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Title Page

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AUTHOR R.A. Raber	SUBJECT CLASSIFICATION Magnetic Amplifiers	NO. TR53A0321
		DATE 3-23-53
TITLE DEMAND COMPUTER FOR PROJECT SIR		
ABSTRACT A description of the demand computer and its functions is given. Methods of testing and adjusting, and gain and response curves for the system and its parts are included.		
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CONCLUSIONS The demand computer has been developed to meet certain requirements for Project SIR. Extra features and wide ranges of adjustment have been incorporated to permit further investigation on the overall system. The prototype will be a sealed unit having external adjustments and terminals for test.		
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By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents—drawings, photos, etc. and for distribution see next page (AO-147-A).

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I. DEMAND COMPUTER FOR S.I.R.

A. Introduction

The demand computer is made up of two servos, the demand shaft and the integral shaft, connected together by gearing and a mechanical differential to position the selectors on a number of potentiometer cards. The cards supply signals which control reactor flux level and coolant flow, and provide a power level reference for component circuits. These quantities are scheduled by the computer in response to steam flow and pressure error signals in order to maintain pressure at a preset value. The computer also uses a limit signal proportional to the difference between actual flux level and the level being called for by the operator.

The computer operates from a single phase, 115 volt, 400 cycle supply. Internal sources supply all other voltages required.

System response, methods of adjustment, and operational checks are included in this report.

B. Modes of Operation

There are five modes of operation for the entire S.I.R. system. The use of the demand computer for each of these modes is as follows:

1. Reactor Automatic - demand computer schedules reactor power level according to pressure error and steam flow signals, but coolant flow is controlled manually. The

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integral shaft is in operation.

2. Automatic - demand computer schedules reactor power level and coolant flow according to pressure error and steam flow signals. The integral shaft is in operation.

3. Semi-Automatic - demand computer schedules reactor power level and coolant flow using only a manual input. The integral shaft is in the zero, or reset, position.

4. Reactor Semi-Automatic - demand computer schedules reactor power level according to the manual input. Coolant flow is operated from a separate manual station. The integral shaft is in the reset position.

5. Manual - demand computer follows reactor power level under the control of the power level limits, but does no scheduling. Reactor power level and coolant flow are controlled from manual stations. The integral shaft is in the reset position.

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II. DEMAND SHAFT

A. General Description

The demand shaft is a position servo responding to steam flow and pressure error signals. It is acted upon by a dynamic velocity limit and power level limits. The electrical output drives a two phase motor which positions a synchro through a 7154/1 gear ratio. Included in the gear train is a mechanical differential for introduction of a signal proportional to the integral of pressure error. The integral shaft is the source of this mechanical integral signal. See figure 1 for a block diagram of the demand shaft.

The following sections describe the portions of the demand shaft in greater detail.

B. Main Channel

The main signal channel consists of two preamplifiers and a "standard amplifier" driving a Kollsman two phase, #XC-1548-0460300-0, motor-tach. Through the gear box this drives an output, or response, synchro #18CT4. The steam flow signals are introduced by 18CX4 and 18CLX4 synchros. Pressure error signals are derived from a special sensor and are applied to the demand shaft through a matching transformer. Figure 2 shows a schematic wiring diagram of these demand shaft circuits.

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The two preamplifiers are 4017 push-pull stages. The first has an AC signal winding where steam flow and pressure error signals are mixed. The stage acts as a discriminator, yielding a DC signal proportional to the combined AC signals at the input. AC magnitude and phase are converted to the proper DC magnitude and polarity. This DC signal is applied to the second preamplifier which acts as a buffer amplifier for introduction of the limits. Gain of the preamplifier stages is shown in figure 4.

The standard amplifier is covered in detail in Technical Information Series DF52A0332. The amplifier is used with velocity feedback for improved response as described in part of the above report. Response data on this loop is included in this report in Figures 15, 16 and 17.

Taps on the secondary of the pressure error signal matching transformer, and a potentiometer, provide a seven to one range of gain adjustment for pressure error. Main channel gain can be adjusted on the second preamplifier. Main channel balance is set on the first preamplifier. These adjustments are covered in detail in a later section of this report. The demand shaft limits are also discussed in a separate section to follow.

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C. Power Level Limits

The purpose of the power level limits is to force the demand shaft to maintain a position within $\pm 2\%$ (of 100%) of the actual reactor power level. For example, if the reactor were at 50% power, the demand shaft could only move within the band representing 48% to 52% power. This assures proper coolant flow in automatic and semi-automatic operation as the reactor makes its relatively slow changes in power level in response to the operator's settings. In manual operation this keeps the demand shaft close to the reactor to minimize transients as the plant is switched back to automatic.

The limit signal is supplied from a source external to the computer, and is a measure of the difference between actual and desired power levels. The signal is amplified in the limit preamplifier, and the plus and minus power limits. These three are 4017 push-pull stages.

The circuit is so connected that the output of each limit stage places a bias on a rectifier connected as a gate on a dumping circuit across the main channel at the output of the second preamplifier. The rectifiers are so oriented that one limit acts for each polarity of main channel signal. Negative bias will dump a portion of the main signal, zero bias dumps all of the main signal,

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and positive bias forces a false signal of opposing polarity into the main channel. Since perfect dumping cannot be achieved, a winding on the input of the standard amplifier is used for compensation to improve the action.

By proper adjustment, with 2% of full power chosen as the desired limit value, the limits cause the demand shaft to slow down its travel and permit the reactor to catch up as the power difference approaches the 2% value, to stop and wait when the difference reaches 2%, and to reverse and go back to meet the reactor as the difference starts to exceed 2%. Under these conditions the time required to change reactor flux level becomes the controlling factor for the system. The curves of figure 6 show the operation of the power limits.

D. Dynamic Velocity Limit.

The dynamic velocity limit restrains the speed of travel of the demand shaft in the increase power direction in proportion to demand shaft position. This results in an exponential characteristic of speed vs. time. This rate of rise control is required to maintain the proper period for increase of reactivity and prevent a "scram" condition..

The velocity limit is a dumping circuit similar to the power limits (see figure 7). It derives its signal from a card on the demand shaft and a current reference.

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The circuit is made up to yield a linear function of speed vs. demand shaft position (see figure 8). The strict requirements on this limit make its adjustment very critical. It has been compensated for line voltage variations, but can suffer inaccuracies due to shifts in standard amplifier balance. For this reason, a mechanical limit is now being considered for the Mark B system to replace the electrical one. Present known methods, however, would have the disadvantage of limiting in both the increase and decrease power directions.

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III. INTEGRAL SHAFT

A. General Description

The integral shaft is a velocity servo responding to pressure error, and yielding a mechanical output proportional to the integral of pressure error. The integrating action is obtained by using the electrical pressure error signal to drive a motor connected to the integral shaft gearing. The position of the output shaft of the gear train is proportional to the integral of the electrical signal driving the motor. The gear train connects to the mechanical differential, mentioned on the demand shaft, through a 2112/1 gear ratio.

For certain modes of system operation, there is a reset position selectable on the integral shaft. This is a position loop connecting the reset synchro to the integral shaft motor through a 42,240/1 gear ratio, and serves as a means of zeroing the shaft to erase all integral contribution.

There is also a non-linear amplifier which can be connected so as to subtract from the pressure error signal a non-linear function of reset synchro volts.

A limit is also used on the integral shaft so that it is held fixed whenever the demand shaft is held by the power level limits.

The following sections describe these features in greater detail. A block diagram and integral shaft wiring are

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shown in figures 9 and 10.

B. Main Channel

The main channel of the integral shaft is the same as that of the demand shaft, except that the first stage has extra windings for the added feature signals.

Pressure error signals are introduced to an AC signal winding on the first preamplifier stage through a gain pot. This gives a fifty to one range of gain control for this signal. Pressure error is taken from the same sensor as is used by the demand shaft, the two channels being in parallel. The gain curves of figure 4 also apply to the integral shaft for pressure error signals.

An extra AC signal winding is used for the reset signal input from the reset synchro. A DC signal winding is used for the non-linear reset signal.

As on the demand shaft, there is a balance adjustment on the first preamplifier and a gain control on the second.

C. Integral Shaft Limit

The limit on the integral shaft is designed to keep the integral shaft at rest whenever the demand shaft approaches the power limit operating point. It consists of a relay driven by two magnetic amplifier stages. The relay contacts are normally open, but, when the limit acts, the contacts short the motor fixed phase and produce plugging. The relay driver stage is a 4635P2 single

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ended stage. Its input windings are connected together through rectifiers in a way which gives improved trigger action for actuating the relay. The limit preamplifier is a 4017 push-pull stage which is balanced off to use the most linear part of the gain curve. The limit signal is taken across the five hundred ohm resistor in series with the output of the second preamplifier of the demand shaft main channel. When the demand shaft power limits act they cause a large dumping current to flow through this resistor, raising its terminal voltage. This voltage is compared to a reference voltage on the integral shaft panel in a bridge, and if large enough actuates the relay. To overcome the effects of hysteresis in the relay the gain of the limit preamplifier and driver stages is kept high. The use of the matching circuit mentioned above permits use of this high gain while keeping the operating signal value fairly high.

The limit circuit first used on the integral shaft was the same as the power limits on the demand shaft, and the limit signal was applied to the two limit circuits in series. Subsequent tests indicated that this system was too critical to adjust. It was almost impossible to adjust all the limit stages to act for exactly the same magnitude of signal. The new circuit performs its function by more direct measurement of the actual quantity

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desired for a signal. Its use, however, eliminates the need for the second preamplifier on the integral shaft main channel. It has been retained for the present to reduce the number of changes and to serve as a future means of increasing gain if necessary.

D. Reset

An 18CX4 synchro attached to the integral shaft gearing is used as a reset synchro which can convert the integral shaft to a position servo and restore it to a zero position. Excitation is applied to the rotor, and the voltage of one stator phase is used as an error signal. Figure 11 shows a plot of this voltage vs. position. The integral shaft zero position is adjusted to match the error voltage null. The reset signal is only connected in for certain modes of system operation.

E. Non-Linear Reset

By using negative bias on a 4017 push-pull stage, a gain characteristic having a dead band is obtained. AC signal windings on this stage apply this characteristic to the reset synchro signal. When the resultant output is introduced into the main channel, a position system with a wide deadband results. Within this band, motor speed can be controlled by pressure error signals as if the position loop did not exist. Beyond this point, assuming proper phasing of the signals, the effectiveness of the pressure

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error signal is reduced in proportion to the reset synchro position (see figure 17). This results in an integral output whose proportionality to pressure error varies with the magnitude of the pressure error already present. This effectively reduces the integral gain for long period errors in pressure, but does not affect gain in the more normal control region.

The use of this circuit has not been fully decided upon. It is to be evaluated later on the simulator.

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IV. DEMAND COMPUTER TESTS AND ADJUSTMENTS

A. General

A testing unit has been built for checking out the entire S.I.R. system and making certain adjustments. This report, however, will cover these tests and adjustments as if they were being made on laboratory equipment. This is the same information that was used in the construction of the tester. The test unit, in many cases, in order to remain more universal and compact, measures quantities by indirect means. Adjustment of the standard amplifier, covered in DF52A0332, will not be repeated here unless required as part of another adjustment or altered.

B. Operational Checks

The operational checks on the computer are of the go, no-go, variety, and are intended to be performed with the system in "Manual" so as not to upset operation. They consist mainly of spot checks of certain points in the data considered important for proper operation. In brief, they may be outlined as follows:

Demand Shaft Position - using the calibrated synchro which replaces the steam flow synchros, with no pressure error input, with no power limit signal, and with the integral shaft at reset, check that the demand shaft follows the position called for on the input synchro.

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Demand Shaft Balance - with the excitation leads of the manual synchro for steam flow shorted, and with no other signals, check that the demand shaft motor is at rest.

Demand Shaft Gain - with zero power limit signal check the time necessary to travel from 105% to 5% power (30 sec.).

Pressure Error Gain - with zero steam flow input and power limit signal, a certain pressure error signal should displace the demand shaft a certain number of percent power (to be specified after simulator tests).

Dynamic Velocity Limit - with no power limit signal, and with sufficient steam flow or pressure error signal to cause travel from 5% to 105% power, check the time required for travel from 5% to 50% power (34.5 sec.), and from 5% to 105% power (51 sec.).

Demand Shaft Power Limits - check that as the reactor power level is varied, the demand shaft is forced to follow within $\pm 2\%$ power.

Integral Shaft Gain - with reset synchro signal removed, check motor speed obtained for a certain pressure error input signal (to be specified after simulator tests).

Integral Shaft Balance - with zero pressure error signal, and reset connected, check that integral shaft comes to rest at zero.

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If the system fails to meet any of these operational checks, the appropriate adjustments from the following sections must be made. Tolerance on quantities indicated above must be specified after evaluation of simulator data.

C. Adjustments

Balance - unless otherwise indicated, the balance is set to zero output with zero input. The stage or stages concerned should be loaded with the input and output impedances they see in the circuit or their equivalents.

Bias - unless otherwise indicated, the bias is set by adjusting the voltage across one of the dummy load resistors to the value given with the stage output at zero. The dummy load resistors are the two seventy-five ohm resistors in series across the output of each stage as shown on figures 2 and 13.

Gain - when desired circuit gains are finally chosen they will specify the tach volts that should result from a given input signal. Adjustments of limit stage gains will be described later in this report.

D. Equipment

DC voltages are measured with a 20,000 ohms per volt meter such as a Simpson Analyzer. Synchro and tach voltages should be read on a vacuum tube voltmeter to avoid loading. A Hewlett Packard meter was used in the lab.

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All data, unless otherwise indicated, was taken with the line voltage set at 115 volts, 400 cycles, and at room temperature.

Frequency response data was taken on a servo analyzing machine using a cathode ray oscilloscope as a null detector. This data could just as well be taken with a low frequency oscillator and Brush recorder equipment.

Pressure error was simulated with an adjustable AC voltage supply of 75 ohms internal impedance, and a range of 0 to 15 volts. Means were provided to reverse the phase of this voltage. Limit signals were supplied from a variable DC source, less than 1,000 ohms in internal resistance, and adjustable from zero to ± 1.5 volts. Steam flow was replaced with an 18CX4 synchro.

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V. DEMAND SHAFT ADJUSTMENTS

A. Adjustments

Balance - first preamplifier, standard amplifier, power limit preamplifier.

Offset - an "off balance" adjustment required on each limit stage.

Bias - each stage, with special adjustment on the power limit stages.

Gain - second preamplifier, standard amplifier, power level limits, pressure error input.

The integral shaft should be frozen in the reset position while making demand shaft adjustments.

B. Balance

To adjust main channel balance the input signals to the demand shaft must be zeroed and the position loop opened. In "Manual" this requires only shorting of the excitation leads to the manual input synchro since the pressure error sensor is replaced by its internal impedance. The power limit signal must be reduced to zero and the link in the velocity limit input opened. The balance control on the first preamplifier is then adjusted for zero output from the second preamplifier. The standard amplifier balance is then set to give zero motor speed.

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The balance and offsets of the limit preamplifier and limit stages will be covered in a separate section.

C. Bias

The following are the nominal values to be adjusted for using the procedure outlined in the section on "Adjustments - Bias":

Main Channel

1st Preamplifier	0.55 volts
* 2nd Preamplifier	1.25 volts
Standard Amplifier	See DF52A0332

Limits

Limit Preamplifier	1.0 volts
*Plus Power Limit	1.0 volts
*Minus Power Limit	1.0 volts
Dynamic Velocity Limit	0.55 volts

*Require additional adjustment. See section on Power Limit Adjustments.

*Changes in bias on the second preamplifier will require rechecking of the limit adjustments.

D. Gain

The adjustment of standard amplifier gain is outlined in DF52A0332. The gain of the limit stages is covered in a later section of this report under "Power Limits". Main channel gain, adjusted on the second preamplifier, affects the position loop response. It has been left in

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the maximum gain position until the present Simulator tests may indicate the need for a specific gain. Any change in this gain setting will require readjustment of the limits.

The pressure error gain pot is given a series of ranges for adjustment by selecting taps on the secondary of the matching transformer. The desired value of gain has not been determined on the simulator as yet.

E. Limit Preamplifier

After the bias of the limit preamplifier has been set, its gain and balance must be adjusted so that ± 0.8 volts signal give ± 1.0 volts output, using the variable DC supply for a signal source. This balance adjustment may cause slight unbalance at zero, but it is the one volt point that is important.

F. Power Limits

The power limits must be adjusted so that ± 0.8 volts signal to the limit preamplifier keeps the demand shaft at rest when steam flow or pressure error signals are calling for demand shaft travel in the increase power direction. A -0.8 volt signal should prevent travel in the decrease power direction. The signal 0.8 volts is equivalent to a 2% difference between actual and desired power. The limit should start to affect demand shaft speed at a signal equivalent to 1.5% power difference. The following adjustments are necessary to properly set this gradient.

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Open the link in the velocity limit input to make it inoperative. Apply sufficient positive limit signal to prevent the demand shaft from moving in response to an increase power signal from the steam flow or pressure error channels. Too little signal will only slow down the speed of travel. Too much signal will cause travel in the wrong direction. Reduce the limit signal to allow the motor to run in the increase power direction at about three quarters of full speed, and adjust the bias of the plus power limit to peak motor speed. If the adjustment is far off it may be necessary to increase the limit signal to slightly restrain motor speed as the final bias adjustment is being made. When the bias has been set, adjust the plus power limit offset so that limiting occurs at 0.8 volts signal to the limit preamplifier. Adjust the gain of the plus limit stage so that motor speed varies the least as the steam flow manual input signal is varied from 0.4 to 1.0 volts, with zero pressure error signal.

Repeat this procedure for the minus power limit using negative signals to the limit preamplifier, and main channel signals calling for decrease power travel.

When this has been completed for both stages, recheck the offset adjustments as they may interact slightly. Inability to get the proper offset may be due to improper gain and balance adjustment of the limit preamplifier, or

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improper bias adjustment of the limit stage. Improper bias adjustment of the main channel second preamplifier may put the limit point out of range of the available adjustments.

G. Dynamic Velocity Limit

The dynamic velocity limit is to limit motor speed linearly in the increase power direction of travel so that at 5% power motor speed is 10% of full speed, and at 50% power the motor reaches 100% speed. The circuit used cannot meet this requirement exactly, so that at 50% power motor speed is only 95%. Full speed is reached at 55 to 60% power. From data obtained on the simulator, the following procedure has been adopted as reliably setting up the limit to most nearly meet the desired characteristic.

With the power limit signal at zero, and the link in the velocity limit signal winding opened, adjust the compensating resistor to give 0.375 volts output from the limit stage. Reconnect the input link and adjust the two hundred ohm pot loading the current reference to obtain zero limit signal (to the velocity limit) when the demand shaft is at the 60% power point. Run the demand shaft to 5% power and adjust the ten thousand ohm pot, in series with the demand shaft velocity limit card so that the motor starts to travel at 10% speed with an increase power signal applied. This is measured

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by reading tach volts. Repeat these last two adjustments until both remain set.

The time for the demand shaft to travel from 5% to 50% power under influence of the velocity limit should be 34.5 sec. If possible a plot of speed vs. demand shaft position should be taken to verify the adjustments, and changes made as required.

Since, as has been pointed out, this limit will be replaced on Mark B by a mechanical one, effort has not been wasted in verifying the universality of this procedure, nor in setting up a simpler procedure adaptable for field servicing.

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VI. INTEGRAL SHAFT ADJUSTMENTS

A. Adjustments

Balance - first preamplifier, standard amplifier, limit preamplifier, non-linear amplifier.

Bias - each stage, with special adjustments on the relay driver stage and non-linear amplifier.

Gain - second preamplifier, standard amplifier, pressure error input, limit circuit, non-linear amplifier.

B. Balance

Main channel balance is adjusted in the same way as on the demand shaft. Input signals are reduced to zero and the preamplifiers and then the standard amplifier are balanced.

The non-linear amplifier and the limit preamplifier balance will be covered in another section of this report.

C. Bias

The following are the nominal bias values to be adjusted for using the procedure outlined in the section "Adjustment-Bias":

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Main Channel

1st Preamplifier	0.55 volts
2nd Preamplifier	1.25 volts
Standard Amplifier	See DF52AO332

Limit

Limit Preamplifier	1.0 volts
Relay Driver Stage	See section on limit

Others

Non-Linear Amplifier	See "Non-Linear Amplifier"
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D. Gain

Adjustment of the standard amplifier is outlined in DF52AO332. Limit circuit gain is covered in the section on the limit. Non-linear amplifier gain is also in a separate section.

There is a fifty to one range of gain adjustment for the pressure error signal. Adjustment of this gain has to be determined on the simulator and will be specified later.

The gain control on the second preamplifier should be left in the maximum position until further tests are made.

E. Integral Shaft Limit

With the limit preamplifier bias adjusted, set the balance for minus one volt output with no signal applied and with limit circuit gain to maximum. The relay driver

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bias and limit circuit gains must then be set. These two affect each other as far as the limit action is concerned and must be adjusted together.

Increase the supply voltage to the maximum value given by tolerances in the specifications (now 122 volts). Remove the limit signal to the integral panel or be sure it is zero. Decrease the bias on the driver stage until the relay picks up, and then increase it again until the relay just drops out. Reduce supply voltage to the minimum value specified (now 107 volts) and apply a limit signal which indicates the demand shaft is limited. This can be done by actually limiting the demand shaft, or by using the variable DC supply. The nominal value for this signal is 1.75 volts, but it will vary slightly between units. With this signal applied, adjust the limit circuit gain until the relay just picks up. Repeat these adjustments until both remain set.

F. Non-Linear Amplifier

The use of this stage has not been fully decided upon so future instructions for adjustment will probably be changed. The following set the stage up to leave a deadband from 0 to $\pm 20^\circ$ of reset synchro travel, and beyond that point a gradient such that 50° of reset travel equal 50% of pressure error. Maximum pressure error gain was used.

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Set the bias pot at about mid-range and with the non-linear circuit connected apply a pressure error signal of 0.25 volts. Record the reset synchro voltage where the motor comes to rest. Reverse the polarity of the pressure signal and again record the reset synchro voltage when the motor comes to rest. The sum of the two reset synchro voltages should be 65 ± 5 volts. If the sum is less than this, increase the amount of bias current. If the sum is greater, decrease the bias. Continue this until the proper setting is made. When bias has been set, adjust the stage balance so that the reset synchro voltages recorded are the same within about two volts for each polarity of pressure signal of 0.25 volts.

With bias and balance adjusted, set the stage gain so that 12.5 volts pressure error signal result in 70 volts from the synchro when the motor comes to rest.

The main channel balance should be rechecked after these adjustments if the non-linear circuit is to be left connected. In order to "reset" when using the non-linear circuit it is only necessary that the reset synchro be connected as it usually is in "Manual". It will override the non-linear circuit.

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FIGURE 1

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OUTPUT vs DISPLACEMENT for KETAY 18CT4

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VOLTAGE GRADIENT OVER $\pm 10^\circ$ RANGE

R=00, GRADIENT = .963 VOLTS/DEG

R=10K, GRADIENT = .888 VOLTS/DEG

R=51K, GRADIENT = .822 VOLTS/DEG

R=00

R=10K

R=51K

50
40
30
20
10
0
10
20
30
40
50

VOLTS

IN

DEGREES

DISPLACEMENT

0

-20

-40

-60

0

20

40

60

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FIGURE 3

1992-1993 1000 The number

STAGE 2 GAIN AT MAX
LINE = 113 V 400M
1ST STAGE BIAS = 0.55 VOLTS
2ND " " 1.25 "
(ACROSS DUMMY
LOAD)

ATTENUATION & PHASE SHIFT OF CLOSED POSITION LOOP

DEMAND SHAFT DYNAMIC VELOCITY LIMIT

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POWER LIMIT SIGNAL - ZERO

FIGURE 7

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106-99 101-504

901-0977

INTEGRAL SHAFT

FIGURE 8

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3453

901 039

FIG-10

RESET SYNCHRO OUTPUT

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FIGURE 11

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901

PRESSURE ERROR GAIN = MAX.
VOLTAGES MEASURED AFTER
MOTOR COMES TO REST
LIMIT SIGNAL = ZERO

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FIGURE 12

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26 SEPT. 1962

GAIN CURVES FOR COMBINATION OF STANDARD AMPLIFIER & KOLLMAN TWO-PHASE MOTOR

FIGURE 14

901 043

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CLOSED TACH LOOP GAIN CURVES

AMPLIFIER GAIN POT
SET AT 10 (MAX GAIN)
GAIN = 1650

AMPLIFIER GAIN POT
SET AT 0
GAIN = MOD 5000

CCW ROTATION

IN RAD/SEC

SIGNAL CURRENT

IN MILLIAMPERES

MOTOR VELOCITY

FW ROTATION

FIGURE 15

A. MARQUISIE

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901-45
(8) 90 in. radius

Fig. 16

ω in rad/sec

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901-045

FIG 17

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END