packaged. If there are signs of damage to this carton or its contents, please notify the shipper within 24 hours and retain carton and packing material for his examination.

1.2 FEATURES OF THIS MANUAL The foldout flap on the front cover contains annotated photos (Figure 1) of this Model 4619 dynamometer/XY controller and Model 4605 torque/speed readout showing connections and functions for both, also the connections on a typical Magtrol dynamometer. For convenient instant reference keep the flap opened out as you go through the connecting instructions (Section 2) and operational checkout (Section 3).

A simplified schematic for the controller (Figure 2) appears on a similar foldout flap on the back cover. This one, when opened out, is for your convenience as you go through the technical data given in Sections 12 and 13. The complete schematic is shown next to it.

For additional convenience and faster identification, functions appearing on the panels of both controller and readout are shown throughout this manual in small capital letters.

2.0 CONNECTING INSTRUCTIONS

Three pieces of equipment must be interconnected for operation of this Model 4619 controller: a Magtrol digital dynamometer, a Model 4605 readout, and the controller.

The Model 4619 controller will additionally provide torque and speed readouts to an X-Y recorder or other analog recording instruments. Information and instructions on this application are given in Sections 4 and 5.

To interconnect the three basic units proceed as follows:

2.1 Plug the dynamometer (cooling fan) line cord into the outlet provided on the rear panel of the readout.

2.2 Connect the 2-pin dynamometer brake cable (part number 88CS2) between the dynamometer and the controller.

2.3 Connect and lock the 14-pin cable (part number 88CS1) between the readout and the dynamometer.

2.4 Connect the BNC to the miniature plug (part number 88CS4) between the readout SPEED OUTPUT and the controller SPEED INPUT.

2.5 Connect the 4-pin miniature cable (part number 88CS3) between the readout TORQUE OUTPUT and the controller TORQUE INPUT.

You are now ready to proceed with equipment checkout and manual operation of the interconnected units.

3.0 OPERATIONAL CHECKOUT

Complete the motor fixturing so that motor and dynamometer shafts are aligned. The means of coupling the shafts should be angularly flexible and must be torsionally rigid. (Note: Torsionally flexible couplings (molded rubber, e.g.) should not be used; because of the high response of the Model 4619 controller they can induce system instability resulting in high-frequency shaft oscillation.)

3.1 Set the front-panel controls on the controller as follows:

3.1. 1 DYNAMOMETER ON/OFF switch to OFF

3.1. 2 SPEED RANGE to the first value above the maximum anticipated free-run speed of the motor.

3.1. 3 SPEED RANGE VERNIER to full clockwise.

3.1. 4 SPEED (CONTROL MODE) to full counterclockwise.
TORQUE (CONTROL MODE) to full counterclockwise.

3.1. 5 STABILIZED/OPEN LOOP switch to OPEN LOOP.

3.1. 6 AUTOMATIC SPEED CONTROL to off (illuminating pushbutton unlit).

3.1. 7 TEST TIME to any desired setting.

3.1. 8 RPM INCREASING/DECREASING to its center neutral position opposite RPM.

3.1. 9 INERTIAL ERROR COMPENSATION to full counterclockwise (zero on both rotating scales).

3.1.10 LINE ON/OFF to ON.

3.2 Start the motor and check to be sure the free-run speed indicated by the tachometer is lower than the SPEED RANGE switch setting.

3.3 Switch the DYNAMOMETER ON/OFF toggle to ON.

3.4 Slowly rotate the SPEED RANGE VERNIER counterclockwise until the BRAKE ENERGIZED light goes on. Then rotate it clockwise very slightly until the light just goes out, and leave it at this setting.

3.5 Slowly rotate the SPEED control clockwise. This causes the dynamometer to load the test motor and the BRAKE ENERGIZED light will go on; continuing clockwise rotation of the SPEED control will load the motor down to locked rotor. (Note: In selecting a specific test point for a torque/speed reading it is usually best to set the SPEED control at a point exceeding the test point, then rotate it counterclockwise back to the test point. This helps settle the system and stabilize the test-point value more quickly. Response sluggishness to these adjustments is normal; it is caused by mechanical inertia and electrical delays.)

4.0 X-Y RECORDING: GENERAL INFORMATION

Two outputs appear on the rear panel of the Model 4619 controller, OUTPUT SPEED and OUTPUT TORQUE. The red jack on each is positive(+), the black is negative(-) and ground. When connecting an X-Y recorder to the controller, use either a jumper or shorting bar to connect the recorder ground to either of the controller's black terminals.

Either axis of an X-Y recorder can be assigned to torque and either to speed, depending on scaling and data presentation; X-Y recorders are rarely square.

The analog outputs from the controller are unidirectional and of low impedance. If you wish to reverse the polarity of the input to either recorder axis, simply reverse the axis input connector from the controller.

4.1 ANALOG SPEED OUTPUT The signal amplitude is 10.00 volts at full scale for each position of the SPEED RANGE switch. Therefore the precise output voltage (E_n) for a given speed (RPM) can be calculated from this ratio:

$$E_n = \frac{10\ \text{RPM}}{\text{RANGE}}$$ (Note: RPM always ≤ SPEED RANGE)

Example for 4-pole 60-Hz motor with free-run speed of 1780 RPM, using the 2(000) position on SPEED RANGE:

$$E_n = \frac{10 \times 1780}{2000} = 8.9\ \text{VDC}\ (\pm 1\%)$$

(Note: Zero RPM will not be absolute zero volts, since up to ±5 millivolts (.05% fullscale) is possible. This value is adjustable; refer to paragraphs 12.0 and 12.2.)

4.2 ANALOG TORQUE OUTPUT The analog torque output (E_q) is proportional to the torque reading of the Model 4605 readout. The relationship is as follows (DR represents the readout of all digits, whole or decimal, but with the decimal point, if any, omitted):

$$E_q = 4 \times DR \times 10^{-3}$$

Example for digital display of 48.2 oz.ft. of torque:

$$E_q = 4 \times 482 \times 10^{-3} = 1.93 \text{ VDC } (\pm 1\%)$$

As with analog speed output, zero torque is not absolute zero volts. If adjustment is required refer to paragraphs 12.0 and 12.1.

5.0 X-Y RECORDING: SETUP AND OPERATION

5.1 Disconnect any test motor or other hardware coupled to the dynamometer shaft.

5.2 Install the calibration beam following the instructions in the dynamometer manual; then using a precision weight establish a torque value within your range of interest.

5.3 Scale the X-Y recorder for the calibration required.

5.4 With the weight removed, check zero. If the zero has moved, reset it and recalibrate.

5.5 Remove the calibration beam and couple a test motor to the dynamometer.

5.6 With the controller SPEED RANGE set higher than the motor free-run speed, start the motor. Scale the speed axis of the X-Y recorder to the desired RPM per inch or centimeter excursion.

5.7 Switch the controller's DYNAMOMETER toggle to ON. The BRAKE ENERGIZED light should be out. Slowly rotate SPEED RANGE VERNIER counterclockwise until the BRAKE ENERGIZED light comes on. Then slowly rotate it clockwise until the light just goes out.

All equipment to record is now set up, and a final, accurate test curve of speed vs. torque can be attempted. But before doing so you should become familiar with the three additional functions that appear on the front panel of the controller: AUTOMATIC SPEED CONTROL, INERTIAL ERROR COMPENSATION, and TEST TIME. They are covered respectively in Sections 6, 7 and 10 following.

6.0 AUTOMATIC SPEED CONTROL

This control operates in the speed-control mode and performs essentially the same function as the manually adjustable SPEED control, but it is smoother operating and automatically repeatable.

6.1 Set the TEST TIME switch to 20 (seconds). This is an average setting; see Section 10 for further information on test times.

6.2 Activate AUTOMATIC SPEED CONTROL by depressing the button to light it up; the light signals activation.

6.3 Set the RPM toggle to DECREASING.

These settings will cause the motor to ramp from free run to locked rotor in approximately 20 seconds. (Note: The AUTOMATIC SPEED CONTROL can be deactivated at any time simply by pressing the button again to put the light out; this will return the motor to free run.)

6.4 At any load point the RPM toggle can be switched up to INCREASING. This reverses the ramp, causing the speed to increase at the same rate as it previously decreased.

6.5 To cancel out the ramp and hold the test point, switch the RPM toggle to its center neutral position.

6.6 There is flexibility in the method of controlling the equipment. For example, the RPM toggle can be left in DECREASING and ramp control initiated solely by the AUTOMATIC SPEED CONTROL button.

7.0 INERTIAL ERROR COMPENSATION: GENERAL INFORMATION AND SETUP

In X-Y recording the motor speed is continually changing. Thus the true torque measurement is the sum of two factors: the actual turning power of the motor, plus the addition (when decelerating) or subtraction (when accelerating) of the stored energy in the system (inertia). The inertia factor is proportional to the rate of change of speed, and the mass of the system.

The INERTIAL ERROR COMPENSATION control supplies an adjustable quantity (≈mass) of the differentiated speed signal (differentiation = rate of change). This electrical value is set up as negative in decelerating and positive in accelerating, and is summed with the unipolar torque signal.

7.1 Release the lock on the side of the control by setting it at its up (1 o'clock) position. Then turn the knob full counterclockwise to bring both rotating bands to zero.

7.2 Set up the equipment as in Section 6. Then establish a torque/speed point manually with either the SPEED or the TORQUE control. When the motor has stabilized and speed is constant, drop the recorder pen to mark this point.

7.3 Return the control full counterclockwise, and using the AUTOMATIC SPEED CONTROL, record a curve around the point obtained manually.

7.4 Return the motor to free run.

7.5 Rotate the control one turn clockwise and repeat the operations in paragraphs 7.2 and 7.3.

7.6 Continue rotating and repeating until the RPM toggle can be switched back and forth from INCREASING to DECREASING while the curve almost retraces itself. At that stage the correct setting has been reached.

7.7 When the correct setting is established, lock it in by setting the lock at its down (2 o'clock) position. The value will be repeatable for future testing if the mass of the system remains approximately the same and the same SPEED RANGE is used.

7.8 Always leave a slight lead — perhaps around .5 percent higher torque — on the deceleration curve The magnetic alignment of the armature to the field is altered upon acceleration or deceleration and in addition it is natural for some rotor heating to occur, resulting in displacement of the retrace curve.

8.0 LOCKED-ROTOR TESTS

To obtain locked-rotor torque as rapidly as possible and with cold-motor performance, the test procedure outlined in Section 6 should be modified as follows:

8.1 Set the DYNAMOMETER ON/OFF switch at ON.

8.2 Set the TORQUE STABILIZED/OPEN LOOP switch at OPEN LOOP.

8.3 Rotate the TORQUE control full clockwise.

8.4 For X-Y data recording, be sure the recorder is on and calibrated, and the pen up.

8.5 Close the circuit breaker to the motor and immediately drop the recorder pen, then raise the pen and open the circuit breaker. This takes approximately two seconds. (Note: Because of magnetic slotting effects and bearing friction, most motors with plain bearings, and to a lesser extent motors with ball bearings, exhibit a range of locked rotor values; typically, a plain bearing is free only when it has rotation to develop an oil film between shaft and bearing. This range of locked-rotor values can be as high as 30 percent, depending on the motor.)

9.0 TORQUE (CONTROL MODE)

This is a manual control, its positions functioning as follows:

9.1 OPEN LOOP With the toggle in this position the TORQUE control regulates current to the dynamometer brake without feedback reference.

9.2 STABILIZED With the toggle in this position the actual torque value is compared with the torque potentiometer setting, and the current to the dynamometer brake is controlled proportional to the difference. Therefore the torque is maintained constant despite any speed changes, temperature changes, or hysteresis effects. (Note: This control is not useful for locked-rotor tests; a torque signal is necessary for closed-loop operation, and if the test motor is not energized there is no torque signal.)

10.0 TEST TIME

Generally, the minimum time a motor is under load beyond the maximum-efficiency operating point, the better. But necessary damping and delays in the data signals limit the speed with which data can be obtained while still maintaining accuracy. As a rule of thumb for best results, use a maximum recording time of 1.5 seconds per inch, or .6 seconds per centimeter. This translates to a TEST TIME setting of 15 or higher for most average conditions, with of course other settings for special situations.

11.0 STABILITY

System damping is controlled by a locking potentiometer on the rear panel of the controller. The potentiometer should not be rotated full counterclockwise, which eliminates the rate feedback signal and results in system instability, or full clockwise, which causes heavy system damping and results in extreme sluggishness. Normally the most desirable position for critical damping is close to center, with acceptable variance from center depending on the motor/dynamometer combination in use. When adjusting, rotate the potentiometer very slowly.

12.0 ZERO ADJUSTMENTS AND SYSTEM BALANCING

On the left side of the controller's back panel is a cover plate fastened by two screws. Removal of this plate gives access to two rows of trim potentiometers behind the panel. (Note that from this point on, some of the functions appearing in small capitals refer to functions shown on the controller's back panel.)

12.1 TORQUE OUTPUT ZERO Proceed as follows:

12.1. 1 Disconnect the 4-pin torque-input cable from the Model 4605 readout. Short all of the cable pins together by wrapping a length of fine wire around all four, being careful not to bend them.

12.1. 2 Connect a millivoltmeter capable of ±1 millivolt resolution to the TORQUE OUTPUT jack.

12.1. 3 Adjust Q BAL for zero ±1 millivolt output.

12.2 SPEED OUTPUT ZERO Proceed as follows:

12.2. 1 Connect the millivoltmeter to the SPEED OUTPUT jack.

12.2. 2 With the dynamometer shaft stationary, adjust the F TO V ZERO for zero ±1 millivolt.

12.3 SPEED OUTPUT CALIBRATION Proceed as follows:

12.3. 1 Connect a digital voltmeter of at least ±.25% accuracy to the SPEED OUTPUT jack. Operate the dynamometer at a constant and known shaft speed of between 1000 and 2000 RPM. Set SPEED RANGE at 2(000).

12.3. 2 Calculate the correct voltage output (E_n) from the equation given in paragraph 4.1 (which at the above setting becomes shaft speed x 10, divided by 2000), and adjust 2000 CAL for the correct E_n.

12.3. 3 Calibrate 4000 CAL by repeating the above, but with SPEED RANGE set at 4(000), an appropriate higher shaft speed, and the substitution of 4000 for 2000 in the equation.

12.3. 4 Calibrate 8000 CAL (8-16-32 CAL on the back panel) with similar resetting of SPEED RANGE, shaft speed, and equation divider. When the SPEED RANGE is at 8(000), 16,000 CAL and 32,000 CAL are calibrated automatically.

12.4 Any needed further adjustments will require more extensive disassembly and internal measurements, as covered in the circuit descriptions and schematic commentary (Section 13). The following abnormal conditions indicate the need for further adjustment, which is explained in the Section 13 paragraph number shown for each.

12.4. 1 Torque signal with variance between clockwise and counterclockwise shaft rotation: paragraph 13.1.3. (Note: Use caution in correcting this condition. Refer first to the instructions on zero balancing in the dynamometer manual.)

12.4. 2 Inability to obtain locked-rotor torque with SPEED control full clockwise: paragraph 13.2.

12.4. 3 Non-uniform INCREASING to DECREASING ramp time: paragraph 13.1.2.

12.4. 4 Excessive residual torque and BRAKE ENERGIZED light constantly on: paragraph 13.1.3.

13.0 CIRCUIT DESCRIPTIONS AND SCHEMATIC COMMENTARY

To gain access to the controller's electronic components, it is necessary to remove both the top cover and the internal enclosure cover over the printed-circuit boards.

Most of the electronic functions are contained on three plug-in circuit cards, as shown on the simplified schematic (Figure 2).

The three printed-circuit boards are part numbers 78B011, 78B013, and 78B014. Each circuit card is connected by a 30-pin connector, with two rows of 15 pins each, and each pin identified by letter or number. The left row is identified from top to bottom with letters A to S (to avoid possible conflict or errors of recognition, letters G, I, O, and Q are not used); the right row is similarly identified with numbers 1 to 15. The power inputs to all circuit boards are +15 VDC pin A, -15 VDC pin C, and +5 VDC pin B; pins J and 8 are common returns.

13.1 CIRCUIT BOARD 78B011 This circuit serves three distinct functions, as follows:

13.1. 1 The bipolar signal is applied to pin S and is linearized by amplifiers F and G. The balance potentiometers for each of these are identified as TP1 and TP2. These outputs are on pads also identified as TP1 and TP2, on the edge of the board. An absolute zero relative to chassis common is unattainable on these outputs; however, amplifiers F and G are balanced when with zero input the trim potentiometers just barely change output polarity.

Amplifier H provides a gain of four (4) to the unipolar torque signal, and in addition provides the differentiating function of the INERTIAL ERROR COMPENSATION .

13.1. 2 Amplifier E is an FET-input operational amplifier. It has two modes of operation: as an integrator when the AUTOMATIC SPEED CONTROL is engaged, and as a voltage follower for manual SPEED control. The amplifier is balanced by the RAMP BAL on the back panel, by adjusting for zero volts at pin 12 on the circuit board with AUTOMATIC SPEED CONTROL disengaged and the SPEED control fully clockwise.

In the integrating mode the time constant or ramp time is determined by the voltage input, which is established by the divider resistors on the TEST TIME switch.

13.1. 3 Various precision references are required in the operation of the Model 4619 controller. They are established by the reference zener diode IN821 operating at approximately -7.5 milliamperes and regulating -6.2 VDC. This potential is applied to the inverting input of amplifier B. Limited gain control of amplifier B permits adjustment to a precise +5.00 VDC, which is effected by the REF 5V potentiometer. The measurement is made between pin 1 (+) and pin 8 (common).

The +5 volts are applied to the noninverting input of amplifier C operating at a gain of two (2), providing +10 VDC at pin 4. This potential is applied to the inverting input of amplifier D operating at a gain of unity for the -10 VDC reference at pin 9.

13.2 CIRCUIT BOARD 78B013 This circuit contains the elements that convert the frequency, or pulse train, received from the Model 4605 readout into a fast-response analog.

The frequency rate equals 60 pulses per shaft revolution for 60-Hz line operation, or 50 pulses per revolution for 50-Hz operation.

The input is applied to pin 6 of the connector, where it is conditioned by a schmitt-trigger monostable chip. The output is available at pin 2. The complement of the output is applied to a bistable chip that divides the input by 2 and 4, which signals appear on pins 9 and 10 respectively.

The conversion of frequency to voltage is accomplished within the plug-in module on the circuit card. This unit has an operating frequency of 0-10 KHz. To maintain a 10-VDC full-scale output per range, the converter gain is automatically adjusted on the 0-2K, 0-4K, and 0-8K RPM ranges. Above 8K the input frequency is automatically divided by 2 and 4 respectively on the 0-16K and 0-32K ranges.

The analog output of the module goes to two places: the output jack on the back panel and the inverting input of amplifier A. Amplifier A is an active filter with a gain of unity; it applies the inverted (+ to -) signal to circuit board 78B014. It is balanced by INVERTER BAL pin 11 to common.

13.3 CIRCUIT BOARD 78B014 This circuit contains four operational amplifiers and a preamp driver for the 2N6228 dynamometer power transistor.

Amplifier J is the SPEED-control summing amplifier. Three pins supply active inputs to the inverting summing point; pin 1 is the speed analog, pin 2 the rate feedback signal, and pin 3 the controlled reference.

Amplifier K operates essentially identically to amplifier J except that its signal sources are an analog proportional to torque or brake current as selected by the STABILIZED/OPEN LOOP switch.

Amplifier L serves the function of automatic biasing off the preamp (and subsequently torque) if there is no speed present on the dynamometer. Automatic biasing is desirable in case the TORQUE control is set for some value when the motor is off and the switch is in its STABILIZED position; in this situation it prevents amplifier K from driving the dynamometer brake to full torque.

Amplifier M is the rate-feedback device essential for the system's stability. It receives a signal from a 1.0-ohm current-sampling resistor in series with the dynamometer brake. The level of this signal is controlled by the back-panel STABILITY control. The signal is decoupled by a 47MFD tantalum capacitor. Therefore the output is an AC signal in phase, and proportional to the brake current change. It is applied directly to the summing points of amplifiers J and K.

14.0 METRIC AND POWER CONVERSIONS

METRIC

millimeters x .03937 = inches
millimeters ÷ 25.4 = inches
grams ÷ 28.35 = ounces
kilograms x 2.2046 = pounds
oz.in. x 72.008 = gr.cm.
oz.ft. x .864093 = kg.cm.
lb.in. x 1.15212 = kg.cm.
kg.m. x 9.80665 = N·m.*
oz.in. x 7.06155 x 10^{-3} = N·m.*

*Newton·metre

POWER

oz.in. x rpm(9.921 x 10^{-7}) = hp
oz.in. x rpm(7.401 x 10^{-4}) = watts
watts ÷ 746 = hp

For further information or technical assistance, please feel free to contact our engineering department at any time.

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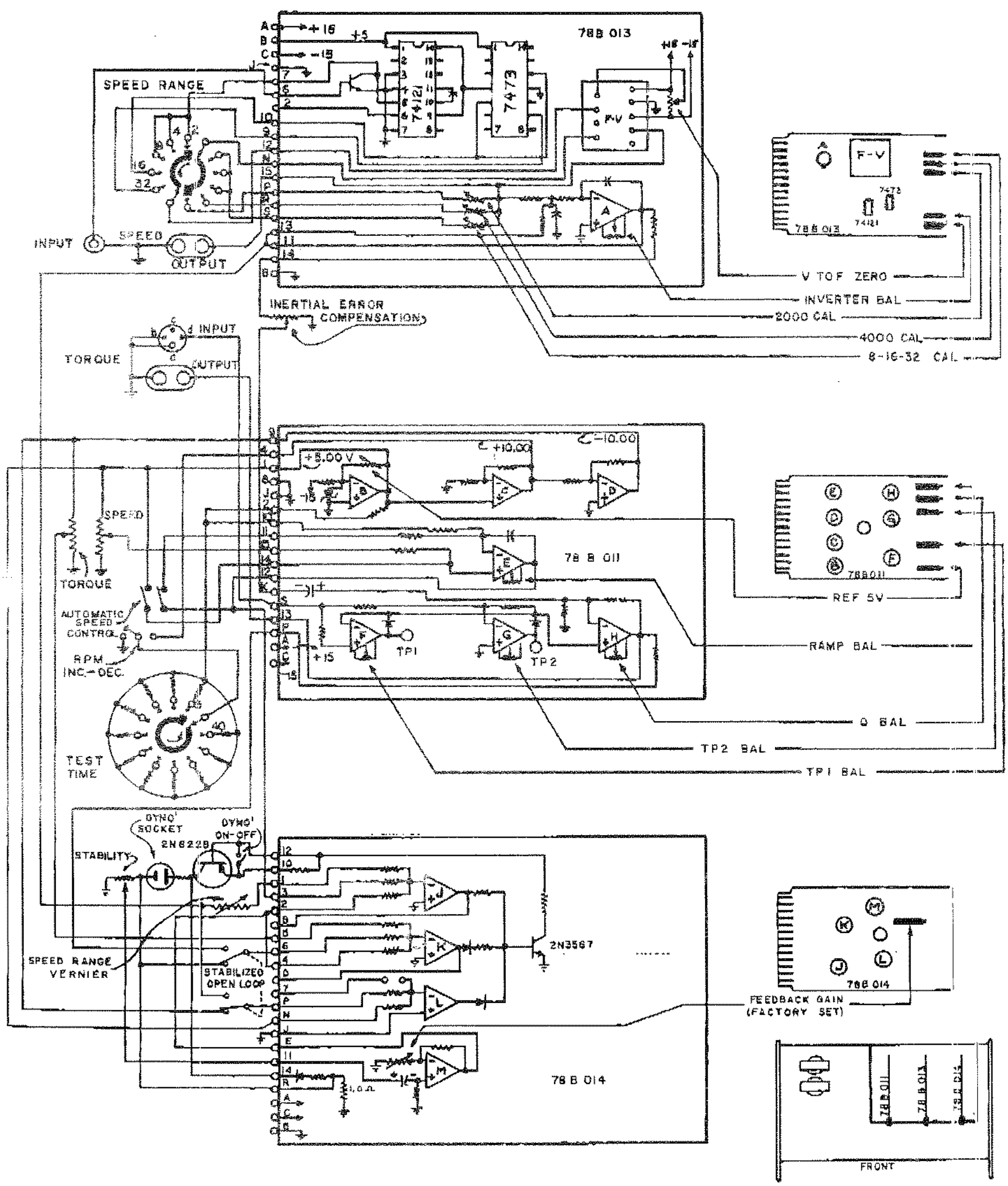
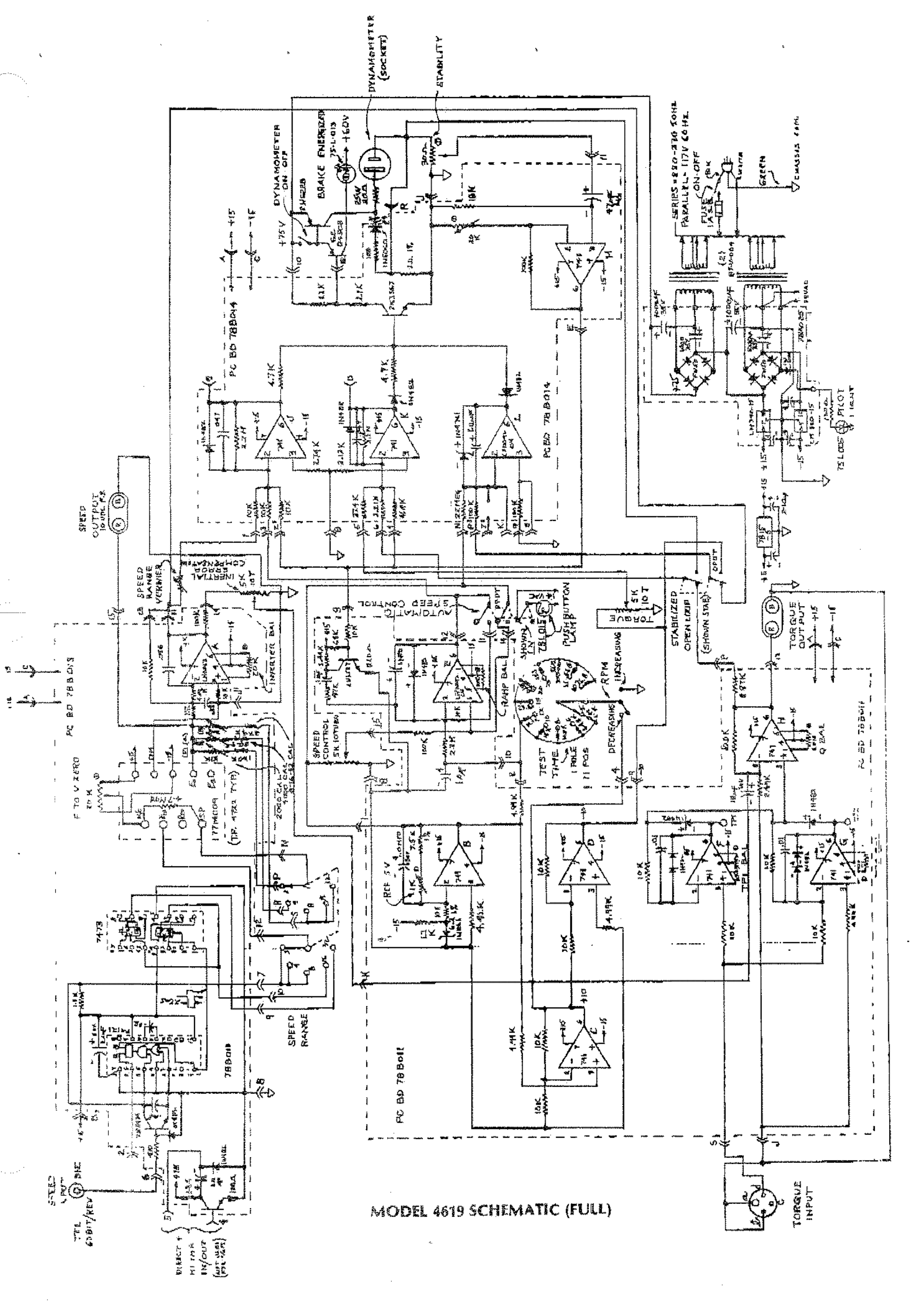


MODEL 4619 SCHEMATIC (BRIEF)

FIGURE 2



MODEL 4619 SCHEMATIC (FULL)