NBSIR 75-773

Report on Characteristics of Three Universal Force Testing Machines

Ervin C. Palasky & J. Eryx Malcolm

Electrical and Mechanical Engineering Section
Product Engineering Division
Institute for Applied Technology

William H. Appleton

Engineering Mechanics Section
Mechanics Division
Institute for Basic Standards

September 1975

Final

Technical Report to
Mechanics Division
Institute for Basic Standards
National Bureau of Standards

NBSIR 75-773

REPORT ON CHARACTERISTICS OF THREE UNIVERSAL FORCE TESTING MACHINES

Ervin C. Palasky & Eryx Malcolm

Electrical and Mechanical Engineering Section
Product Engineering Division
Institute for Applied Technology

William H. Appleton

Engineering Mechanics Section
Mechanics Division
Institute for Basic Standards

September 1975

Final

Technical Report to
Mechanics Division
Institute for Basic Standards
National Bureau of Standards

U.S. DEPARTMENT OF COMMERCE, Rogers C. B. Morton, *Secretary*
James A. Baker, III, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

Table of Contents

Page

Section 1 - Introduction and general summary 1
1.0.0 Scope and purposes of manual 1
1.1.0 Basic machine operation logic 2
1.2.0 The Machine crosshead 2
1.3.0 The Crosshead drive controller 2
1.4.0 The measuring circuits 5
1.5.0 The sensors and indicators 5
1.6.0 The Automatic and external controllers 5

Section 2 - Power 5
2.0.0 Machine Power 5
2.0.1 Control operations 5
2.0.2 Motive power 6
2.0.3 Power flow chart 6
2.1.0 Power control chassis 6
2.2.0 Master power control 6
2.3.0 Crosshead power 10
2.4.0 General power distribution 10
2.5.0 The 24 volt power supply PS301 12
2.6.0 Other functions on the power chassis 12

Section 3 - The machine crosshead 13
3.0.0 The machine crosshead 13
3.1.0 Crosshead power 13
3.2.0 The oil control valve (2) 16
3.3.0 The drive motor (5) 16
3.4.0 Signal summary in power source 16
3.5.0 Crosshead speed clutches (8), (9) and (10) 18
3.6.0 Synchronization summary 18
3.7.0 Clutch selection signals 18
3.8.0 Clutch operation 20
3.9.0 The fail safe brake (11) 20
3.10.0 Movement limiting switches 21
3.11.0 Isolated operation of the crosshead for test purposes 21
3.11.1 Synchronization circuit adjustment 21
3.11.2 Install Substitute crosshead control signal 23
3.11.3 Instrumentation of the test set up 23
3.11.4 Machine controls to be used 23
3.11.5 Test operation 23
3.11.6 Test results 23

Section 4 - Synchronization 25
4.0.0 Synchronization 25
4.1.0 Initialization of the synchronization 27

Page

4.2.0 Operation of sync or relay K404 30
4.3.0 Importance of synchronization relay K404 31
4.4.0 Details of failure detector 31
4.4.1 The control failure detector 31
4.4.2 Excessive speed signal 31
4.4.3 Out of control signal 33
4.4.4 Detection of an error 33
4.4.5 Operation of the sensor detector electronics 33
4.4.6 The input rectifier 33
4.4.7 The amplitude comparator section 33
4.4.8 The threshold detector 36
4.4.9 The output drivers 36
4.4.10 The output signal characteristics 36
4.4.11 Reset of the system 38

Section 5 - Direction control 38
5.0.0 Crosshead direction control relays 38
5.1.0 Motion relay turn-on 39
5.1.1 The system at rest 39
5.1.2 Relay turn on 39
5.2.0 Holding operation of motion direction relays 41
5.3.0 Turn-off of the direction control relays 41
5.4.0 Indicator lights 42
5.5.0 Associated safety functions 42
5.5.1 Range exceed problems 42
5.5.2 Limit exceed problems 42

Section 6 - Crosshead drive control 43
6.0.0 Crosshead drive servo control 43
6.1.0 Command servo motor 43
6.2.0 Command servo signal mixer 43
6.3.0 Input control signal 46
6.3.1 Control by relay K409 46
6.3.2 Control by jog relay K408 46
6.3.3 Operational control 47
6.4.0 The output signal 47

Section 7 - The measuring circuits 47
7.0.0 The measuring circuits 47
7.1.0 The load cells 49
7.2.0 The load cell amplifiers and mixer 49
7.3.0 Range selection 52

Section 8 - Maintain load 52
8.0.0 Introduction 52
8.1.0 Signal sources 52
8.2.0 The error signal 52

Page

8.3.0 Reaction rate control 54
8.4.0 Servo drive control 54
8.5.0 Cross reference 54

Section 9 - The indicating circuits 54

Section 10 - Velocity mode feedback control system 55
10.0.0 Introduction 55
10.1.0 Description and results of tests 55
10.2.0 Conclusions 65

Illustrations

1.1.0 General System Layout
1.1.1 General System Layout (Expanded)
2.0.3 Power Control Layout
2.1.0 115 VAC Power Control and Distribution
2.2.0 Main Power Control
2.3.0 Crosshead Power Control
3.0.0 Machine Crosshead System Layout
3.0.0a Machine Crosshead System Layout (Expanded)
3.2.0 Oil Gear Pump Illustration
3.7.0 Manual Speed Selection System
3.11.0 Crosshead Test Layout
3.11.2 Crosshead Test Layout (Expanded)
3.11.6 Crosshead Speed Curve
4.0.0 Servo Motion Control Loops
4.1.0 Synchronization Circuits
4.4.0 Synchronization Null Detector
4.4.5 Synchronization Phase Sensor and Detector
4.4.6 Synchronization Input Signal
4.4.10 Synchronization Control Signal
5.0.0 Motion Direction Control Circuits
6.0.0 Servo Control Circuits
6.0.0a Servo Motion Control Loops
7.0.0 Measuring Circuits
7.1.0 Load Cell Equivalent Circuits
7.1.1 Load Cell Location
8.0.0 Maintain Load Circuits
9.0.0 Indicating Circuits
10.1.0A Bode Plots
10.1.0B Bode Plots
10.1.0C Loop Diagram
10.1.0D Bode Plots
10.1.0E Bode Plots
10.1.0F Test Configuration

Section 1 - Introduction and general summary

1.0.0 Scope and purposes of manual

The manual is written to assist in the servicing of the universal testing machines manufactured by Gilmore industries, Inc., and now in use in the National Bureau of Standards. These machines are designated as models M421 and are further identified by the numbers listed below.

1. Model M421-200 S/N 4366
2. Model M421-50 S/N 4367
3. Model M421-10 S/N 4368

The manual is intended to serve as a supplement to, and expansion of, documentation supplied by the manufacturer, for the purpose of study and repair of the machines. Operation and calibration instructions are entirely left to the Gilmore industries manual.

The manufacturer's documentation consists of:

1. An operation and maintenance manual.
2. A set of schematics.
3. A set of various manufacturing specifications for components used as part of the machine.

This manual supplements item 1 above and attempts to clarify item 2. Primary focus of the manual is on electrical or electronic information or procedures. Circuit details found in the schematics but not described in the literature are added. Drawings are redrawn, assembling pertinent related material and eliminating parts which are intercoupled to the functions but not under examination in the explanation. This clarification facilitates understanding and servicing the machines.

Mechanical and hydraulic details and maintenance are left to be described in the manufacturer's catalog.

A procedure is developed and presented for isolating the crosshead drive, for operation outside the control loop for testing purposes.

The Gilmore manual, on pages 7, 8 and 9 lists the general specifications and references further documentation which supports understanding of the machines.

1.1.0 Basic machine operation logic

Figure 1.1.0 outlines in very simplified form the operational layout of the machines. The machines can be divided into three basic systems. These systems are identified by number on the diagram.

1. Control and movement.
2. Response and indication.
3. Feedback activated control due to response.

Figure 1.1.1 is a duplicate of Figure 1.1.0 with some details added. The details are the major functions of the blocks. Minor functions are omitted and will be added in later sections devoted to detailed descriptions.

The blocks are generally described below in order to provide a summary overview to the reader. More detail is supplied in later sections.

1.2.0 The machine crosshead

The crosshead, mounted on the testing frame, applies force to the specimen under test. It is a mechanical system, driven by a hydraulic force system which is electrically powered and controlled.

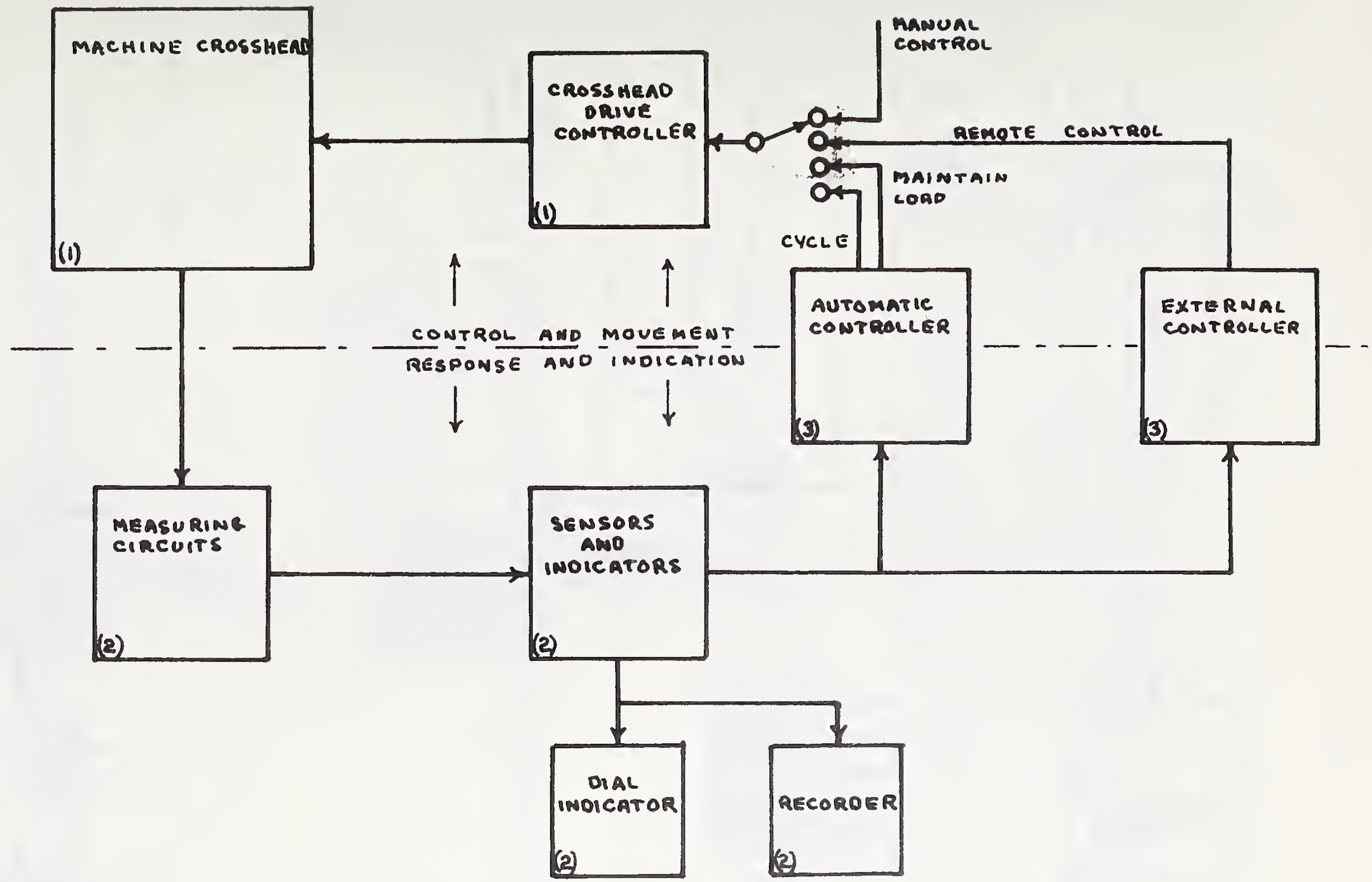
The system is described in some detail on pages 11, 12, 12a and 13 in the Gilmore manual. It is a slave system, responding to control and reporting its condition but with no ability to alter its own operation.

1.3.0 The crosshead controller

The controller accepts external direction and monitors the crosshead response to attain speed, direction and force as directed. The controller also monitors a series of safety sensors and shuts down the crosshead motion in the event that a condition is detected which might cause damage to the machine.

The function of operation of the crosshead controller is manually selected prior to operation. Four methods of operation may be used. The titles listed are generally descriptive of the function itself.

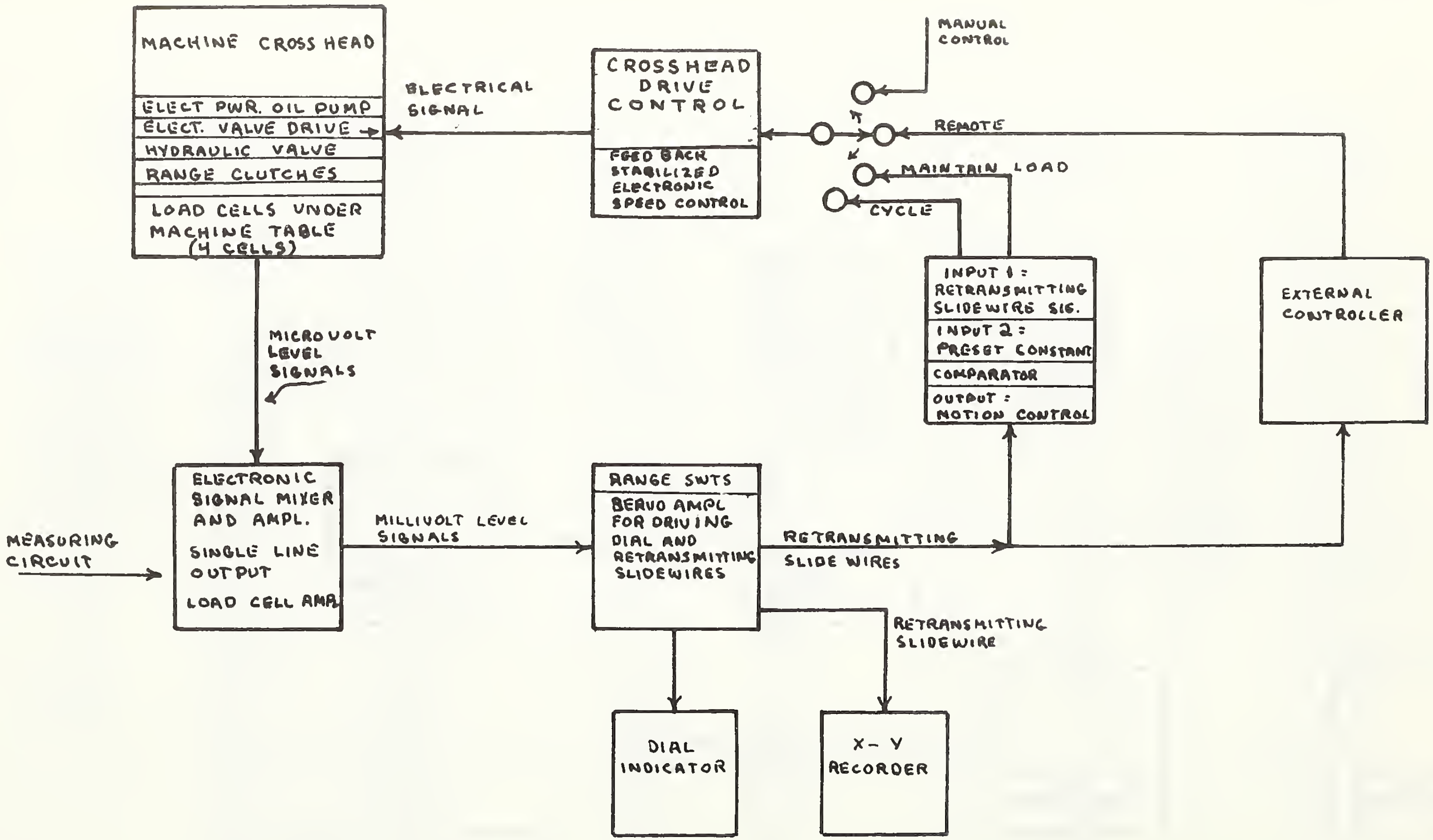
1. Manual operation.
2. Maintain load.
3. Cycle between fixed load points.
4. Remote control.



UNIVERSAL TESTING MACHINE

GENERAL SYSTEM LAYOUT

FIG 1.1.0



UNIVERSAL TESTING MACHINE

GENERAL SYSTEM LAYOUT WITH SOME DETAILS

FIG. 1.1.1

1.4.0 The measuring circuits

These circuits sense the force on the specimen through interpretation of the output signals of four load cells under the crosshead bed plate. The load cells are described in the Gilmore manual on pages 13, 34 and 35. The load cells feed a signal mixer which is followed by an amplifier.

The output of the amplifier is proportional to the total load on the machine and is used to drive the dial indicator and the retransmitting slidewires which in turn are used as references for various balancing and indicating circuits.

1.5.0 The sensors and indicator

These are the dials and retransmitting slidewires which serve to interface the measuring circuits to the operator or to other parts of the machine. They serve as reference signals for the automatic and remote control functions.

1.6.0 The automatic and external controllers

These systems provide a limited spectrum of operations which may be called to replace the manual control. Functions which may be accomplished are:

1. Unattended operation.
2. Cyclic operation.
3. Preset loading.
4. Constant loading.
5. Remote control.

Section 2 - Power

2.0.0 Machine power is basically electrical. Specifications for the power are found on page 10 section 3.2 of the Gilmore manual. Two facets to the electrical power usage are apparent.

2.0.1 Control operations inside the machine are based on a source power of 115 volt, single phase, 60 hertz. In addition to a.c. use this is converted to numerous and different direct voltages to specifically satisfy requirements of various parts of the machine.

2.0.2 Motive power to drive the force parts of the machine and load the samples is derived from a 440 volt, 3 phase, 60 hertz source. Use of this power is controlled by the circuits driven by the power listed above under section 2.0.1.

2.0.3 Figure 2.0.3 is a flow chart depiction of power control chassis 300 which is described in sections immediately below.

2.1.0 Power control chassis

Power control is located on chassis 300. This is the central control point and source of power for the machine. However, auxiliary power supplies will often be found on local chassis when they are dedicated to use on that chassis. Input power to these supplies is controlled on chassis 300.

There are several distinct parts to chassis 300 and they are described in the following sections. Figure 2.1.0 is a schematic diagram of chassis 300.

2.2.0 Master power control - chassis 300

Figure 2.2.0, an extraction of part of Figure 2.1.0, is a schematic of the master power control.

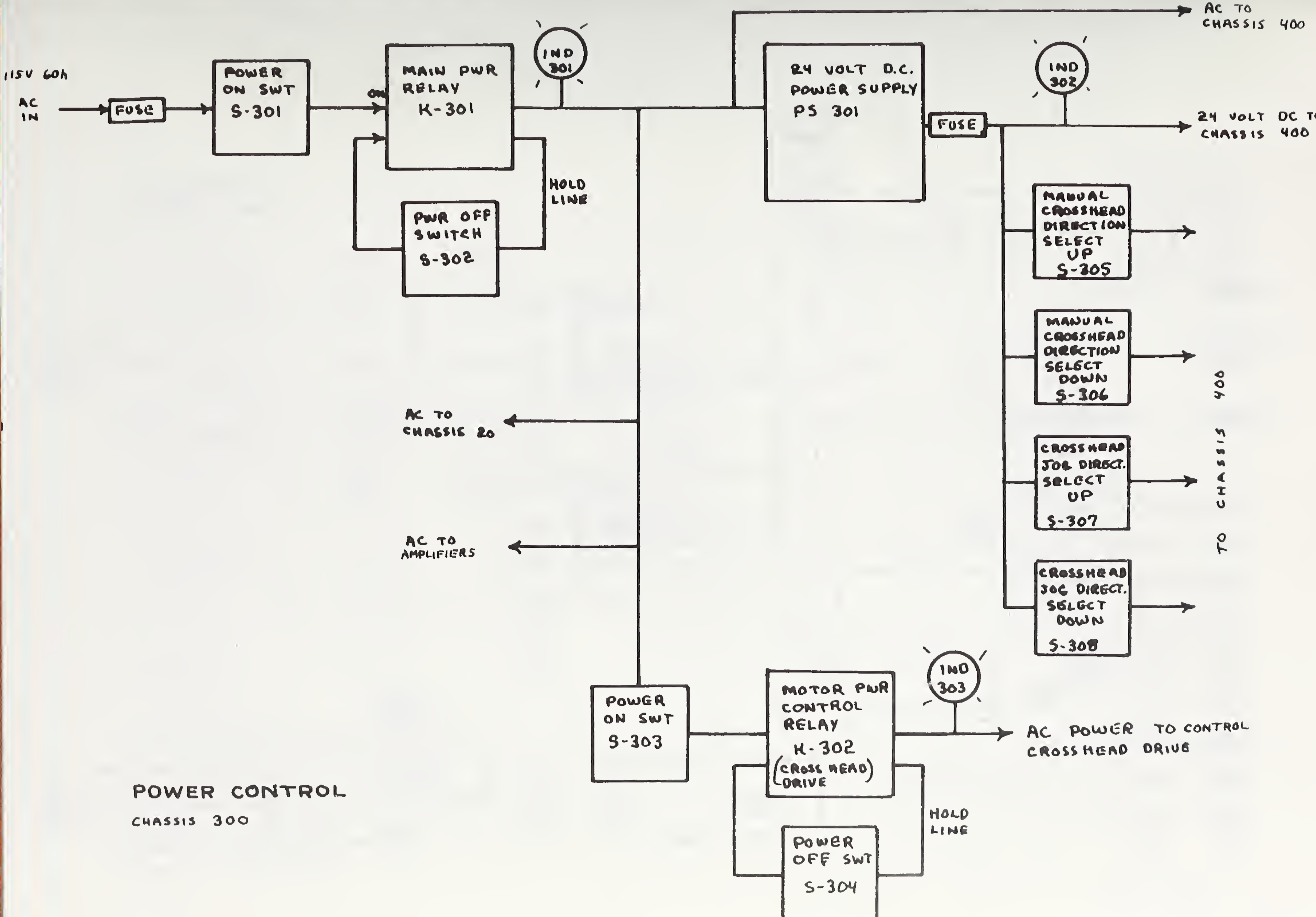
Fuse F301 with a rating of 10 amperes is the basic protection in this circuit. A burnout of this fuse will turn off the entire machine, including the crosshead power.

This subsystem is based on locking relay K301 which is activated by depressing normally open switch S301. This switch is labelled power on. As soon as relay K301 picks up, a set of contacts on the relay maintains the hold condition through the normally closed switch S302. This switch is labelled power off.

Power is turned off by depressing switch S302 which breaks the holding current through relay K301.

An indicator lamp I301 senses the operation of relay K301 and gives a visual indication that power is present at this point.

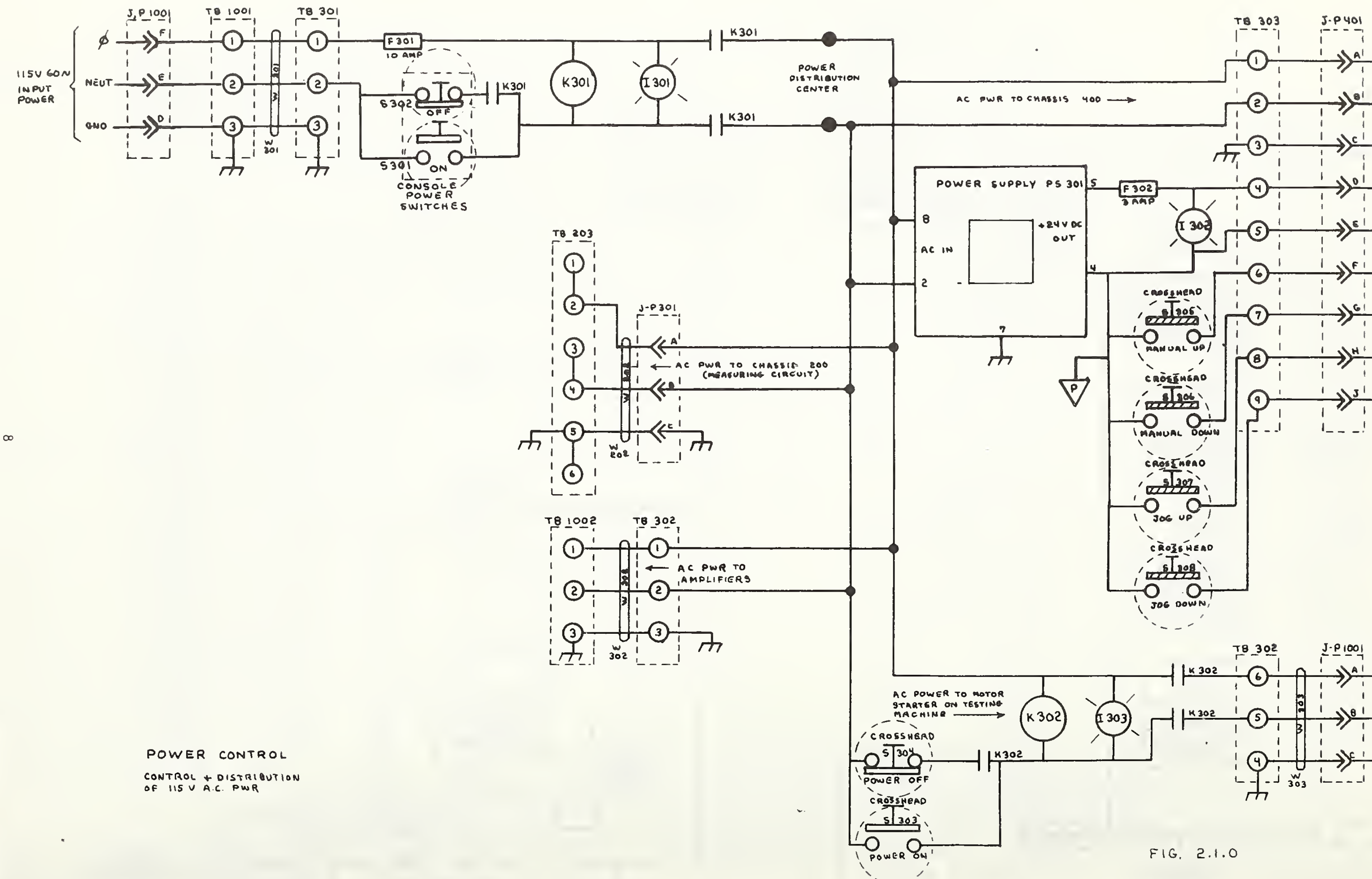
The power applied to the machine is routed through two contact sets of relay K301 to the distribution point on the chassis. The contacts of this relay all carry the entire control current



POWER CONTROL

CHASSIS 300

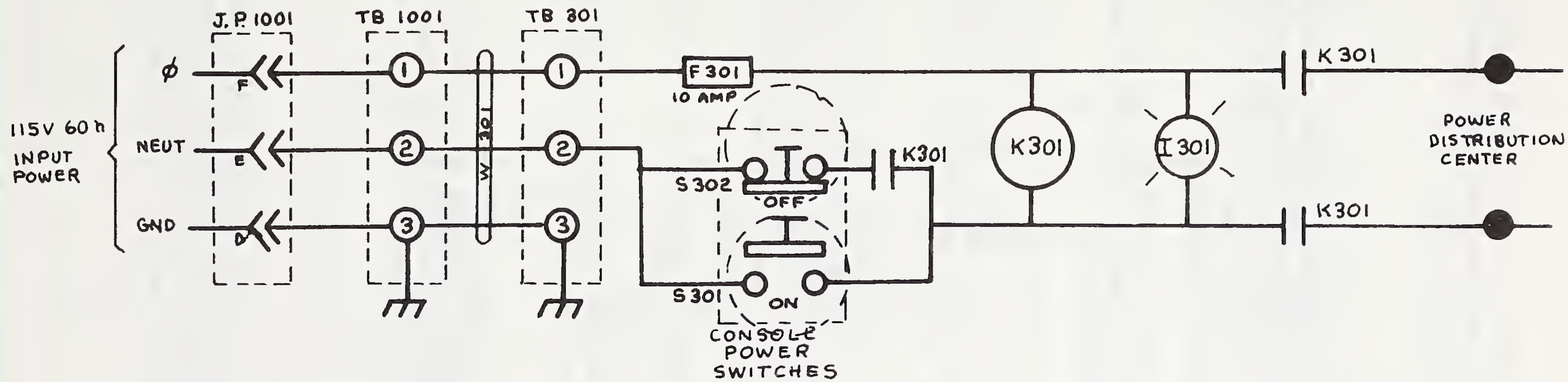
FIG 2.0.3



POWER CONTROL

CONTROL + DISTRIBUTION OF 115 V A.C. PWR

FIG. 2.1.0



MAIN POWER CONTROL

FIG. 2.2.0

used in the machine. Failure of a set of these contacts could result in an operated relay and the absence of power in the machine, even though the indicator light is on.

2.3.0 Crosshead Power

The 440 volt power breaker is on the loading frame. This must be on to operate the crosshead. It does not actually apply power to the system but rather makes the power available on call of the circuits on chassis 300. The 440 volt power drives an oil pump on the loading frame. This is the source of the hydraulic energy used in the system.

Figure 2.3.0 is an extraction of part of the schematic figure 2.1.0 and details the parts of chassis 300 which directly command the crosshead driving power.

The input power to this part of the circuit is from the distribution point on chassis 300. Section 2.2.0 details the method in which power reaches this point. The crosshead power control is hung on this point along with a number of other connections to other parts of the machine.

This subsystem is based on locking relay K302 which is activated by depressing normally open switch S303. This switch is labelled crosshead power on. As soon as relay K302 picks up, a set of contacts on the relay maintains the hold condition through the normally closed switch S304. This switch is labelled crosshead power off.

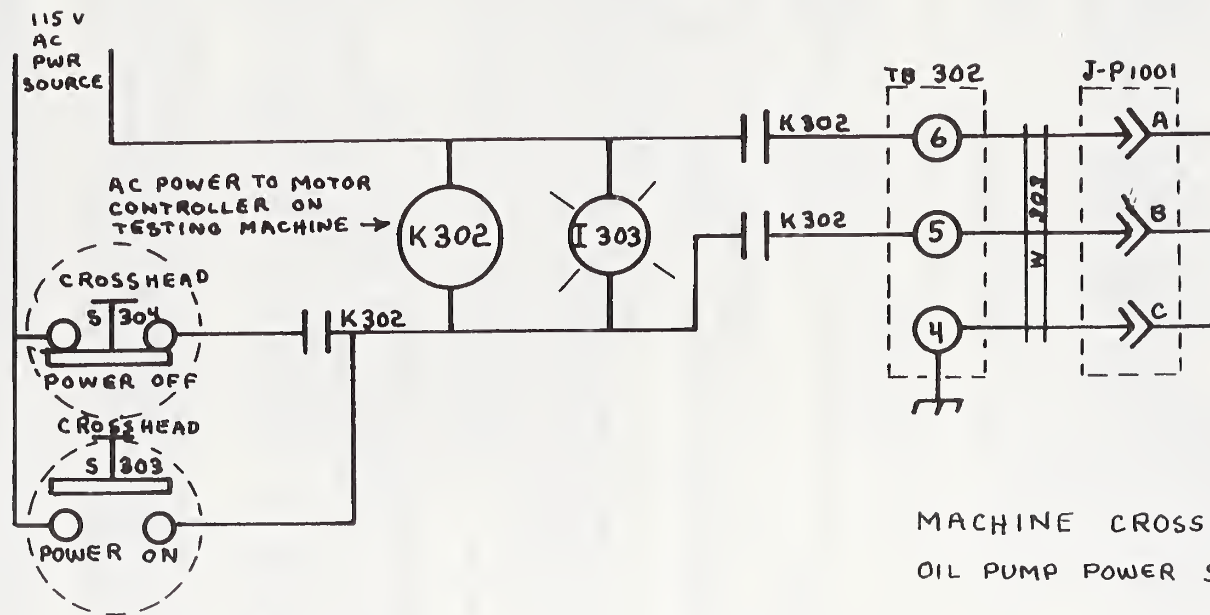
Power is turned off by depressing switch S304 which breaks the holding current through relay K302.

An indicator lamp I303 senses the operation of relay K302 and gives visual indication that power is present at this point.

The power applied to the crosshead is routed through two contact sets of relay K302. Failure of either of these sets of contacts would result in the absence of power to the crosshead even though the indicator lamp shows power to be on.

2.4.0 General power distribution

The power distribution point on chassis 300 services some system parts without interposing any protective devices. These parts thereby relate back to the basic 10 ampere fuse F301 for protection. Fuses may exist for later local uses



MACHINE CROSSHEAD

OIL PUMP POWER SOURCE

FIG. 2.3.0

and the above comment is related only to protection on chassis 300.

Direct 120 volt service is provided to:

1. Chassis 200.
2. Chassis 400.
3. The Oil-Gear Co. amplifiers which regulate the hydraulic valve speed control.
4. Positive 24 volt power supply PS301. This supply is on chassis 300 and is used as operating power for relays.

Figure 2.1.0 shows the above listed connections.

2.5.0 The 24 volt power supply PS301

This supply is located on chassis 300 and is used for operating relays.

Indicator light I302 is energized by the output of this supply and indicates that voltage is present at the output.

Fuse F302, with a rating of 3 amperes, protects this supply from excessive current demand in all uses. Failure of this fuse will be evidenced by the failure of indicator I302 to light.

All 24 volt current is either used on or traverses chassis 400.

2.6.0 Other functions on the power chassis

Four machine control switches not associated with power supply are mounted on this chassis. These will be listed here and discussed in sections where they relate to some specific operation.

1. Crosshead manual up.
2. Crosshead manual down.
3. Crosshead jog up.
4. Crosshead jog down.

The operation technique of all four of these switches is to provide a ground return for relays on other chassis. This is a return to the 24 volt supply. This means that they function by operating a relay which in turn performs the control listed on the switch label.

Section 3 - The machine crosshead

3.0.0 The machine crosshead

The crosshead is the mechanism by which the system converts all instruction and control to useful output. This section of the manual outlines its relationship to other parts of the system and details a method in which it may be essentially isolated from other systems for either study or adjustment. Gilmore manual pages 11, 12, 12a and 13 should be referred to for many details not listed here.

Communication between the crosshead and other systems is in an electrical form.

Input signals to the crosshead are:

1. Power.
2. Movement control.
3. Power control.

Output signals from the crosshead are:

4. Movement response.
5. Force signals.
6. Safety condition signals.

Figure 3.0.0 is a basic layout of the relationship of the crosshead to the overall system. Legend and numbers on this layout show the signal distribution as outlined above.

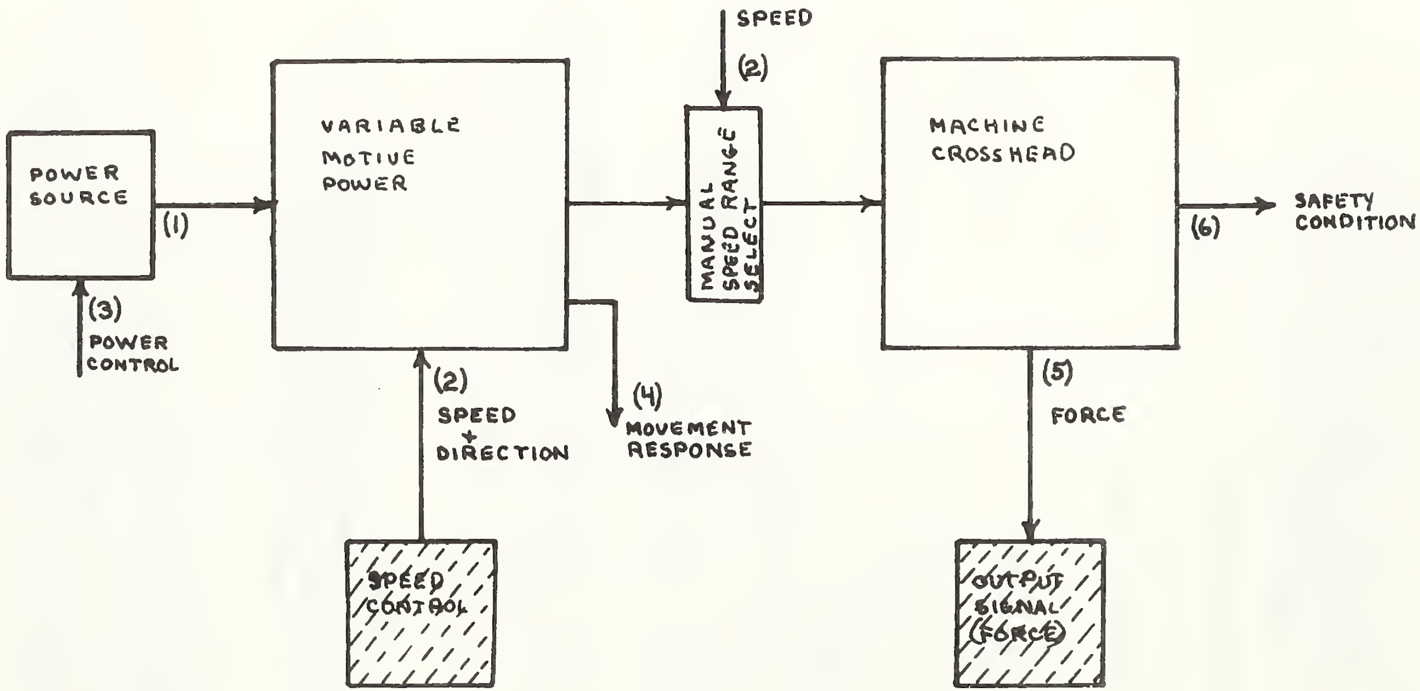
Figure 3.0.0 is too simplified to permit effective description of necessary details. Figure 3.0.0.a is an expansion of Figure 3.0.0 to serve as a reference for discussions immediately following.

3.1.0 Crosshead power

Power to the crosshead starts with a 440 volt electrical system which drives an electrically powered hydraulic pump. Application of this power is by procedures outlined in sections 2.2.0 and 2.3.0 of this report. In summary here we list following requirements:

1. Console power must be on.
2. Crosshead power must be on.

Under these conditions, the pump will be running and oil pressure will be present. No movement will occur until further control requirements are satisfied. The representation of this part of



MACHINE CROSSHEAD

SIMPLIFIED PLAN

SHADED BLOCKS = AUXILARY FUNCTIONS INCLUDED FOR CLARITY.

FIG 3.0.0

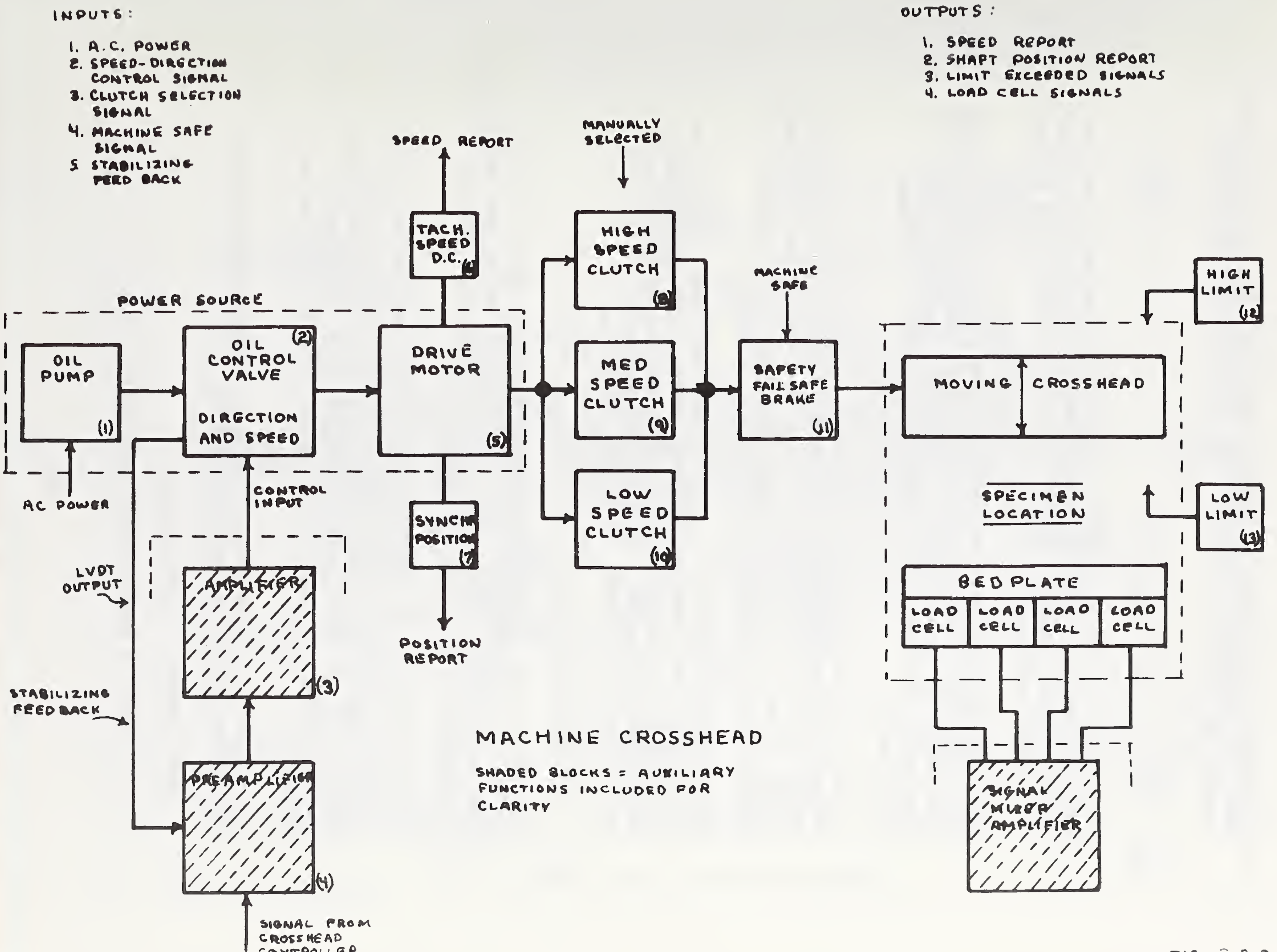

INPUTS:
1. A.C. POWER
2. SPEED-DIRECTION CONTROL SIGNAL
3. CLUTCH SELECTION SIGNAL
4. MACHINE SAFE SIGNAL
5 STABILIZING FEED BACK
OUTPUTS:
1. SPEED REPORT
2. SHAFT POSITION REPORT
3. LIMIT EXCEEDED SIGNALS
4. LOAD CELL SIGNALS
SPEED REPORT
MANUALLY SELECTED
TACH. SPEED D.C. (6)
HIGH SPEED CLUTCH (8)
MACHINE SAFE
HIGH LIMIT (12)
POWER SOURCE
OIL PUMP (1)
OIL CONTROL VALVE (2)
DIRECTION AND SPEED
DRIVE MOTOR (5)
MED SPEED CLUTCH (9)
SAFETY FAIL SAFE BRAKE (11)
MOVING CROSSHEAD
AC POWER
CONTROL INPUT
SYNCH POSITION (7)
LOW SPEED CLUTCH (10)
SPECIMEN LOCATION
LOW LIMIT (13)
LVDT OUTPUT
AMPLIFIER (3)
BED PLATE
LOAD CELL
LOAD CELL
LOAD CELL
LOAD CELL
POSITION REPORT
STABILIZING FEED BACK
MACHINE CROSSHEAD
SHADED BLOCKS = AUXILIARY FUNCTIONS INCLUDED FOR CLARITY
PREAMPLIFIER (4)
SIGNAL MIXER AMPLIFIER
SIGNAL FROM CROSSHEAD CONTROLLER

FIG. 3.0.0a

the system is indicated by block (1) of Figure 3.0.0a. It will be seen that the pump is isolated from the drive motor by the oil control valve (2).

3.2.0 The oil control valve (2)

The oil control valve controls both machine speed and direction. This unit and its associated amplifiers (3) and (4) are supplied by the Oilgear Company. Figure 3.2.0 is an illustrative diagram of how this unit works.

An electrical signal drives the torque motor powered swing valve. The differential pressure resulting from the swing plate movement then moves the slide block to an off center position. This results in an oil pressure proportional to the slide block displacement.

An LVDT reports the position of the slide block. This signal is sensed by the same amplifier system which drives the swing plate torque motor. The LVDT signal is compared with the original drive signal to reach a balance on the slide block position needed to properly drive the system at the requested speed.

The original signal is a 60 hertz sinusoidal signal, applied to the preamplifier, whose amplitude is proportional to the speed requested. The phase of the signal determines the direction of the crosshead movement. Gains are set so that a 1 volt r.m.s. signal drives the machine at maximum rated speed.

3.3.0 The drive motor (5)

The speed of the drive motor is proportional to the oil pressure output of the oil control valve. It should be noted here that the drive motor output is extended over the three speed ranges by clutching using clutches (8), (9) and (10).

The drive motor is an important part of the speed control loop. Attached to its output shaft are a d.c. tachometer (6) and a position synchro (7). The outputs of these units are constantly monitored by the speed control circuits in the electronics cabinet. The units report the speed of the motor and the shaft position.

This hydraulic drive motor is the means of actually moving the crosshead by way of the clutching system.

3.4.0 Signal summary in power source

1. A.c. power to turn on drive power (115V a.c.).

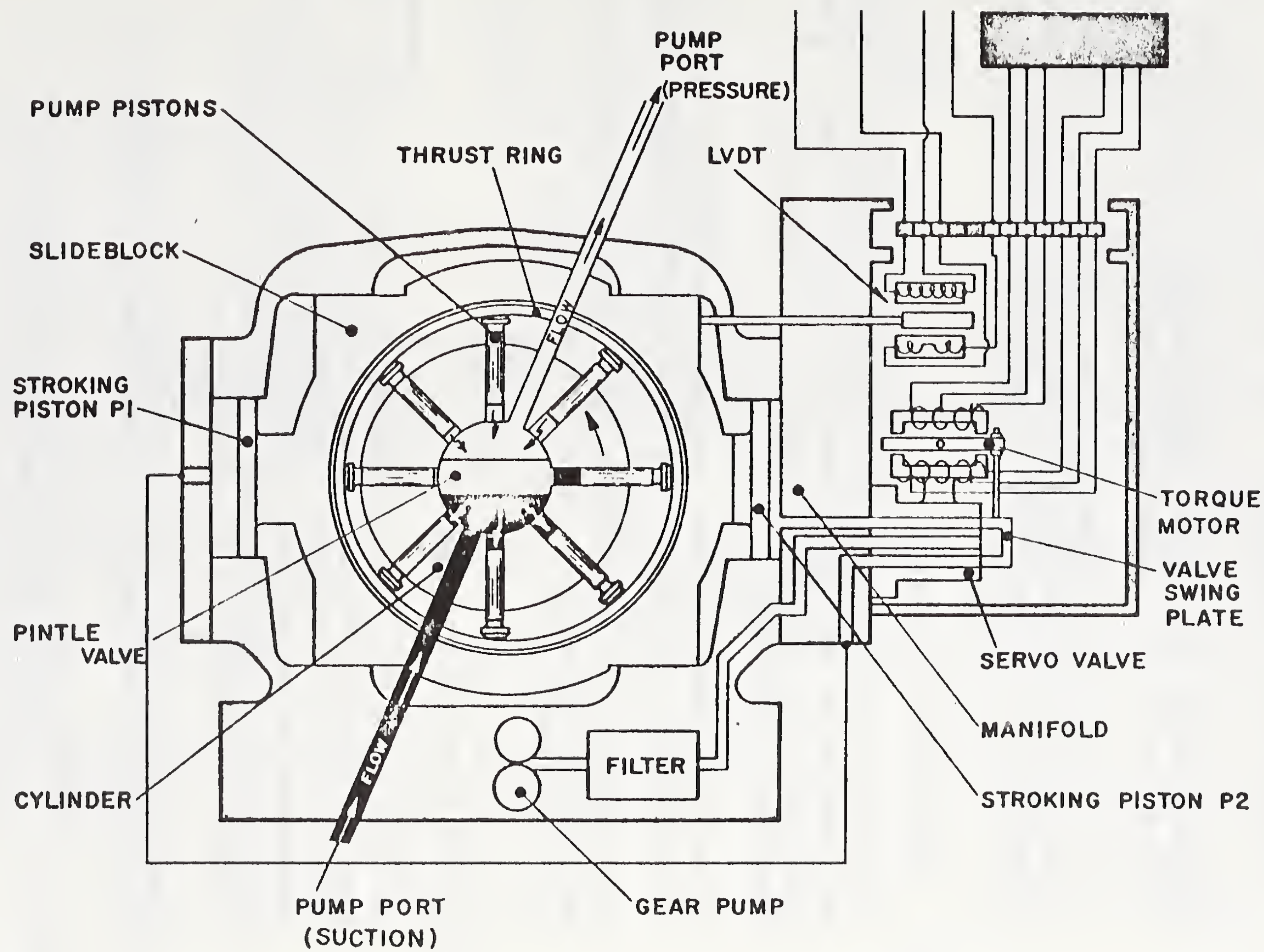


Fig. 2. Schematic View of Pump and "V" Control Components.

FIG 3.2.0

2. A.c. input drive power to drive oil pump (440V 3 Ø a.c.).
3. Swing valve drive input, 1 volt r.m.s. = full speed.
4. LVDT feedback output from slide block.
5. D.C. tachometer output, voltage proportional to speed.
6. Synchro motor shaft position signal.

3.5.0 Crosshead speed clutches (8), (9) and (10)

Operation of the machine to this point is simple and free of interfaces which could cause machine damage. Activation of the clutches changes this picture since the machine can now move.

The first safety feature enters at the clutch circuit level. This is the synchronization circuit. Details of this circuit are given elsewhere but it is necessary to summarize its method of operation here for clarification.

3.6.0 Synchronization summary

The position synchronizer located on the drive motor shaft is monitored and as this shaft departs in position from a reference shaft inside the electronic console a voltage proportional to the departure is generated.

If the displacement voltage is greater than a preset limit, power to operate the clutches is removed or prevented from appearing.

Relay K404 is the synchronizing relay and must be operated before the clutches are engaged. Gilmore manual pages 39 and 40 deal with this circuit.

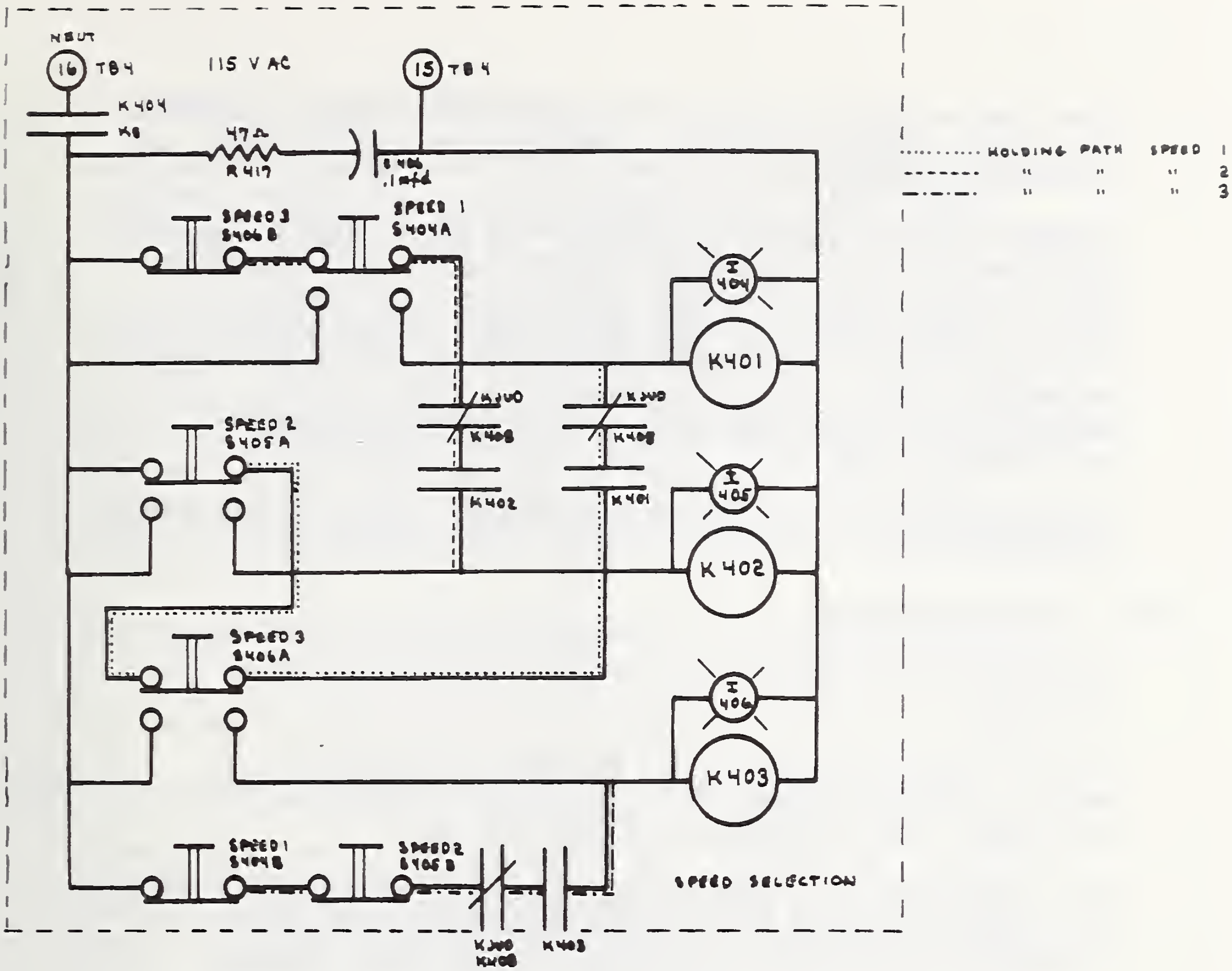
3.7.0 Clutch selection signals

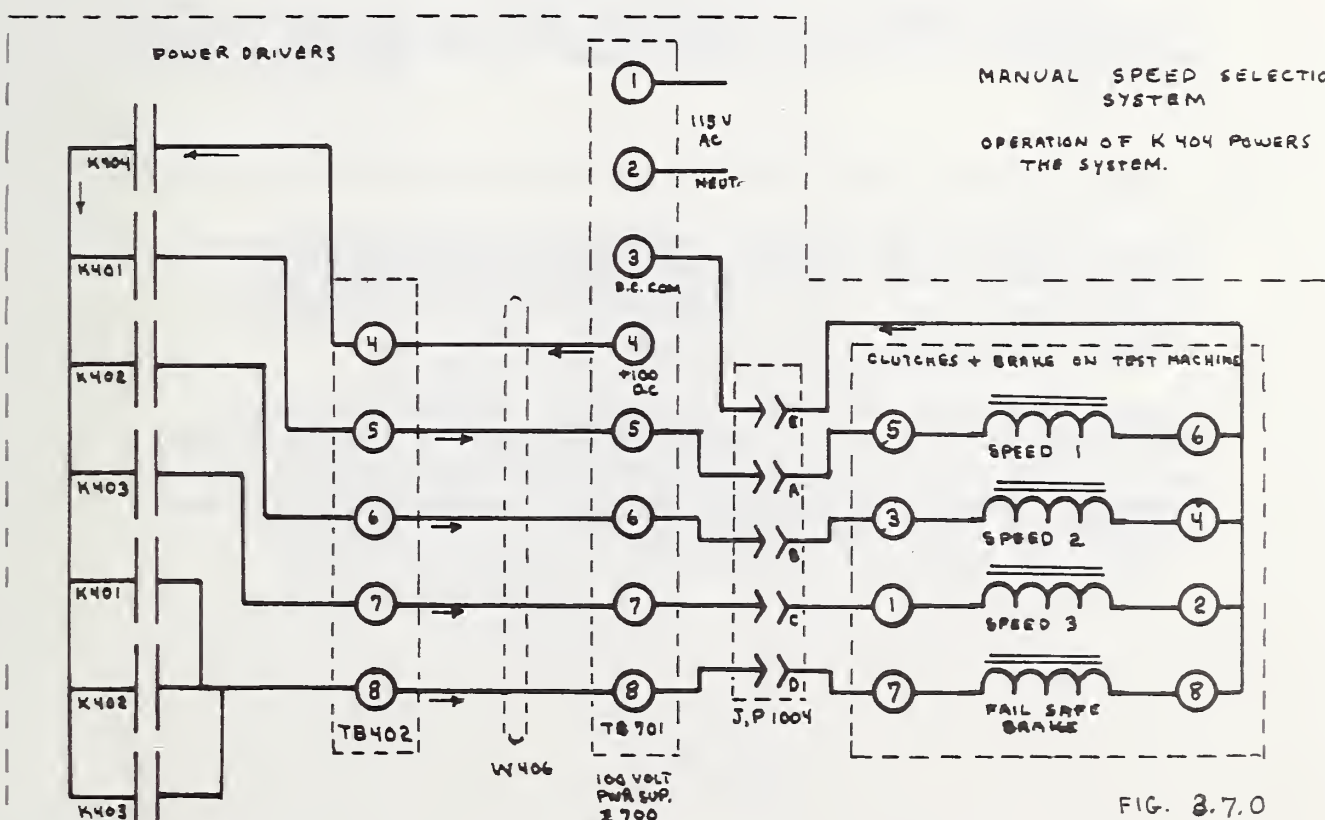
The upper part of Figure 3.7.0 shows the schematic of the clutch speed selection circuits. Clutch operation is by means of locking relays K401, K402 and K403. These relays are mutually interconnected in addition to being self locking. Only one can be on at a time. Page 17 of the Gilmore manual details operator use of the speed range clutch selection.

These relays are operated by push buttons on the front face of chassis 400. The push buttons are numbered as follows:

1. Low speed push button is S404.
2. Medium speed push button is S405.
3. High speed push button is S406.

Operation of any of these buttons will cause contacts on that button to open the holding circuit of the other two relays. No





MANUAL SPEED SELECTION SYSTEM

OPERATION OF K404 POWERS THE SYSTEM.

FIG. 3.7.0

power may be applied to any of the speed select relays unless the sync. relay K404 is activated. K404 contacts supply current to the entire circuit.

Another relay can enter the picture. Jog relay K408 if operated will open the holding circuits normally used by all relays. A special path is then available to turn on the low speed clutch only. Circuit details of this function are unclear and will have to be traced out. The Gilmore drawing D27142 sheet 4 of 6 shows an earlier circuit which is redlined out. The low speed selection parts of this circuit may still be in. The Jog function is operational.

Indicator lights on chassis 400 show which, if any, clutch relays are operated.

3.8.0 Clutch operation

The lower half of Figure 3.7.0 shows the operating path of the clutches.

The power source to operate the clutches is a 100 volt d.c. supply located on chassis 700. This supply receives an a.c. 120 volt input from the power distribution set up.

Sync relay K404 is in series with all uses of this power. The use of K404 at this point and in the clutch selection circuit described above (section 3.7.0) is a double safety measure.

Since only one relay of the group K401, K402 and K403 may be on at any time, only one of the clutches shown in this diagram may be on at a time.

3.9.0 The fail safe brake (11)

Whenever none of the clutches is energized, a brake is applied to the crosshead drive. This brake is of a type that does not require power when it is in the braking mode. It is therefore necessary to supply an active signal to release it.

Figure 3.7.0 shows the brake connections. Contacts on relays K401, K402 and K403 are connected to form an "OR" circuit so that when any one of then is activated, the fail safe brake will be released. Gilmore manual pages 12a and 57 refer to the fail safe brake.

3.10.0 Movement limiting switches

There are switches mounted on the loading frame which sense the crosshead travel if it is either higher than or lower than presetable points. These switches are shown on Figure 5.0.0 and illustrated on Figure 3.0.0a parts (12) and (13.)

These switches act as a safety device and also may be used at the operator's discretion to stop the machine at a fixed point.

The switches operate by disengaging the direction control relays, K405 and K406, which select the direction of crosshead travel. The limit switch will disengage only the relay causing the movement which made the crosshead approach it. The machine is halted by an insistence under these conditions of a zero velocity in the direction of travel toward the switch.

The reason for this type disengagement is to allow the machine to be reversed from the switch. Other circuits must be kept alive.

The movement control relays are discussed in detail in section 5.

3.11.0 Isolated operation of the crosshead for test purposes.

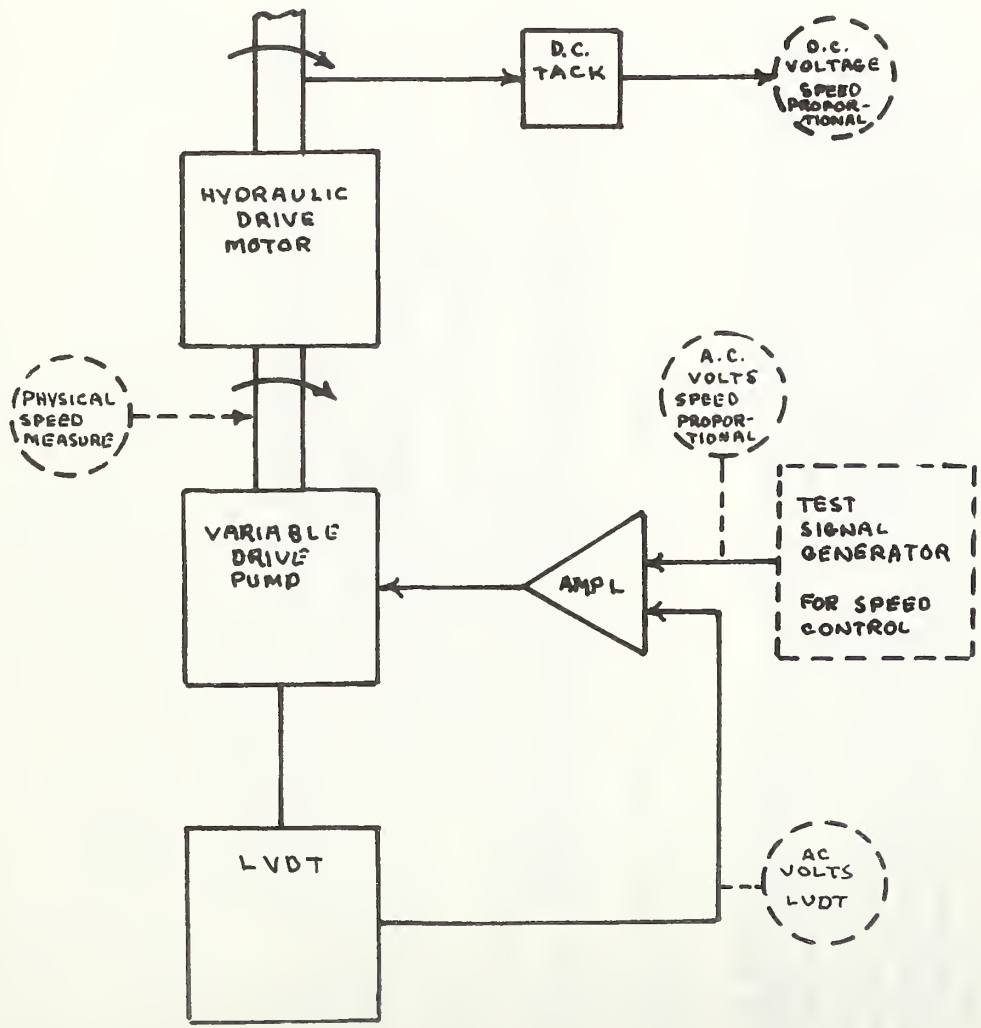
A method is presented for operating the crosshead without using the crosshead control circuitry. This procedure is useful in testing and calibrating the machine. Caution is advised since some of the safety devices are defeated in order to make this method convenient and simple. Most danger is eliminated by starting this procedure with the crosshead position a safe distance away from the limits of travel. Figure 3.11.0 shows the test configuration.

3.11.1 Synchronization circuit adjustments

The synchronization circuit through relay K404 will defeat any attempt to move the crosshead. This circuit must be circumvented.

1. Remove card X402 from its connector in chassis 400.
2. Short-circuit connector pin 23 to pin 21 on X402's connector.

Relay K404 will now stay operated and permit powering the clutch circuits. K404 will no longer provide any safety protection.



GILMORE MACHINE

TEST CONFIGURATION NO. 1
CROSSHEAD DRIVE CONTROL

FIG. 3.11.0

3.11.2 Install substitute crosshead control signal

A calibratible and measurable signal whose character is not subject to feedback variation is needed to establish a constant input to the system. A small test box has been built for this purpose. Figure 3.11.2 shows the circuit of this box and the interconnection of the box with the crosshead assembly and the current source.

1. Disconnect the leads on the oil gear preamplifier pin no. 1.
2. Install the test box as shown in Figure 3.11.2. Start with the Variac set at zero.

3.11.3 Instrumentation of the test set up

1. Connect a d.c. voltmeter to the drive motor tachometer. Use a ten volt scale.
2. Connect an a.c. voltmeter to the test box output terminals. Signal here should not exceed 2 volts. Positions of these meters are shown on Figure 3.11.2.

3.11.4 Machine controls to be used

1. Main power on.
2. Crosshead power on.
3. Speed range select (Any one of the three is usable). Selection depends on the speed the tester wishes to use.

3.11.5 Test operation

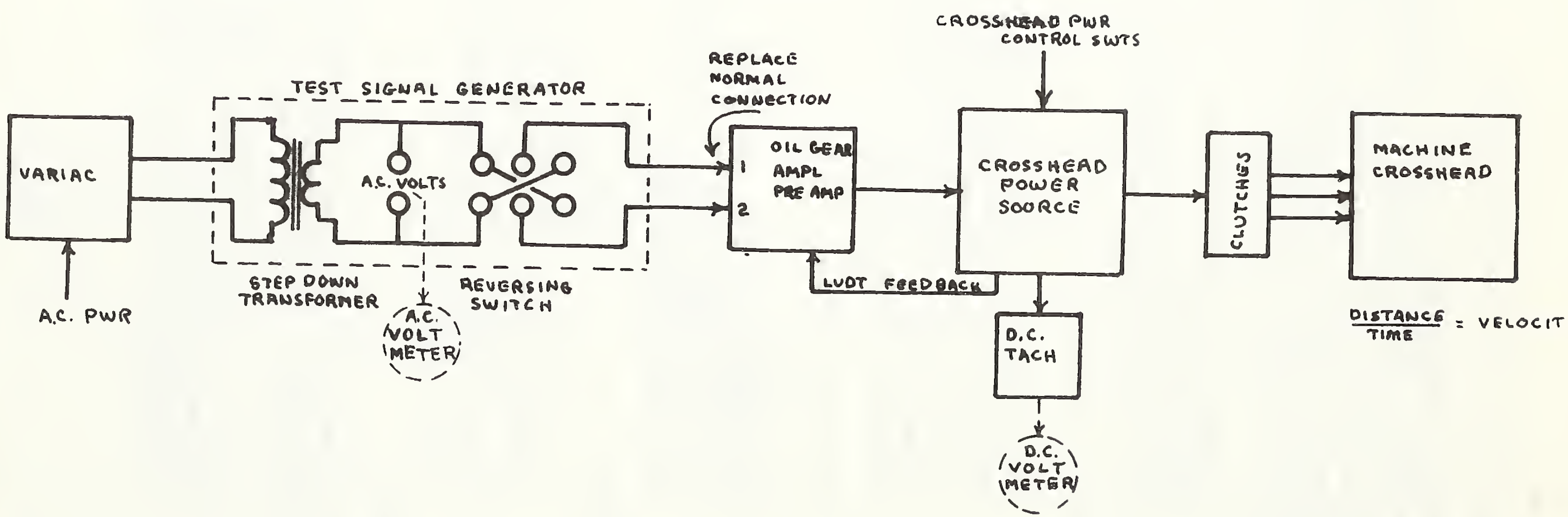
1. Direction of crosshead movement is now under control of the reversing switch on the test box.

2. Speed of movement of the crosshead is now under control of the Variac.

3.11.6 Test results

Nominal maximum speed is attained in any range with the input signal equal to 1 volt. This may be ascertained in either of two ways:

1. When a reading of 6.48 volts appears on the tachometer voltmeter.
2. By measuring the distance the crosshead moves in one minute.



MACHINE CROSSHEAD

TEST SYSTEM LAYOUT

FIG. 3.11.2

The gain controls on the oil gear preamplifier and/or amplifier are varied to attain this condition. Since both input and feedback gains are involved, this adjustment may not be attained immediately. When satisfactory points of operation are reached, it is suggested that the gain settings be recorded for future reference.

A further note of caution is in order. The tester may obtain an apparently good set of values for these gains and find that there is some tendency toward oscillation under operational or loaded conditions. Under these circumstances it is necessary to find a new set of gain settings which will characteristically be lower in value than the previous ones.

More precisely settable procedures will require significantly more study of the resonance characteristics of the crosshead assembly and probably a more sophisticated test procedure.

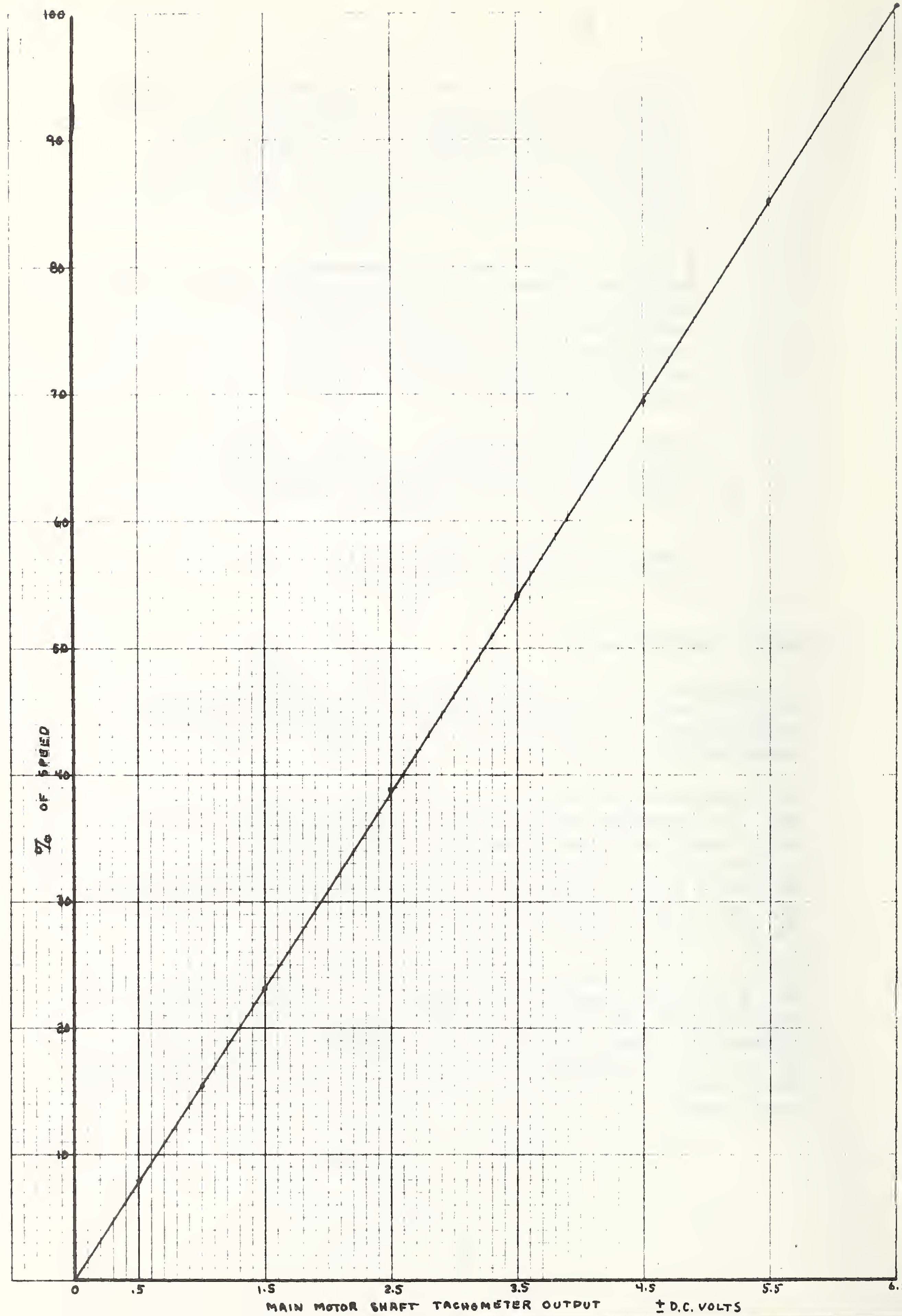
Figure 3.11.6 is a graph showing crosshead speed plotted against tachometer voltage.

Section 4 - Synchronization

4.0.0 Synchronization is a title, covering the machine alignment function, which is used as an indicator of control performance. Gilmore manual page 40 is suggested as additional reading to understand this function.

The crosshead drive motor is controlled by circuits on chassis 400. The crosshead drive motor has a slave to master relationship with a small servo-control motor in this chassis. The synchronization circuit measures the relationship between these two motors and disconnects the drive train if evidence appears that the drive motor is not fully responsive to the position of the servo control motor.

The servo control motor is driven by electrical signals called into play by the operator of the machine. These are direction and speed signals. An error signal develops proportional to the difference in shaft positions of the two motors. This signal is applied to the crosshead control amplifier and the crosshead drive motor moves in a direction and at a rate that tends to cancel the error signal.



100
90
80
70
60
50
40
30
20
10
% OF SPEED
0
.5
1.5
2.5
3.5
4.5
5.5
6.5
MAIN MOTOR SHAFT TACHOMETER OUTPUT ± D.C. VOLTS

Figure 4.0.0 shows the motion control loops. Further reference is made to this diagram later. The section of interest in this discussion is the dotted block labeled Control Failure Detector, which is attached to the crosshead control amplifier input.

Two things are immediately evident:

1. The synchronization circuit monitors the crosshead control signal itself.
2. The crosshead control signal itself monitors the relationship of the servo to drive motors, through the synchros. Any instability in the system will be seen at this point.

4.1.0 Initialization of the synchronization

A method exists to start the system with the motors synchronized. This is accomplished by preventing movement of the crosshead drive motor and turning the servo motor until the attached synchros yield the information that the two shafts are aligned.

A relay K409 is assigned to the direction of this process. Figure 4.1.0 shows the relationship of this relay to the rest of the synchronization circuit. The actual movement of the servo motor is also a function of K409 and is discussed under a later section. For this section we need only know that movement occurs.

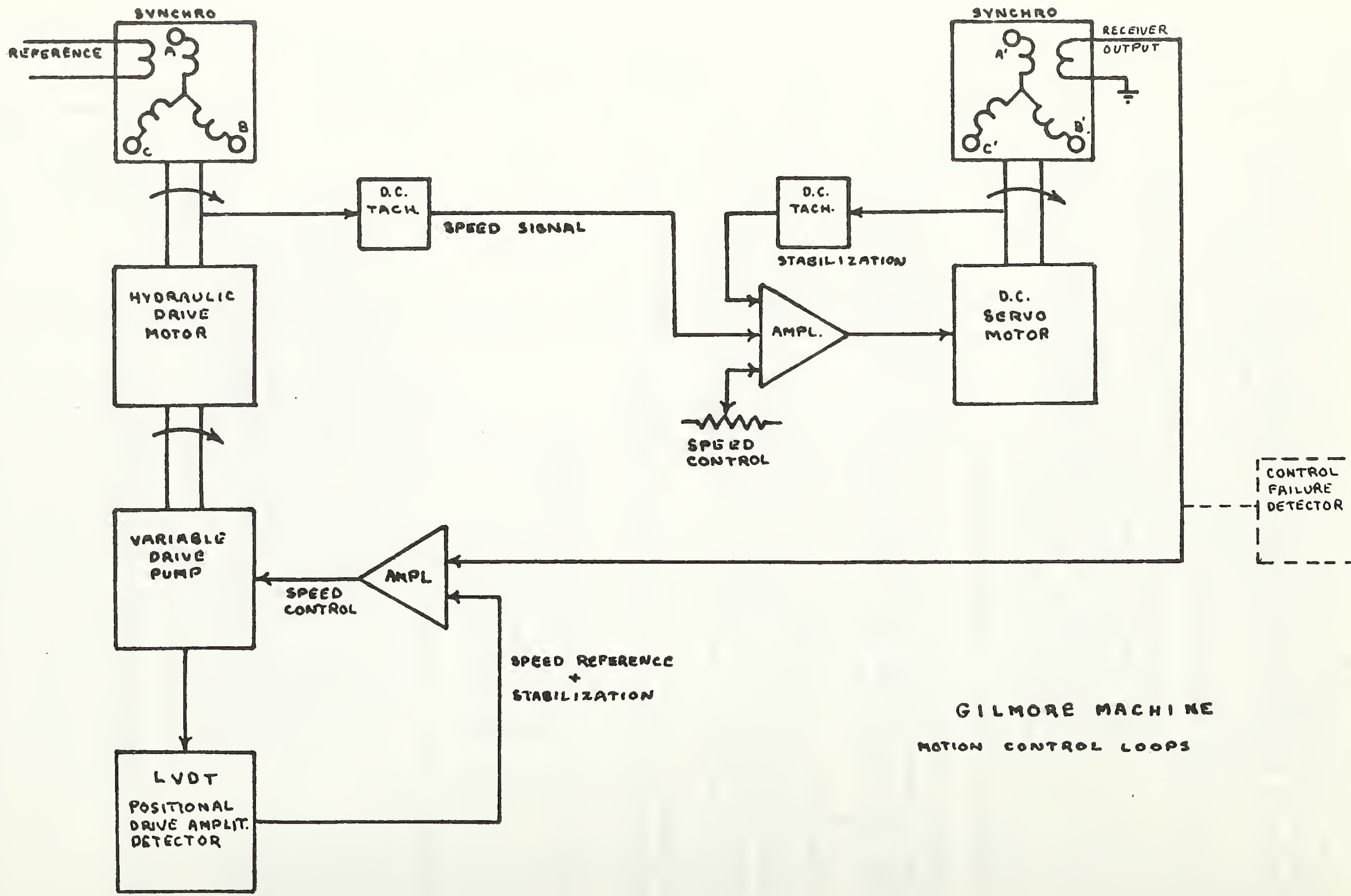
The movement of the servo motor occurs whenever K409 is operated. There are six paths by which K409 is initiated:

1. By sync on switch.
2. By the remote console lead.
3. By manual down switch.
4. By jog down switch.
5. By manual up switch.
6. By jog up switch.

Relay K409 can be prevented from operating by:

1. Operation of synchronizing relay K404. This means that since K404 is operated, the machine is already aligned and K409 cannot be useful.
2. Operation of the sync off switch. This is a logical error. There is no point in calling for sync on at the same time that a call is issued for sync off. This condition will occur only when someone is pushing buttons in a random or illogical manner.

Both relays K409 and K404 are operated by grounding, one



GILMORE MACHINE

MOTION CONTROL LOOPS

FIG. 4.0.0

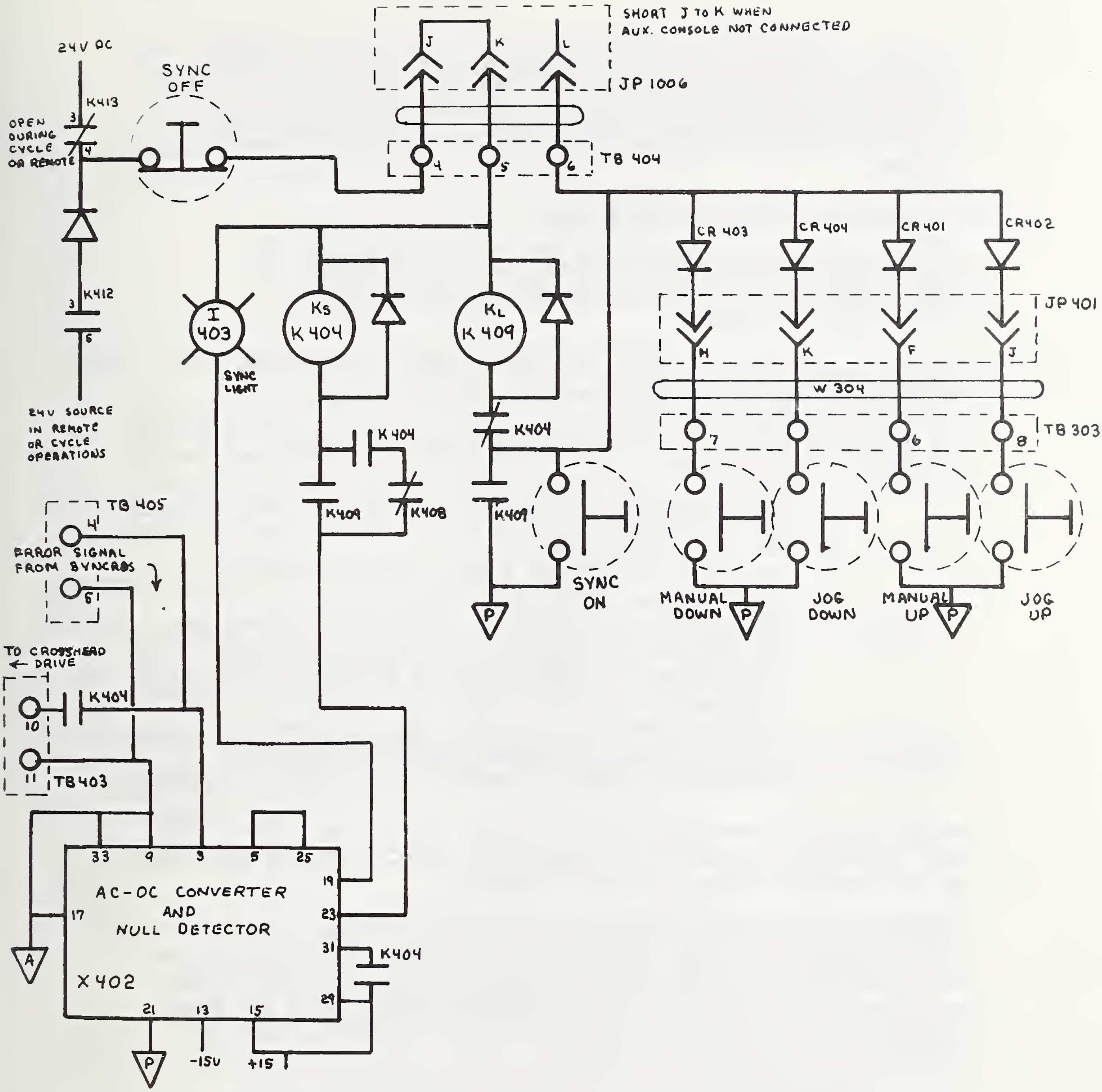

SHORT J TO K WHEN
AUX. CONSOLE NOT CONNECTED
J
K
L
JP 1006
24V DC
SYNC
OFF
K413
OPEN
DURING
CYCLE
OR REMOTE
TB 404
CR 403
CR 404
CR 401
CR 402
JP 401
I
403
SYNC
LIGHT
Ks
K 404
KL
K 409
K412
24V SOURCE
IN REMOTE
OR CYCLE
OPERATIONS
W 304
TB 303
K 404
K404
K409
K408
SYNC
ON
MANUAL
DOWN
JOG
DOWN
MANUAL
UP
JOG
UP
TB 405
ERROR SIGNAL
FROM SYNCROS
TO CROSSHEAD
DRIVE
K404
TB403
AC-DC CONVERTER
AND
NULL DETECTOR
X 402
K404
-15V
+15

FIG. 4.1.0

terminal. Except in error detected or manual sync off modes, the terminals of the relays sensing the 24 volt drive source are awaiting operation, with the voltage present. All six methods of turning K409 on are by grounding the low terminal.

4.2.0 Operation of sync on relay K404

When K409 has been turned on by any of the six means, it locks itself on and the servo motor searches for the synchronized position.

At this time the error signal of the synchros is sensed by detector X402 which is also shown on Figure 4.1.0.

The fact that K404 is not operated causes the following actions:

1. The crosshead clutches cannot operate.
2. The fail safe brake is on.
3. The crosshead control signal is removed from the crosshead drive amplifiers.
4. The null detector X402 is forced into a sensitive mode so that it will not report the null until the alignment of the shafts is very close. In a practical operational state, the shafts are never exactly lined up. The starting alignment forced by this system is closer than the shafts will travel in relation to each other except when halted.

Relay K409 also sensitizes relay K404 by closing the path to the null detector along which the relay K404 will ultimately be turned on by grounding through the null detector.

When the null detector senses a very close alignment, it grounds the return lead of K404, and the relay and the sync on light are both operated. The sync on light is a variable intensity light and glows with a brillance related to the closeness of the shaft positions. In operation, dimming of this light gives warning prior to an out of sync shutdown.

Operation of K404 disconnects K409 and sensitizes machine circuits such as clutch control and the control amplifier.

The locking circuit for relay K404 is now held through a series of a set of contacts of K404, a set of contacts of a non-operated K408 (the jog relay) and the null detector circuit. The action of the null detector is now broadened to a point where it will hold the relay K404 operated even with a one volt error signal.

Relay K404 can be turned off, thereby stopping the machine, by three methods. These three methods are representative of abnormal or forced stops. Just stopping the motion of the crosshead does not call for a disconnect of relay K404. However, disconnect of relay K404 will force a stop of the crosshead. Aborted stops occur as a result of three conditions:

1. Manual operation of the sync off button.
2. The detection, by the null detector, of a crosshead drive signal in excess of 1.1 volts.
3. Operation of the jog relay K408.

4.3.0 Importance of synchronization relay K404

This relay serves as a safety valve in the machine. Its contacts open or close paths which have the potential to damage the machine if not used properly. The sensor which controls K404 is in a position to sense the feedback control loop where out of control signals appear as excessive attempts to compensate for fluctuations.

4.4.0 Details of the failure detector

A plug-in failure detector is included in the machine on chassis 400. Gilmore industries entitles this as null detector no. X402. Figure 4.4.0 is the Gilmore schematic.

Operation of the circuit might be better explained by describing it as a synchro phase detector and trigger. It monitors the phase relationship between the main drive synchro and the servo control synchro.

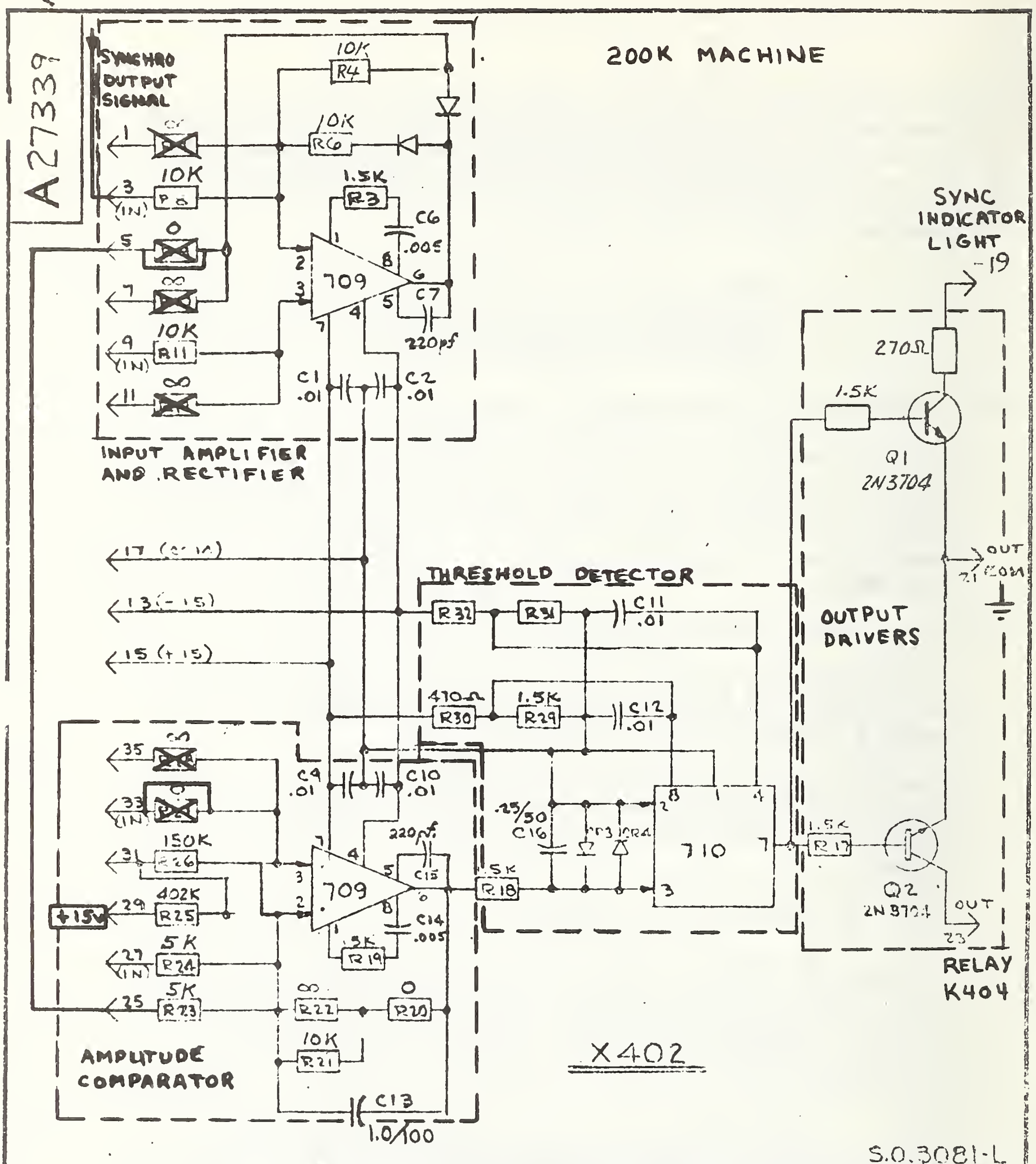
4.4.1 The control failure detector

The control failure detector monitors the output of the servo control synchro. This signal is the drive signal fed into the Oil Gear Company preamplifier as the crosshead drive signal. Figure 3.11.0 shows the position of the circuit.

This signal is a 60 hertz sine wave varying from zero volts to nominal 1 volt for full crosshead speed. Maximum voltage is over 2 volts r.m.s. but this will be attained only during an out of control situation.

4.4.2 Excessive speed signal

This is defined as a controlled crosshead movement at greater than nominal rated speed. Such conditions could be due to poor adjustment of system variables, to



S.O.3081-L

B.M. A-26711

DRILLING C-26709-A

ASSEM. C-27340

REV.	DATE	APPR.	GILMORE INDUSTRIES CLEVELAND, OHIO
			NULL DETECTOR (MODIFIED)
			SCHEMATIC
B	3-31-72		SCALE DATE
A	6-17-68		DRAWN APPR.

A27339 B

FIG. 4.4.0

certain component failures, or to failure of the crosshead to move as directed.

Signal characteristics just prior to detecting this condition will show a steady 60 hertz signal of nearly 1.1 volts r.m.s.

4.4.3 Out of control signal

This fault is characterized by the failure of the two system synchros to track with each other.

The signal is a rapidly fluctuating 60 hertz signal from 0 to over 2 volts r.m.s. and alternating in and out of phase with the 60 hertz system supply power.

4.4.4 Detection of an error

Either type of error is detected by an amplitude detection based on a 1.1 volt threshold accepted at the output of the servo control synchro.

If this voltage exceeds 1.1 volts the system is shut down by opening relay K404.

4.4.5 Operation of the sensor detector electronics

Figure 4.4.5 shows the working parts of this system. This schematic has been stripped of parts which are superfluous to this explanation.

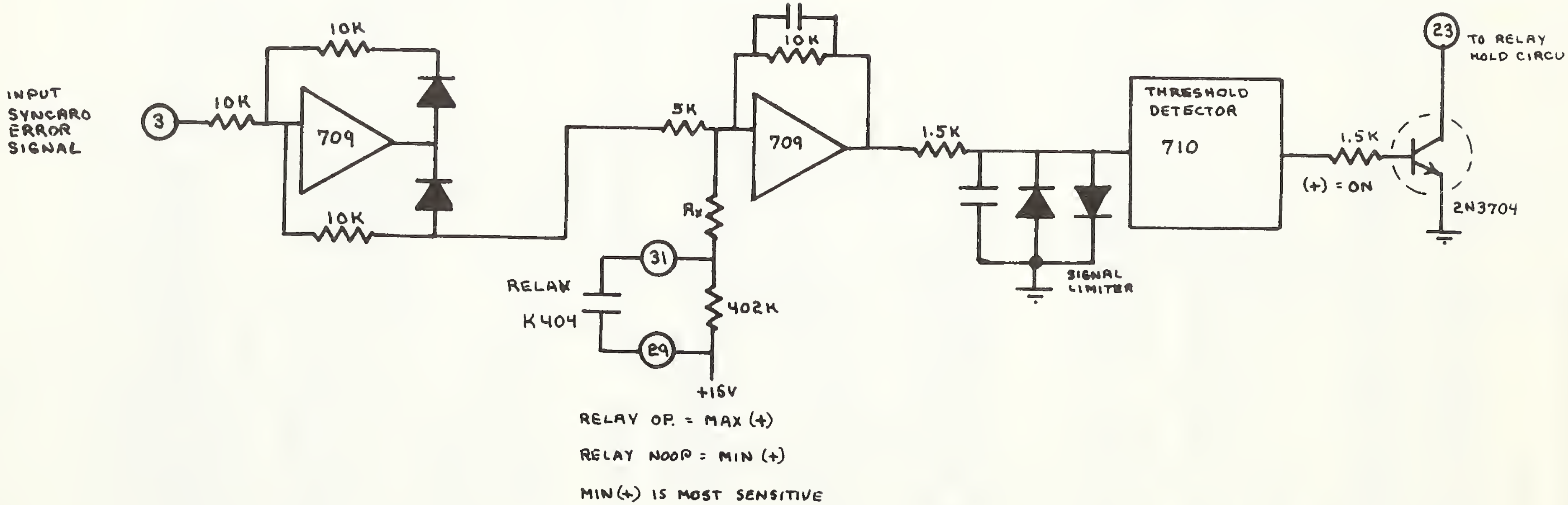
The unit can be divided into four sectors as outlined below:

1. Input amplifier and rectifier.
2. Amplitude comparator.
3. Threshold detector.
4. Output drivers.

4.4.6 The input rectifier is a unity gain operational amplifier which offers a choice of a negative or positive one half wave sample of the crosshead drive signal. The negative signal was chosen for use in this system. Figure 4.4.6 illustrates this signal.

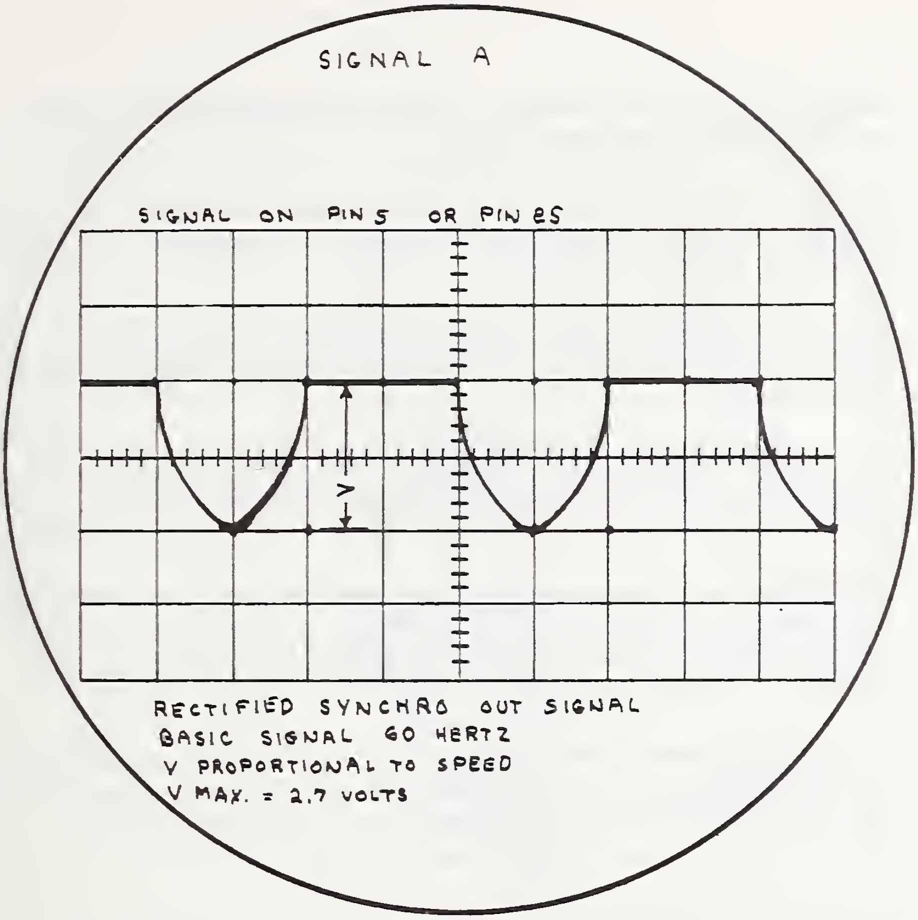
4.4.7 The amplitude comparator sector

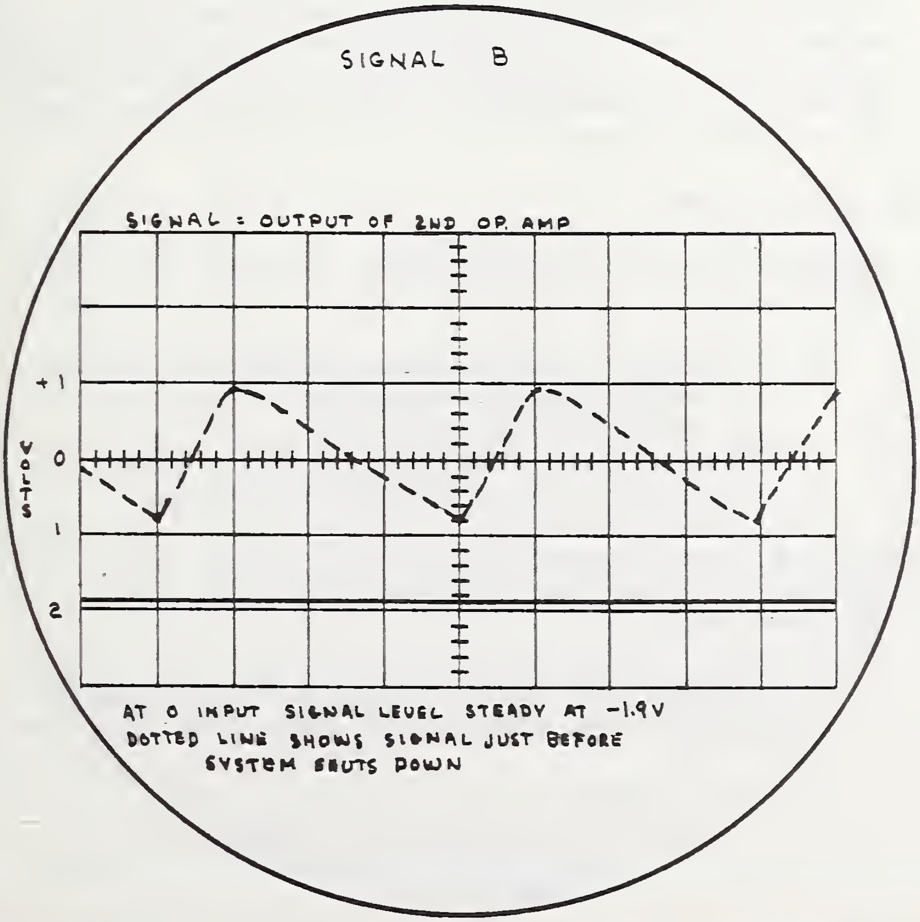
The amplitude comparator sector compares the output of the input rectifier with a d.c. bias signal and



PHASE SENSER DETECTOR
OPERATIONAL PARTS ONLY

FIG. 4.4.5





USCOMM-NBS-DC

FIG H.H.6

amplifies the difference. The lower section of Figure 4.4.6 illustrates this signal.

The d.c. bias used in this sector has two levels of operation. The selection of level of operation is based on relay K404.

The operational level is used whenever the machine is in normal operation and is the mode described heretofore in this manual.

An alignment mode also exists. This mode is automatically called for when relay K404 is in the non-operate condition.

The purpose of this mode is to require that the starting alignment be very close to in-phase before the machine is initially turned on. This avoids a surge when the clutches are powered up.

During alignment, the positive d.c. bias is reduced and the detector becomes responsive to very small signals. The synchros will align themselves in a position to satisfy this small signal sensitivity.

4.4.8 The threshold detector

This amplifier reports the output of the amplitude comparator as either a go or no go signal addressing the output drivers. The crossover input is at ground level. The output of this detector is able to drive the inputs of the output drivers.

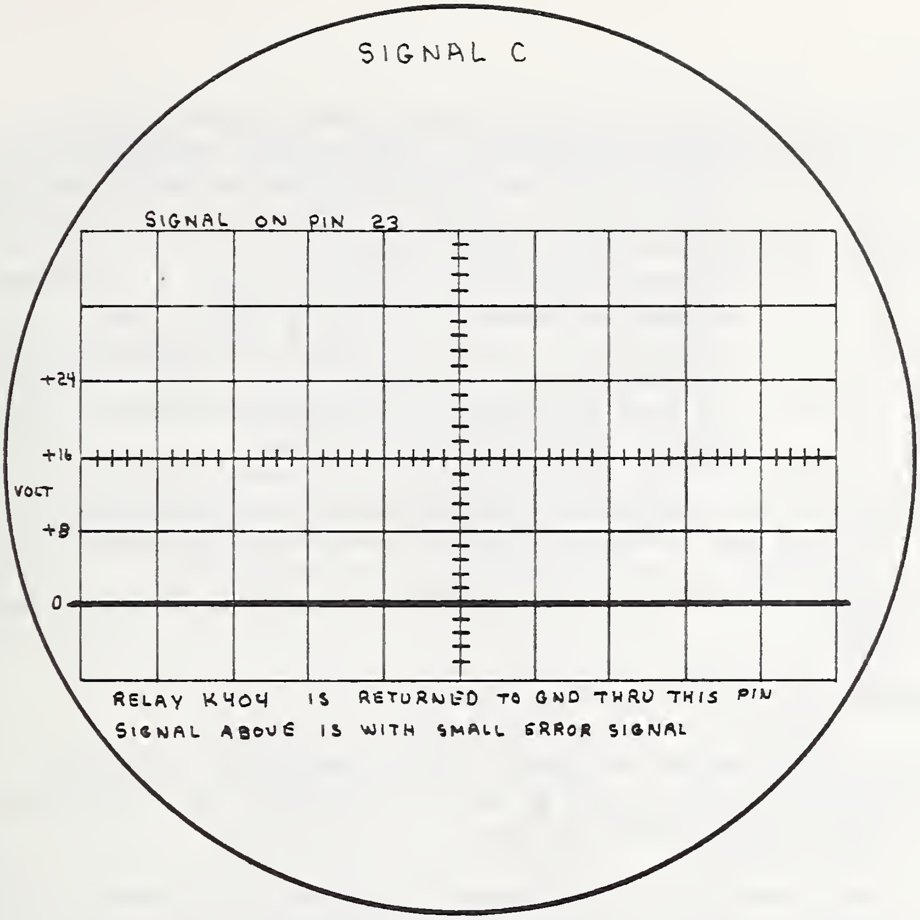
4.4.9 The output drivers

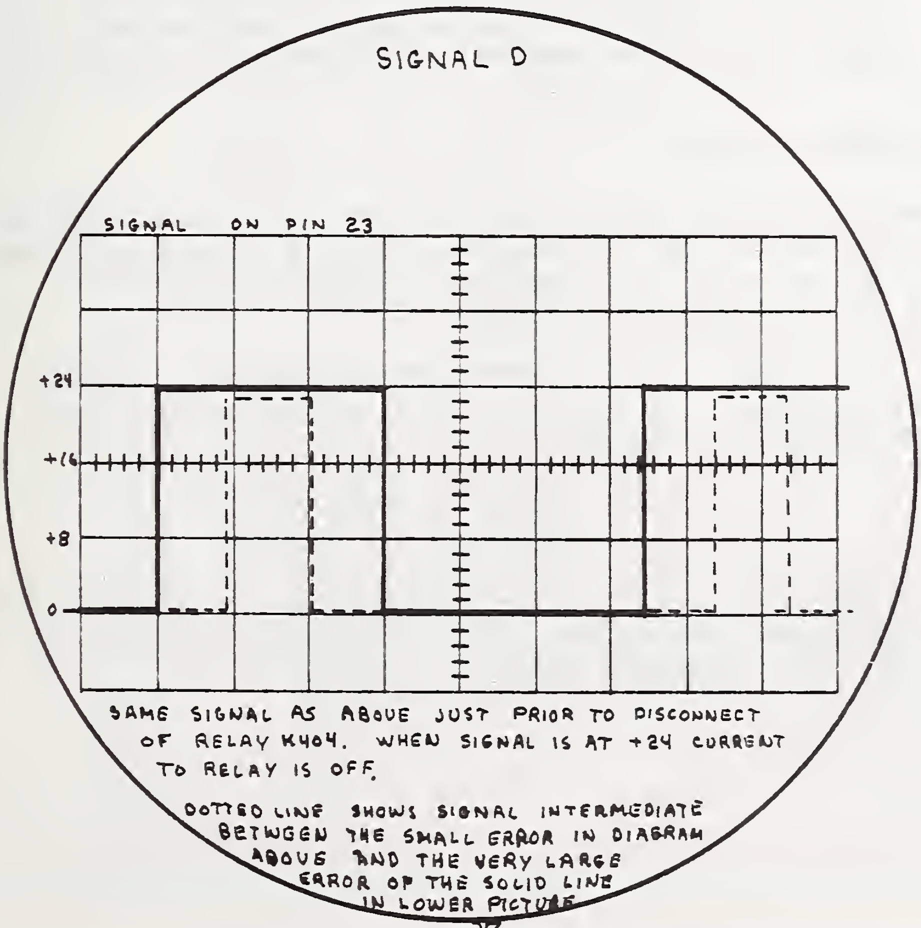
The output drivers are transistors in series with the driven units.

1. Relay K404 cannot operate without the output driver because its coil current is returned to ground through the driver.
2. The front panel indicator light is driven in the same manner by another transistor.

4.4.10 The output signal characteristics in the relay driver setups are illustrated in Figure 4.4.10 and are explained below:

1. Steady state +25 volts when totally inoperative.
2. Steady state ground level when fully operative.





USCOMM-NBS-DC

FIG. 4.4.10

3. A pulsed +25 volt signal when operative but approaching cut off. When the variable pulse duty cycle (time variable) reaches approximately 45% of full time, relay K404 will open up and the system will be shut down.
4. Approaching cut off will be audibly indicated by increasing buzzing from relay K404. The inductance of relay coil K404 is the source of this behavior. It integrates the pulse duration and when the duty cycle reaches the value defined above, the relay opens.

Except for the positive voltage attained, the signal driving the indicator lamp is the same. The lamp drive transistor is in parallel with the relay drive transistor. Dimming of the lamp signals approaching cut off.

4.4.11 Reset of the system

The null detector system is self resetting. Removing the conditions which caused shut down allows the unit to resume its normal settings.

The operation of K404 is self locking if triggered, however. Manual operator intervention is needed to restore the entire system to an operable condition. Service is restored by realigning the synchros and reactivating other desired conditions and controls.

Section 5 - Direction Control

5.0.0 Crosshead direction control relays control the direction of the crosshead in most but not all test conditions in which the machine is used. The exception is in Maintain Load Function where a different control system is employed.

Direction is selected by the polarity of input to the crosshead servo control motor. Two relays, mutually exclusive, are used to achieve this polarity control.

1. Relay K405 will direct downward movement.
2. Relay K406 will direct upward movement.

The shifting of direction is shown by labelled relay contacts on the servo motor control diagram Fig. 6.0.0. This section deals with the operation of the relays themselves.

In addition to direction control functions, there are certain safety measures which enter the system at the direction control points. These are discussed below.

Figure 5.0.0 is a schematic of the circuits treated in this section.

5.1.0 Motion relay turn-on

Motion relay turn-on is by grounding the return terminal of relay.

5.1.1 The system at rest can have both motion relays in the off position. Certain safety responses will in fact return both relays to off at the same time.

5.1.2 The relays can be turned on by four different paths:

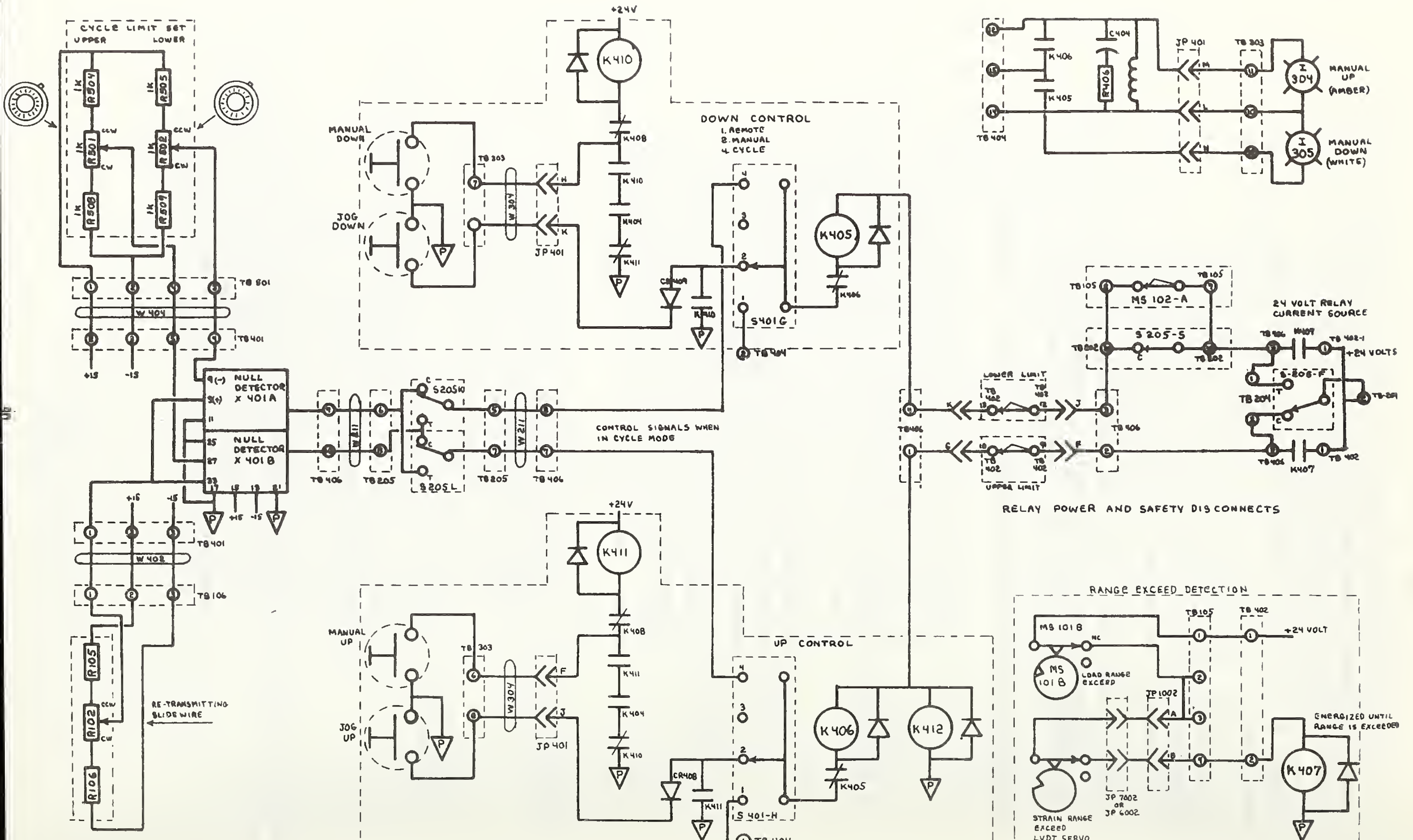
1. By a signal from the remote console through position 1 of the function switch. An example is switch section S401G on this diagram.
2. By a jog switch through a diode by using position 2 (Manual) of the function switch. An example on switch S401G is by the jog down switch, via diode CR409 and position 2 of switch S401G.
3. By closing the contacts of a pickup relay dedicated to this purpose and driven by the manual control select switches.

   An example of this operation starts with the depressing of the manual down switch. This picks up relay K410 as we are not in a jog phase. Relay K410 holds on through the following series of contacts.

   1. Jog relay K408 not operated.
   2. Relay K410 operated.
   3. Sync relay K404 is operated.
   4. Up drive relay K411 is not operated under these conditions.

4. By a null detector which senses the attainment of a preset limit in the cycle mode. This system is outlined immediately below:

   1. Null detector X401B compares the retransmitting slidewire R102 with the preset upper limit and will, when a match is made, turn on, through compression-tension selector switches S205K and S205L, the proper up or down control relay to start the crosshead



CYCLE LIMIT SET
UPPER
LOWER
NULL DETECTOR X 401A
NULL DETECTOR X 401B
DOWN CONTROL
1. REMOTE
2. MANUAL
4. CYCLE
MANUAL DOWN
JOG DOWN
MANUAL UP
JOG UP
UP CONTROL
CONTROL SIGNALS WHEN IN CYCLE MODE
RE-TRANSMITTING SLIDE WIRE
MANUAL UP (AMBER)
MANUAL DOWN (WHITE)
24 VOLT RELAY CURRENT SOURCE
+24 VOLTS
LOWER LIMIT
UPPER LIMIT
RELAY POWER AND SAFETY DISCONNECTS
RANGE EXCEED DETECTION
+24 VOLT
LOAD RANGE EXCEED
STRAIN RANGE EXCEED LVDT SERVO
ENERGIZED UNTIL RANGE IS EXCEEDED

FIG. 5.0.0

moving in the direction opposite to that which brought it to this balance point. This selection of relay is accomplished through position 4 of the function switches S401G and S401H.

2. The reversing action at the other limit is a function of null detector X401A.

5.2.0 Holding operation of motion direction relays

Each of the four means of turning on the direction control relays has associated with it a variation of a relay hold scheme.

1. The remote connection is a direct line, and the holding pattern is a function of the remote console.
2. The jog operation will hold the direction relay on only as long as the jog button is held depressed.
3. In manual operation, the drive relay (K410 or K411) serves as a holding relay.
4. In cycle the null detectors serve as hold down drivers also.

5.3.0 Turn-off of the direction control relays

These relays do not guarantee motion since other machine factors must be satisfied or called upon to actually achieve motion. The four paths of operation are again the basis for the list below of how the direction control relays are cancelled.

1. Remote turnoff is a function of unspecified (as far as this discussion is concerned) procedures.
2. Turn-off in jog is automatic as soon as the button is released.
3. Turn-off in manual has two forms. This discussion excludes those safety features which are part of this schematic. Since the relays lock on in manual mode, turn-off must be a deliberate process. It is accomplished as follows:

    1. Whenever the alternate direction control is activated, it cancels the one in existence.
    2. Activation of the sync off procedure will cancel both direction control relays by cancelling the driver-hold relays K410 and K411.

4. There is no provision for turning off both relays

in the cycle mode since that action is logically incompatible with the cycle mode. Turning off a particular direction control is accomplished by turning on the opposite direction control.

5.4.0 Indicator lights on the face of chassis 300 show which, if any, of the direction control relays is on. The control circuits for turning on these lights are shown in Figure 5.0.0

5.5.0 Safety functions associated with the direction control system All normal turning on of the direction control relays is accomplished by grounding the return terminal of the relays.

All safety turnoffs are accomplished by removing the current supply to the relays.

Response to a safety violation is to prevent further movement in the direction that has led to the problem but to leave open optional travel in the opposite direction to relieve the condition which led to the problem.

5.5.1 Range exceed problems

Two forms of range exceed are recognized:

1. Load range.
2. Strain range.

Both conditions are detected at appropriate points and reported by opening a normally closed relay K407. This circuit is shown on schematic Figure 5.0.0.

Opening K407 would cut off current to both directional relays except for the presence of tension-compression switch S205F, which holds current on whichever of the two will carry the crosshead in the direction needed to relieve the strain or load.

5.5.2 Limit exceeded problems

These problems are caused by the crosshead reaching the microswitches that detect a motion so extreme that no further motion in that direction is to be permitted.

A switch is positioned at each limit of travel to prohibit travel in that direction. No bypass is possible of these switches.

Section 6 - Crosshead Drive Control

6.0.0 Crosshead drive servo control

This controller acts through the Oil Gear amplifiers to actually control the rate of movement as well as the direction of movement of the crosshead.

Figure 6.0.0 shows the elements involved in this control.

The principle of operation is to drive the servo control motor in the desired manner and then to entice (via the Oil Gear amplifiers) the crosshead drive system to follow this movement.

Figure 6.0.0a is a block diagram showing the control loops involved.

6.1.0 The command servo motor

Motor X403 is the servo control motor. (See Figure 6.0.0) This motor has a d.c. tachometer on its shaft and is directly coupled to a synchro labelled the synchro receiver.

A meter is connected to the driving signal to show the rate of loading of the motor.

The motor is driven by amplifier X404 whose purpose is to provide the power gain needed to convert the drive signal to a level capable of driving the motor. A special power supply X403 supplies the current for this amplifier to use in driving the command servo motor. This supply is not well regulated and does not have to be. Ripple on its output will not introduce problems.

6.2.0 Command servo signal mixer

Operational amplifier P65AU is the source of the signal which was the subject of section 6.1.0 above. This is a feedback amplifier mixer which combines the motion command with the motion response of both the command servo and the crosshead drive motor. Its output is the one amplified to drive the command servo.

Three signals are fed into a current summing input of this amplifier:

1. The motion control signal. This signal has a number of sources, the sum of which appears on the input of R21 as the effective drive signal.

2. A negative feedback signal derived from the command servo tachometer. This is on the shaft

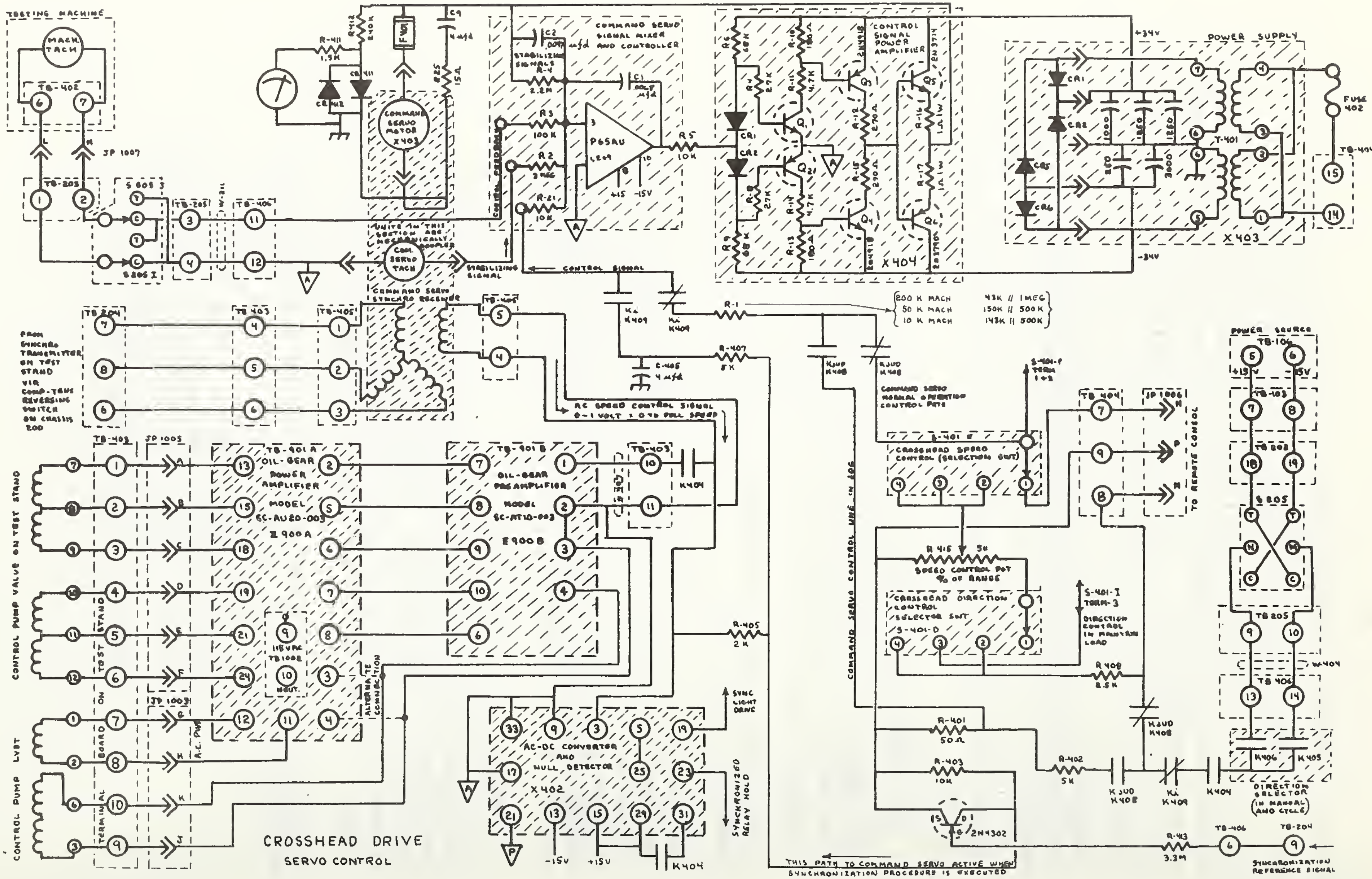
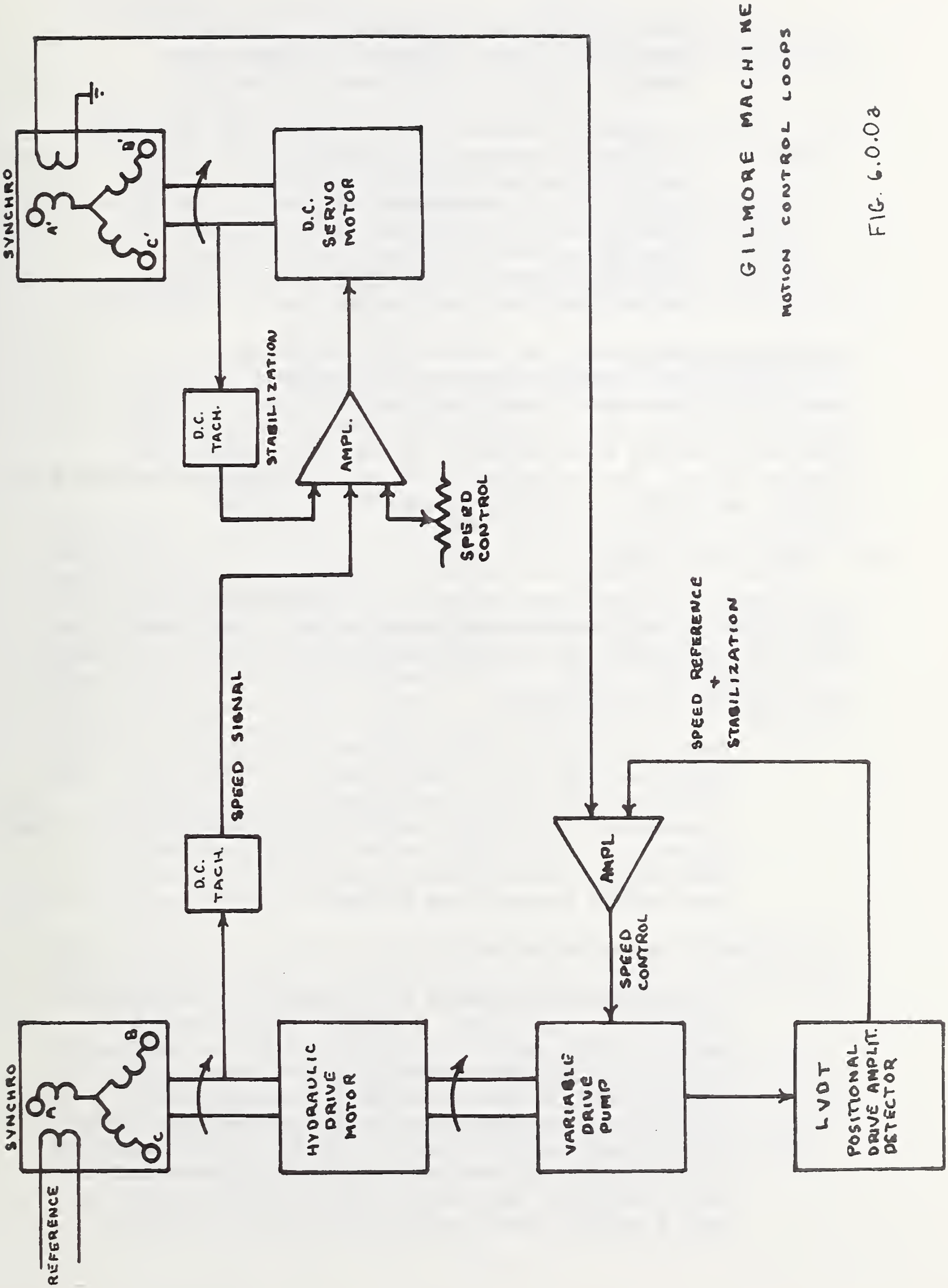

CROSSHEAD DRIVE
SERVO CONTROL
TESTING MACHINE
MACH. TACH
POWER SUPPLY
X403
X404
CONTROL SIGNAL POWER AMPLIFIER
COMMAND SERVO SIGNAL MIXER AND CONTROLLER
P65AU
COMMAND SERVO MOTOR X403
CONTROL SIGNAL
STABILIZING SIGNAL
COMMAND SERVO SYNCHRO RECEIVER
OIL-GEAR POWER AMPLIFIER MODEL SC-AU20-003 E900A
OIL-GEAR PREAMPLIFIER MODEL SC-AT10-003 E900B
AC-DC CONVERTER AND NULL DETECTOR X402
AC SPEED CONTROL SIGNAL 0-1 VOLT : 0 TO FULL SPEED
CROSSHEAD SPEED CONTROL (SELECTION SWT)
CROSSHEAD DIRECTION CONTROL SELECTOR SWT
SPEED CONTROL POT % OF RANGE
COMMAND SERVO CONTROL LINE IN 406
TO REMOTE CONSOL
POWER SOURCE
DIRECTION SELECTOR (IN MANUAL AND CYCLE)
SYNCHRONIZATION REFERENCE SIGNAL
THIS PATH TO COMMAND SERVO ACTIVE WHEN SYNCHRONIZATION PROCEDURE IS EXECUTED
CONTROL PUMP VALVE ON TEST STAND
CONTROL PUMP LVDT
TERMINAL BOARD ON TEST STAND
SYNC LIGHT DRIVE
SYNCHRONIZED RELAY HOLD
200 K MACH 43K // 1MEG
50 K MACH 150K // 500K
10 K MACH 143K // 500K

FIG. 6.0.0



GILMORE MACHINE

MOTION CONTROL LOOPS

FIG. 6.0.0a

of the command servo motor and acts to stabilize or counteract the motion control signal. The magnitude of this feedback is determined by resistor R2 which is its input resistor.

3. A negative feedback signal derived from the cross-head motor tachometer. A significantly larger negative feedback signal, similar to 2. above, originates in a tachometer attached to the drive motor shaft. This signal enters the amplifier through resistor R3. From the resistance of R3, the contribution of this path is 7-1/2 times larger than that from the servo motor tachometer.

Recapitulating the above, we see an input signal which is stabilized by two feedback responses. Fortunately for the simplicity of operation, these loops do not require adjustment in normal operation. It is possible that further study of this system will dictate more desirable relationships between the feedback ratios. Such adjustments are not operationally necessary but will be preset to a single optimum set of values.

6.3.0 Input control signal

This section will deal with the sources and adjustment of the input signal to the command servo signal mixer. This signal enters, as outlined above, through resistor R21.

6.3.1 Control by relay K409

The first control path encountered when tracing backwards from R21 is that dictated by relay K409. This is the special path for synchronizing the machine by alignment of the Synchro receiver with the synchro transmitter. This input enters through resistor R1. These signals are isolated by relay contacts and no interference between them exists.

6.3.2 Control by jog relay K408

The next choice presented to the servo control is that dictated by relay K408. A special short movement is called for by jog and this is a direction sensitive command. Relay K408 selects a special signal via resistor divider R402 and R401 whose polarity is determined by up-down selection relays K405 and K406, via terminal board 406 pins 13 and 14. Operation of jog as outlined in another section forces the operation of one or the other of relays K405 or K406 thus assuring that a current source will exist for this operation.

6.3.3 Operational Control

Absence of K409 and K408, as outlined immediately above, will result in the input signal coming through selector switches S401-D and S401-E. These are arms of the machine function selector switch.

1. Remote function places control in the remote console entirely.
2. Manual function and cycle function obtain current through the speed control potentiometer, through resistor R408 and ultimately through the direction control relays K407 and K405 at the same point as the jog operation in section 6.3.2.
3. Maintain load uses the same speed control potentiometer as in 2 above. Its signal source is the maintain load amplifier M180A via switch S401-I.

6.4.0 The output signal

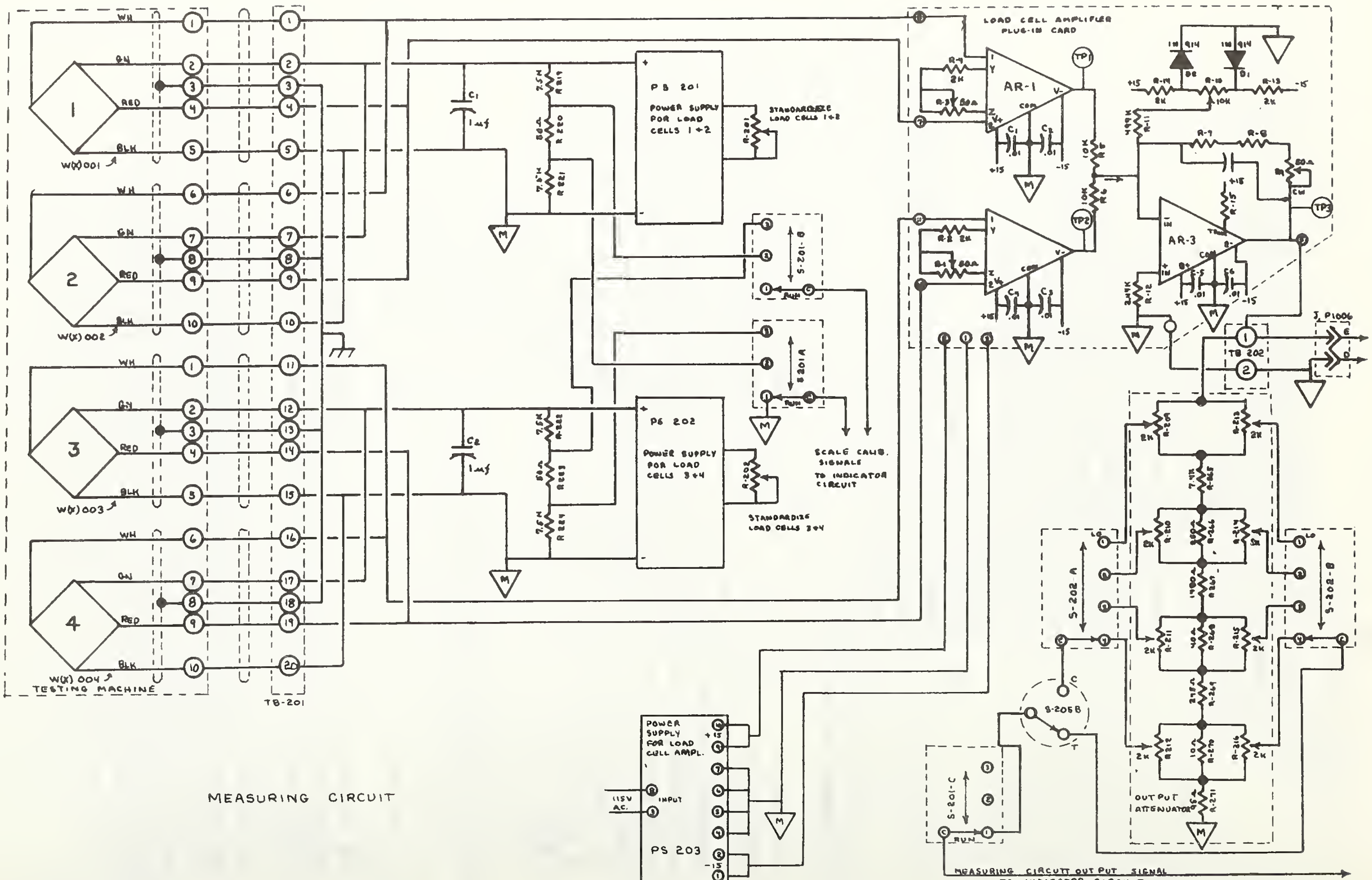
Discussion in this section has been related to driving the command servo motor. The output or crosshead drive signal is derived from the positional relationship of the synchro transmitter on the crosshead drive motor and the synchro receiver on the command servo motor. The command synchro is shown on Figure (6.0.0). The drive signal appears on TB405 pins 4 and 5. The signal is fed directly to the Oil Gear preamplifier via TB403 terminals 10 and 11. The signal is also subject to interruption by relay K404 and is monitored by detector X402, which is explained in section 4.4.0.

Section 7 - The Measuring Circuits

7.0.0 The measuring circuits

The measurement of force is based on the response of four load cells located under the loading frame lower platen. These cells are connected as described in Gilmore manual section 7.1.

Subsequent to original delivery of these machines the Astrodata amplifying system was replaced with an amplifying system mounted on a card and shown on Figure 7.0.0. This figure shows the load cells, their power supplies, the load cell amplifiers and mixers, and the output dividers. It is extracted from Gilmore drawing D27142 sheet 2.



MEASURING CIRCUIT

FIG 7.0.0

Figure 7.0.0 shows the parts that are discussed in this section section of the manual. It starts with the load cells and ends with a single output which is proportional to force.

7.1.0 The load cells

The method of connecting the load cells is given in Gilmore manual section 7.1. The electrical equivalent of a pair of the cells as connected is shown in Figure 7.1.0 for the 200K machine. Location and mounting details will be found in section 4.3 of the Gilmore manual. Figure 7.1.0a shows the load cell orientation on the platen.

Figure 7.0.0 shows the details of the connection of all cells in the machine.

Power supplies PS201 and PS202 serve the load cells and are dedicated to this one use. Potentiometers and switches shown on the drawing are used to calibrate or standardize the cells. These parts are designated potentiometers R201 and R202, switches S210A and S201B. These components are mounted on chassis 200.

Instructions for standardizing the load cells are given in the Gilmore manual section 5.1.4.

7.2.0 The load cell amplifiers and mixer

The signal amplifiers, the mixer, and the power supplies for these parts are mounted in a box attached to the loading frame. These components are placed close to the load cells to minimize noise problems. The minimum forces detected by the load cells correspond to a 1/2 microvolt signal. The distance between the console and the loading frame and the number of connecting lines made close placement of the amplifiers mandatory if the lowest range of the machine was to be used.

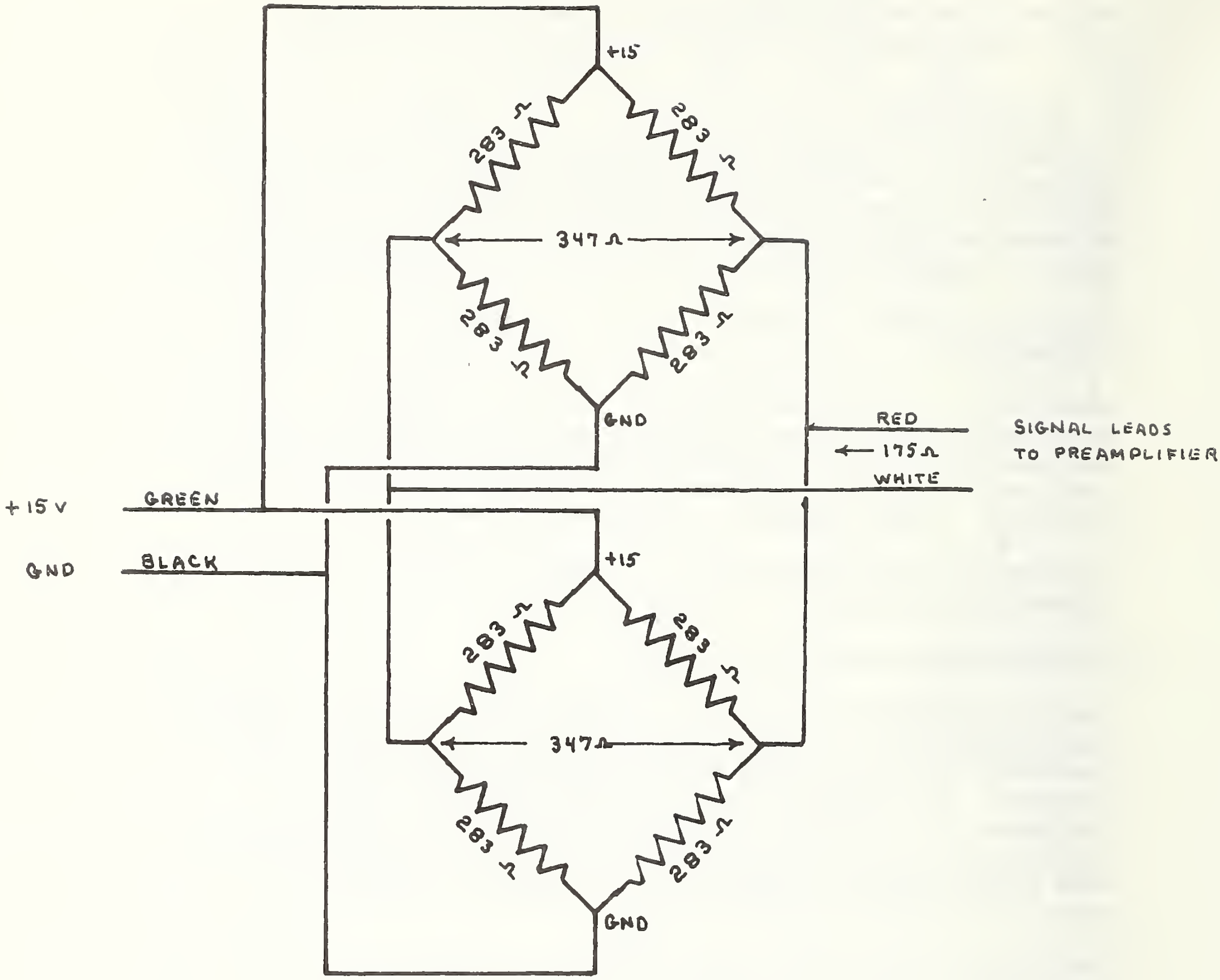
The single output line of these components carries an amplified signal whose minimum is in the low millivolt range.

Parts involved in this section are shown on Figure 7.0.0 and are identified as:

1. Power supply PS203.
2. Amplifiers AR-1, AR-2 and AR-3.

The output line has two destinations:

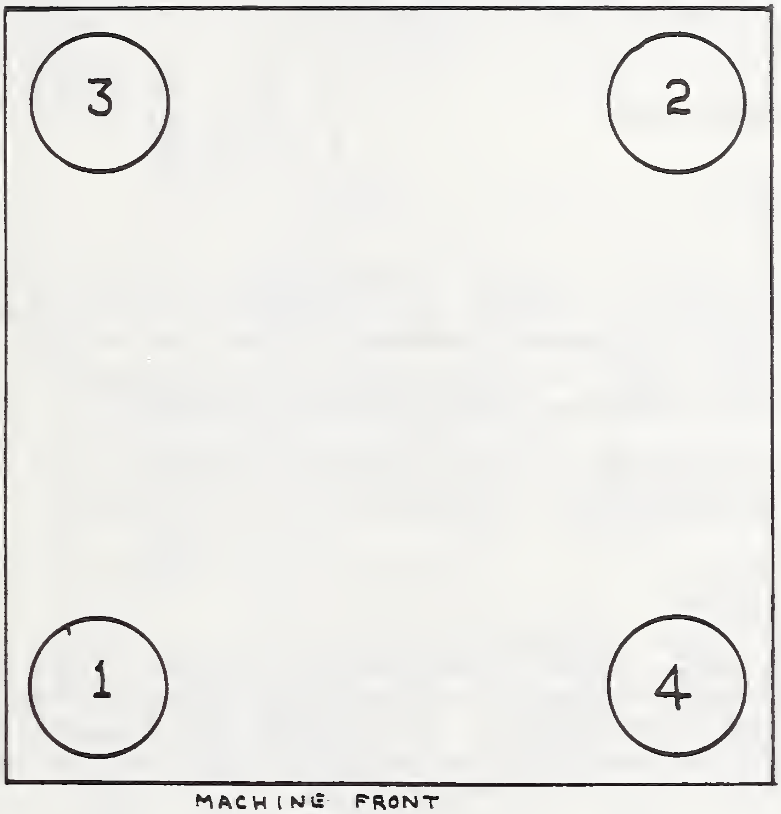
1. The remote console.
2. The range selection divider in chassis 200.



GILMORE 200K MACHINE

LOAD CELL EQUIVALENT CIRCUIT AND METHOD OF CONNECTION.

FIG. 7.1.0



LOAD CELL LOCATION GILMORE MACHINES

FIG. 7.1.0a

7.3.0 Range selection

The manufacturer chose to use a single fixed gain wide range amplifying system for the machines.

Range changing is accomplished by using a fraction of the amplifier output for the higher loads. Figure 7.0.0 shows this system. The signal input enters the system on TB202-1 terminal. With the range changing accomplished, the signal output leaves the system on the moving contact of switch S210-C.

A description of the divider and its use and adjustment is given in Gilmore manual section 7.1, page 34.

Section 8 - Maintain Load

8.0.0 Introduction

This section explains the electronics used in the maintain load mode. This circuit is unusual in its relation to the drive systems in that it bypasses the normal up and down relays. The system is called when the function switch is in the maintain load position, or it can be called by the remote console.

Figure 8.0.0 shows the circuits which are discussed. The function switch is in the maintain load position on this diagram.

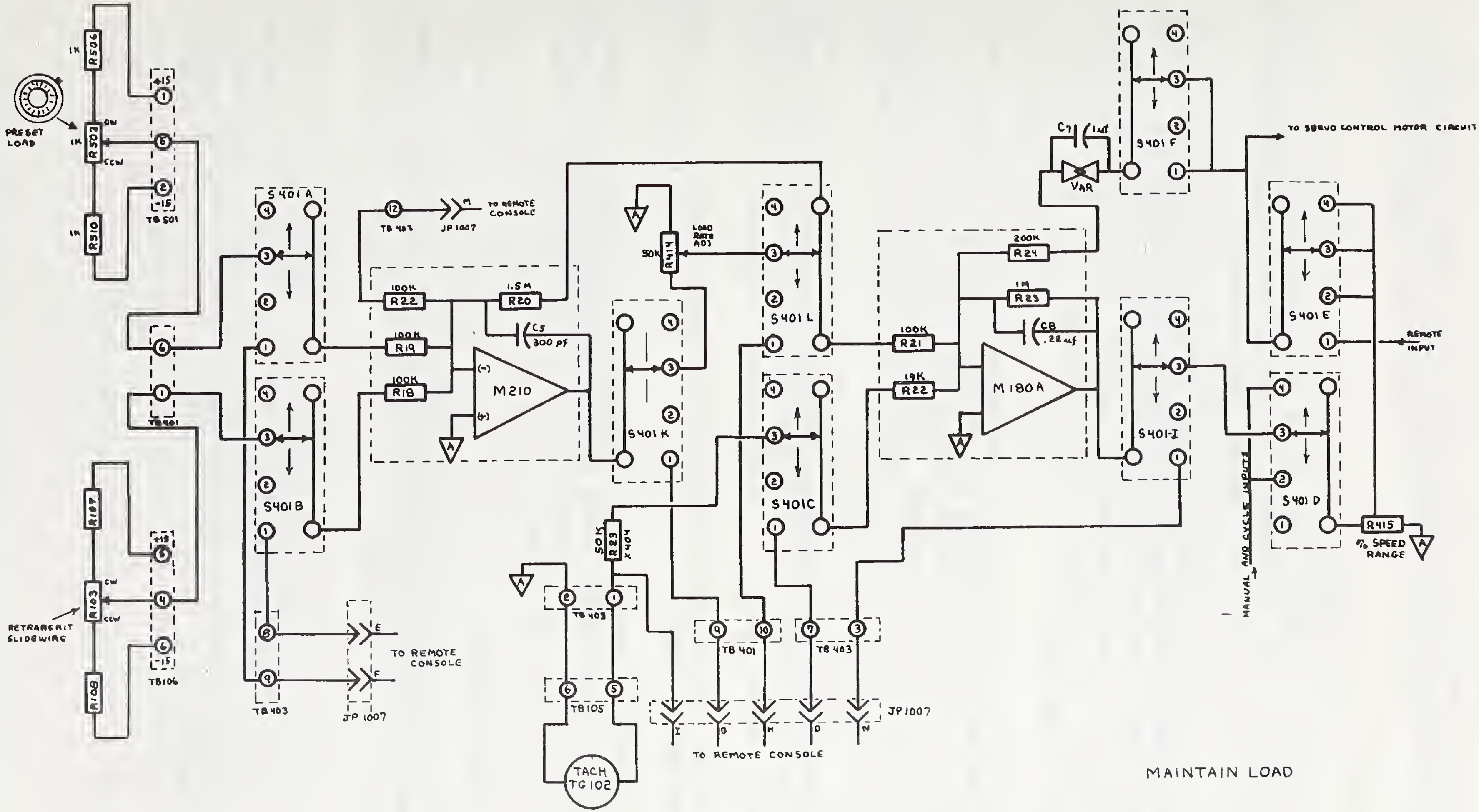
8.1.0 Signal sources

A reference signal (which is entered as a percent of full scale voltage reference) is given to the machine by the operator using the preset load potentiometer. This signal enters operational amplifier M210 by the path from the source potentiometer R503, through TB501-5, TB401A and resistor R19.

The reference signal is compared with the retransmitting slidewire R103. The slidewire reports the percent of range position actually in force on the machine. The slidewire signal enters amplifier M210 from the source slidewire R103 by the path RB106-4, TB401-1, S401B and resistor R18.

8.2.0 The error signal

If these signals are equal in amplitude, amplifier M210 reports a zero output. If the signals are not equal, the amplifier delivers



MAINTAIN LOAD

FIG 8.0 0

a signal proportional to their difference, whose polarity will show which input exceeds the other.

8.3.0 Reaction rate control

The output of amplifier M210 is not fed directly to the crosshead servo control. It is entered into another operational amplifier whose task is to mix two forms of rate control.

The output of M210 is fed via switch S401K to potentiometer R414 whose arm will now represent a linear fraction of the error signal. This fraction voltage is fed through switch S401L and resistor R21 to amplifier M180A. This is now the error signal modified to drive amplifier M180A at a lower rate than the full signal out of M210.

The tachometer TG102 monitors the movement of the slidewire drive and produces a signal which is proportional to the rate the slidewire is changing and whose polarity shows the direction in which the slidewire is moving. This signal is also fed to M180A. The path is through TB105-5, TB403-1, resistor R23 (on card X404), switch S401C and resistor R22.

At balance point both signals discussed above are zero.

8.4.0 Servo control drive

The output of M180A is presented to the servo control motor input through switch S401I.

S401D and S401E are the normal input switches to the servo motor controller. The normal speed control potentiometer R415 is still in this circuit. It can serve if desired to modify further the speed with which the system will try to maintain a load.

8.5.0 Cross reference

Maintain load operation is discussed in Gilmore section 5.3, which provides additional insight into this system and defines the proper use of the controls.

Section 9 - The Indicating Circuits

9.0.0 The indicating circuits are covered in detail in the Gilmore manual section 7.1.

The diagram has been redrawn to aid in understanding the system. Figure 9.0.0 shows the circuits.

Section 10 - Velocity mode feedback control system

10.0.0 Introduction

This section contains the open loop frequency response characteristics of the Manual mode (velocity control mode) of the 200 000 lbf Gilmore testing machine. No other modes were investigated. The tests were performed with no test sample in the machine.

Open loop phase and gain responses to different sinusoidal frequencies are plotted as a Bode plot.

One ordinate is plotted as 20 log $\frac{V\ response}{V\ input}$ in dB; the other ordinate is plotted as phase shift in degrees. The abscissa is plotted as the frequency in Hz.

There is no measurable difference between the responses in the High speed mode and in the Medium speed mode. Since there is no measurable difference between High & Medium speed modes only the High and Low speed modes are plotted.

10.1.0 Description and results of tests

Six tests were performed on the Gilmore machine. In test number 3, 4, and 5 the methods were found to be in error. The tests were repeated in test number 6.

Test number 1 (Figures 10.1.0A and 10.1.0B) is of the outer loop (loop number 1 on block diagram Figure 10.0.1C). The loop was broken at TB 406 terminal number 11 (Figure 6.0.0). The input was applied through R3 to the P65AU operational amplifier, and the response was taken from TB 406 terminal 11 which is connected to the Machine Tachometer output.

The curves of Figures 10.1.0A and 10.1.0B show that the low frequency open-loop gain is the same for both High and Low speed modes. The responses of these modes are different at higher frequencies. There appears to be a pair of complex poles at about 4 hertz (ω =12.5), because the gain plot shows peaking somewhere between 2 and 4 hertz. The natural frequency , $\omega_n = 2\pi f_n$ of these poles is approximately 4 hertz. The actual resonant frequency is $\omega_n\sqrt{1-2\zeta^2}$ where zeta, ζ , is the damping ratio. Zeta cannot be determined exactly with the data points shown; more

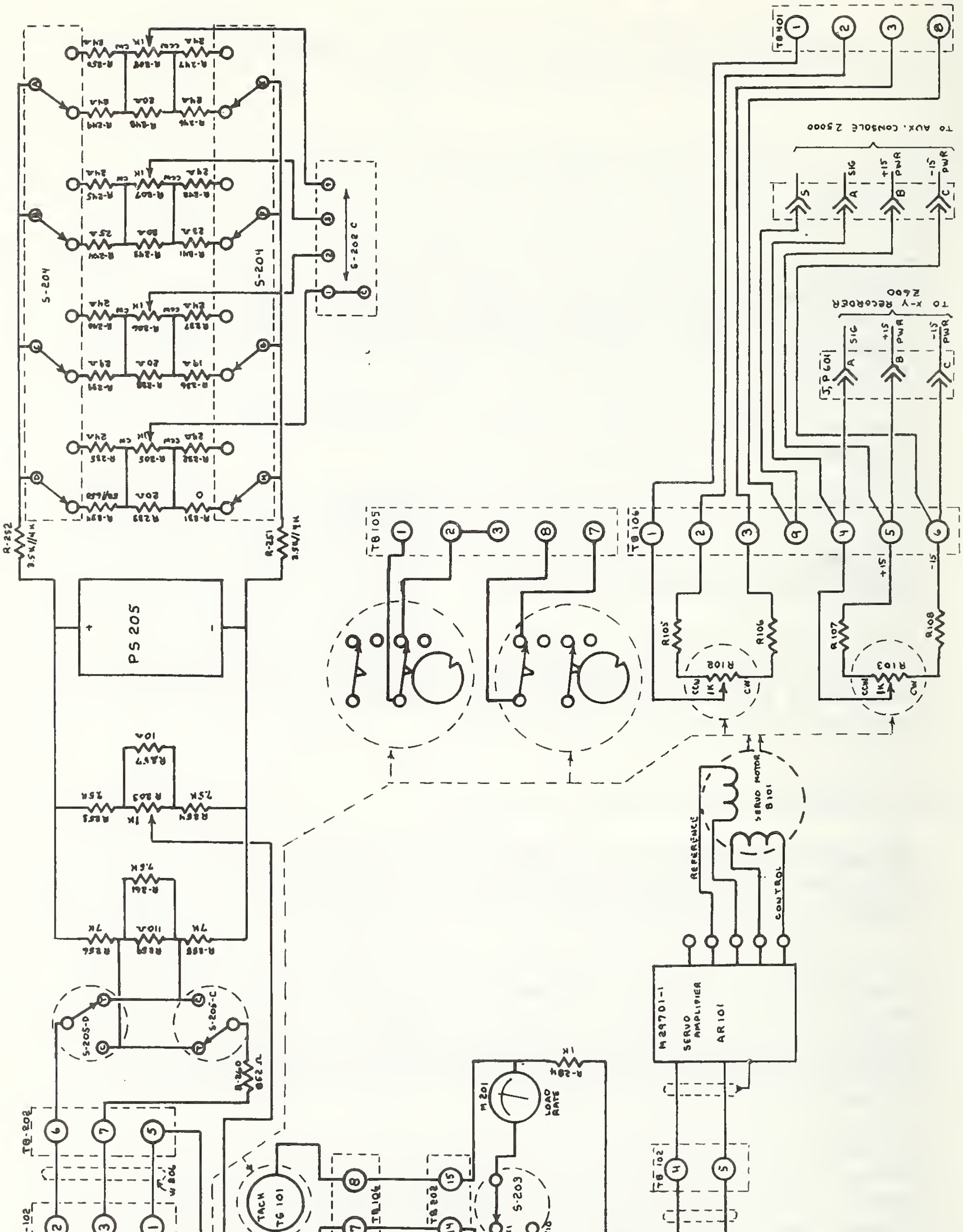

PS 205
TB 105
TB 106
TB 401
TO AUX. CONSOLE Z5000
TO X-Y RECORDER Z400
SERVO MOTOR B101
REFERENCE
CONTROL
M29701-1
SERVO AMPLIFIER
AR101
TACH TG 101
M 201
LOAD RATE
S-204
S-203
PB 201

FIG. 9.0.0

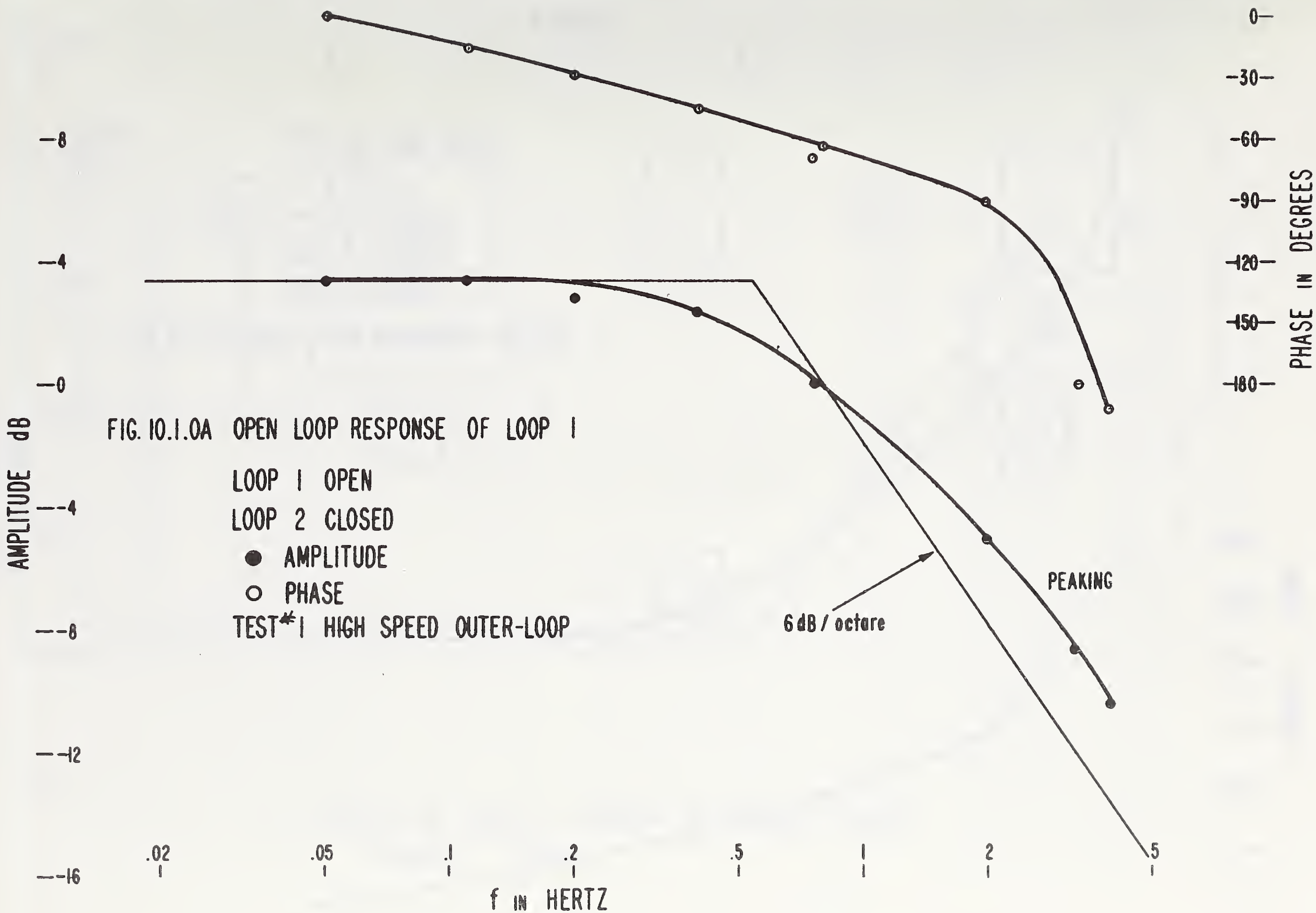


FIG. 10.1.0A OPEN LOOP RESPONSE OF LOOP 1

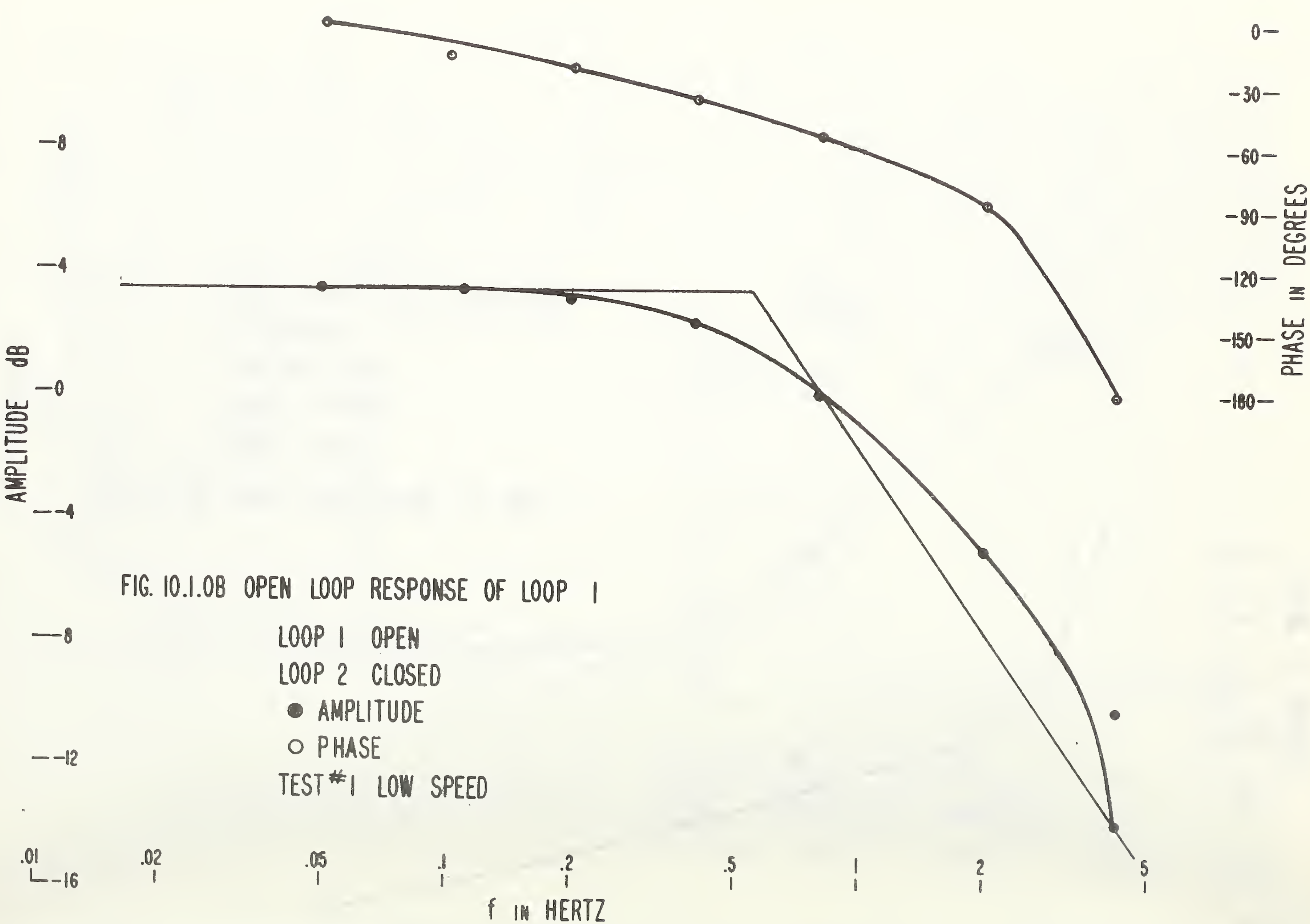


FIG. 10.1.0B OPEN LOOP RESPONSE OF LOOP 1

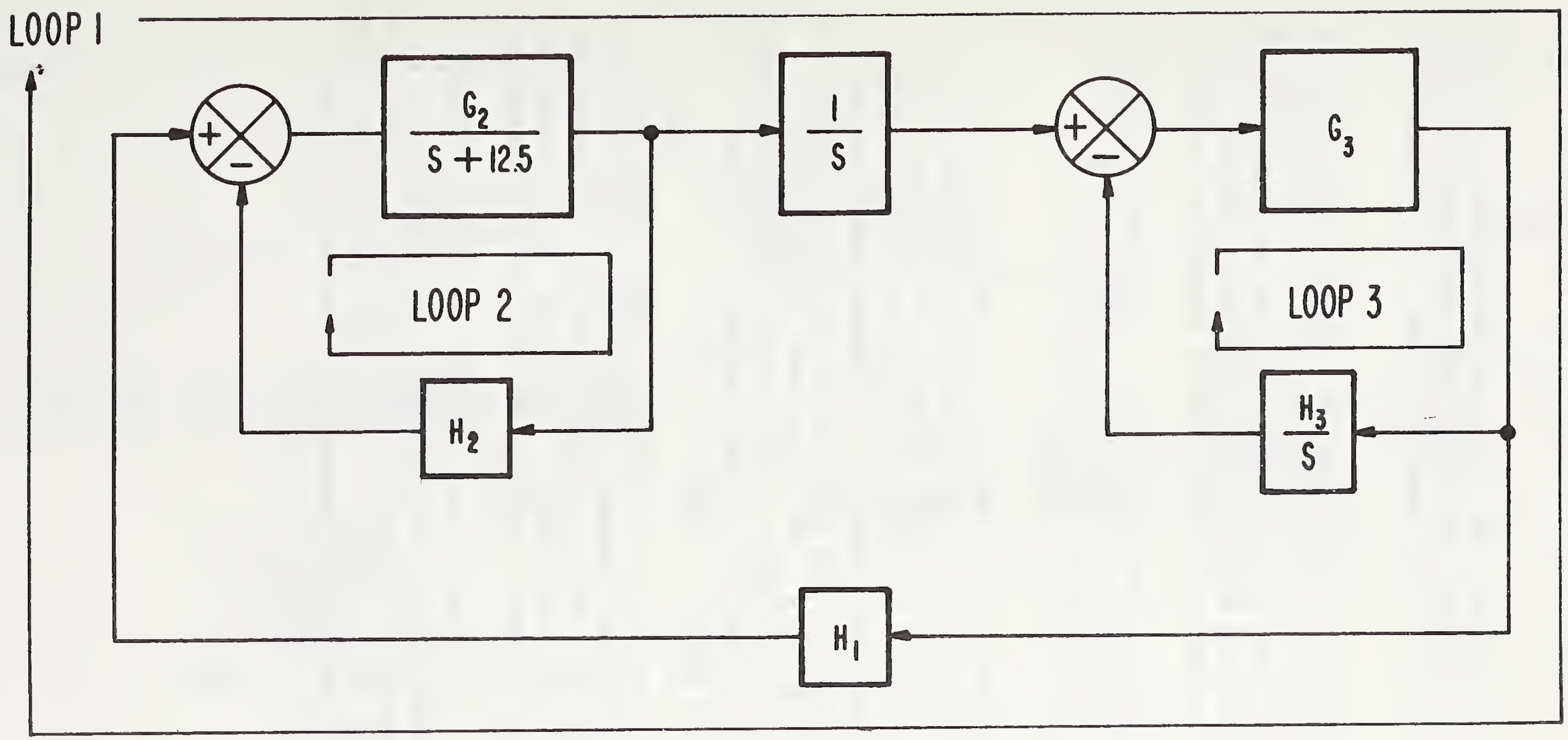


FIG 10.1.0C BLOCK DIAGRAM OF VELOCITY MODE CONTROL SYSTEM

points would be needed to find zeta, ω_n , and the resonant frequency.

Zeta appears to be different for High and Low speeds. High speed appears to have a lower zeta (more peaking), and therefore the machine will be more likely to overshoot when in the High speed mode.

Test number 2 (Figure 10.1.0D) is of the velocity stabilization loop (loop number 2 on Figure 10.1.0C). This loop was broken at R2 on board X404 (Figure 6.0.0). The input was applied through R2, and the response was taken from the terminal from which the lead of R2 was disconnected (Command Servo Tachometer output).

This plot shows a pole at about 2 hertz. For normal operation this loop is closed, and the closed loop response has a pole at about 8 hertz. This frequency is high compared with the frequencies of interest of loop number 1.

Test number 6 (Figure 10.1.0E) is of the synchronization loop (loop number 3 in Figure 10.1.0C). The loop was broken at terminal number 1 of the Oil-Gear preamplifier (Figure 6.0.0). The input was applied to terminal 1 and the response was taken from the wire removed from terminal 1 (Command Servo Synchro Receiver). The signal at the point where the loop was broken is phase synchronous 60 hertz. The input used was amplitude modulated on a 60 hertz carrier. The carrier was obtained from a socket on the control panel. A block diagram of the test instruments used is shown in Figure 10.1.0F.

The Bode plot for test number 6 (Figure 10.1.0E) shows an integrator (1/s) with what appear to be complex poles at about 4 hertz. The closed loop response has a corner at 0.55 hertz and the complex poles at about 4 hertz. This loop (loop 3) has the dominant poles that appear in the outer loop (loop 1) response.

As a test of the experimental results the open loop response of loop 1 will be compared with the responses from loops 2 and 3. The open loop responses of loops 2 and 3 are known, so the closed loop responses can be calculated. The close loop responses of 2, 3, H , and 1/S connected in cascade should correspond closely with the open loop response of loop 1.

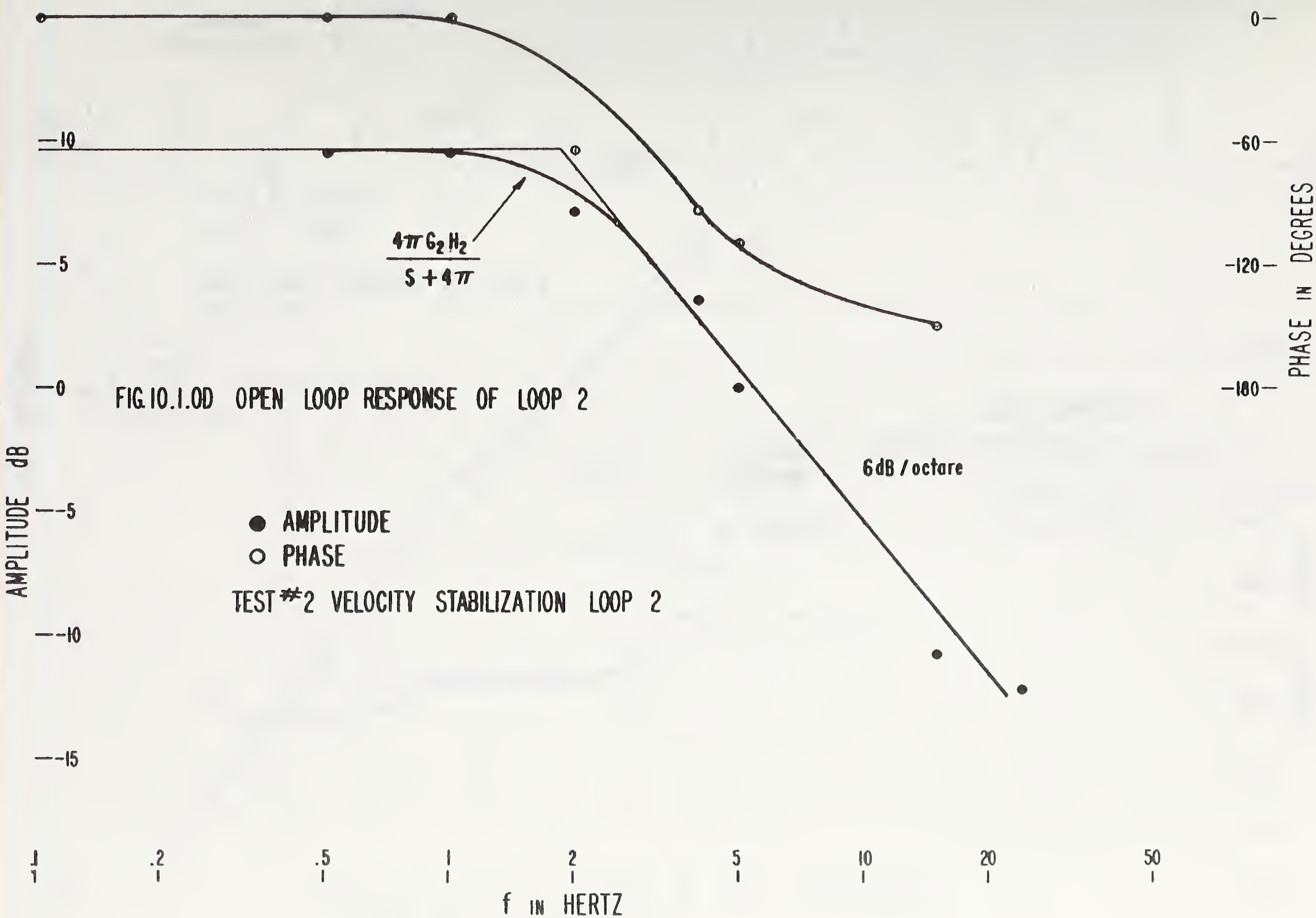


FIG.10.1.0D OPEN LOOP RESPONSE OF LOOP 2

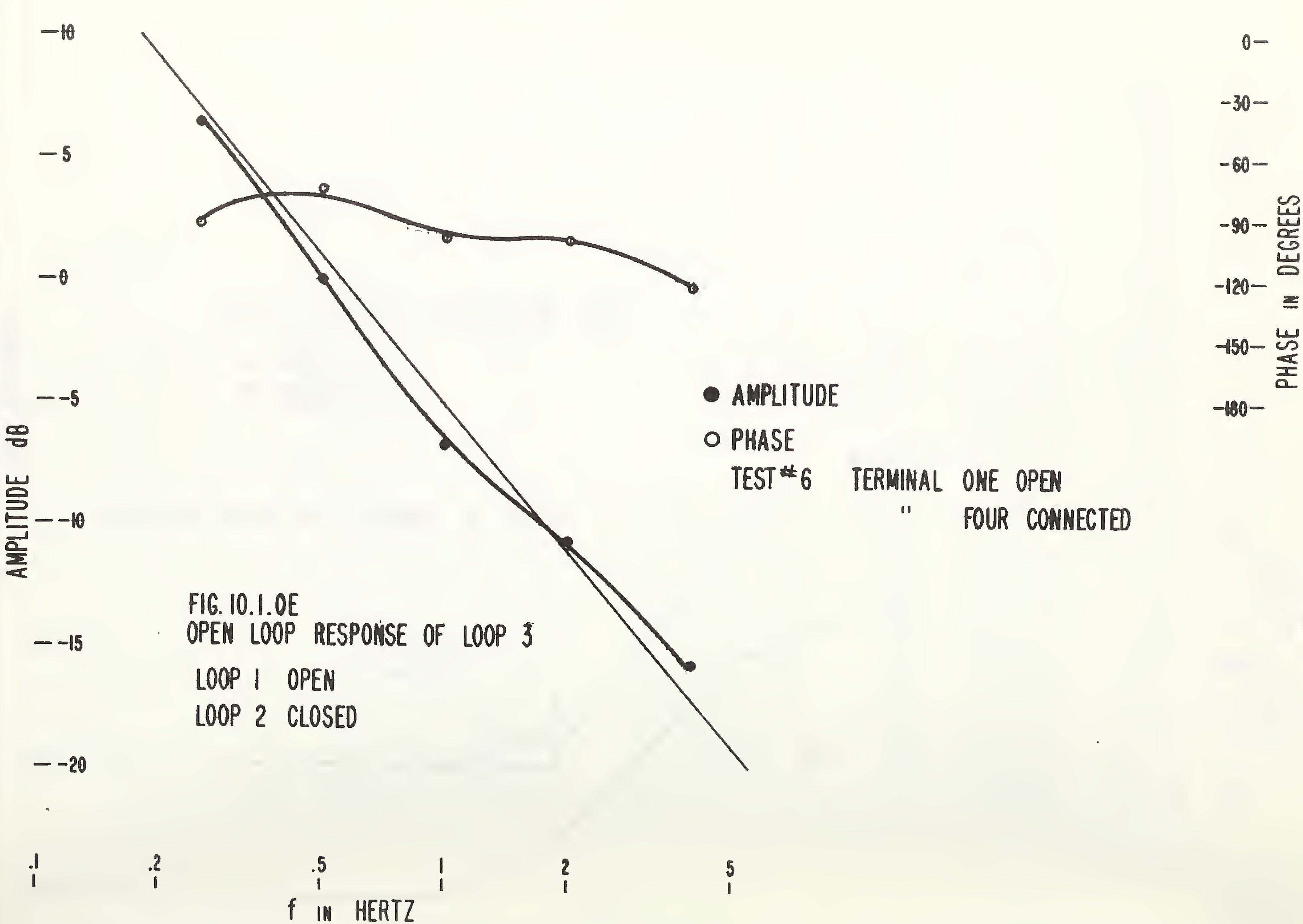


FIG. 10.1.0E
OPEN LOOP RESPONSE OF LOOP 3

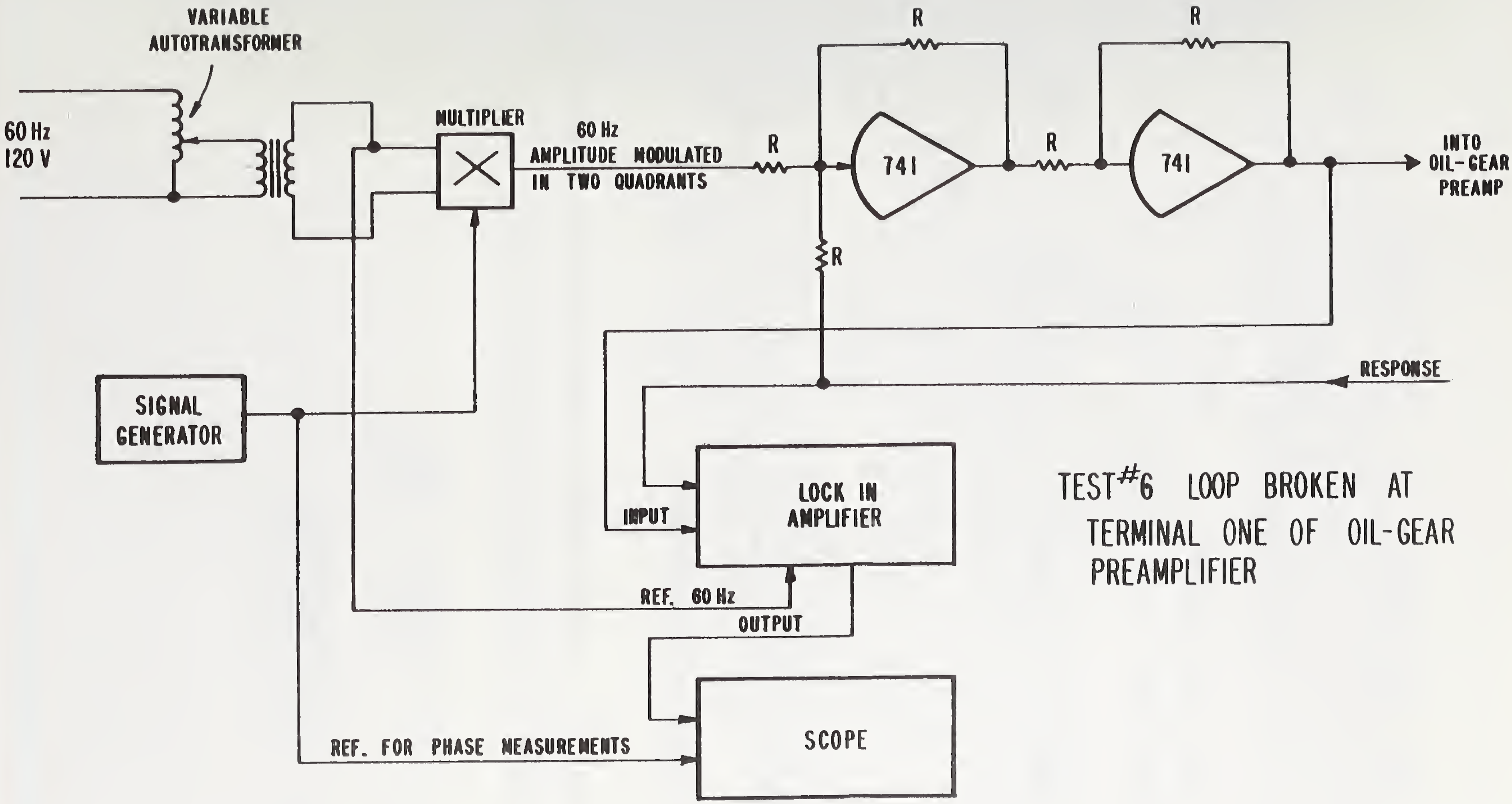


FIG 10.1.OF BLOCK DIAGRAM OF TEST INSTRUMENTS USED IN TEST NUMBER 6

Loop 1 open loop response $= \dfrac{1.5 \times .55 \times 2\pi}{S + .55 \times 2\pi}$

$= \dfrac{5.2}{S + 3.4}$

Loop 2 open loop response $= \dfrac{G_2 H_2}{1 + \frac{S}{4\pi}}$

where $G_2\ H_2 = 3.$

Loop 2 closed loop response $= \dfrac{\dfrac{G_2}{1 + \frac{S}{4\pi}}}{1 + \dfrac{G_2}{1 + \frac{S}{4\pi}}} = \dfrac{G_2}{1 + \frac{S}{4\pi} + 3}$

$= \dfrac{G_2}{4 + \frac{S}{4\pi}} = \dfrac{4\pi G_2}{16\pi + S}$

Loop 3 open loop response $= \dfrac{G_3 H_3}{S}$

where $G_3\ H_3 = 3.6.$

Loop 3 closed loop response $= \dfrac{G_3}{1 + \frac{3.6}{S}} = \dfrac{S G_3}{S + 3.6}$

Cascade H_1, $\frac{1}{S}$, closed loop 2, and closed loop 3 and compare this to the open loop response of loop 1.

$$\frac{5.2}{S + 3.4} = H_1 \frac{1}{S} \frac{4\pi G_2}{S + 16\pi} \frac{S G_3}{S + 3.6}$$

$$\frac{5.2}{S + 3.4} = \frac{4\pi G_2 H_1 G_3}{(S + 16\pi)(S + 3.6)}$$

There is very close correlation between the dominant poles on both sides of the equation. This shows that the closed loop response of loop 3 has the dominant pole observed in the open loop response of loop 1. The complex poles were left out of the exercise above because they cannot be determined quantitatively from the few data points on the graphs.

10.2.0 Conclusions

The conclusions that can be drawn about the possible optimization of the servo system are as follows:

The machine has conservative parameters (large phase margin and large gain margin) when there is no sample in the machine. These parameters change with a sample in the machine, and thus the machine will require different optimization for each sample. Optimization will require many tests of the response of the machine for each sample. If the machine is to be used to test one kind of material, it may be cost-effective to optimize. If the machine is to be used to test non-identical samples, optimization will not be worthwhile.

As it is adjusted now, the machine is intended to work on the worst-case sample. This means the response is slower than it could be with optimization, but the conservative parameters assure that the machine will not oscillate with any sample.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 75-773	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Report on Characteristics of Three Universal Force Testing Machines			5. Publication Date 6. Performing Organization Code
7. AUTHOR(S) E. C. Palasky, J. E. Malcolm and W. H. Appleton			8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No. 4460112 11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Mechanics Division Institute for Basic Standards National Bureau of Standards			13. Type of Report & Period Covered Final 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Three universal testing machines at the National Bureau of Standards have been analyzed in detail. Information developed in the study is organized in this manual which provides a better understanding of the theory, structure, and operation of the machines, an improved basis for maintenance, a clear and logical set of schematic drawings, and other data that supplement the manufacturer's documentation.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*
Automatic control; constant loading; force machine; load cell; mechanical testing; velocity feedback

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[ ] Unlimited [X] For Official Distribution. Do Not Release to NTIS [ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13 [ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED 20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price

USCOMM-DC 29042-P74