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HFIR HOMOGENEITY SCANNER, PRODUCTION MODEL, OPERATING AND MAINTENANCE MANUAL

J.W. Reynolds, R.L. Shipp, T.F. Sliski,
W.H. Longaker and K.K. Klindt

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INSTRUMENTATION AND CONTROLS DIVISION

HFIR HOMOGENEITY SCANNER, PRODUCTION MODEL, OPERATING AND MAINTENANCE MANUAL

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FEBRUARY 1967

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ABSTRACT

Fuel material in an HFIR fuel plate is U_3O_8 dispersed in aluminum, resembling an airfoil in cross section. To ensure uniform generation of heat within the plate, all plates must be tested (nondestructive) to determine that the U_3O_8 content is within specified limits. The HFIR Homogeneity Scanner was developed for this purpose. It is a "density-thickness" gauge that scans a plate with a highly collimated, 0.062-in.-diam beam of x rays and detects those transmitted through the plate. Variations in the transmitted beam due to absorption in the fuel plate are used as a measure of fuel density.

This manual describes the operation of this machine and maintenance procedures for the electronic components.

1. GENERAL DESCRIPTION

1.1 Fuel Plate Measurements

1.1.1 Fuel Plate Tolerances

The HFIR Homogeneity Scanner (Fig. 1) is a "density-thickness" gauge for checking that the U_3O_8 particles contained in a U_3O_8-Al dispersion (whose cross section resembles an airfoil, Fig. 2) are within specified limits: +30% Spot and ±10% Average within the Maximum and Minimum Outline (Fig. 3) of a fuel plate and approximately -70% of the nominal loading at the thin edge of the inner fuel plate for the area outside the Maximum Outline.[1] The density is measured by scanning the plate with a highly collimated, 0.062-in.-diam beam of x-rays and detecting those transmitted through the plate. Variations in the transmitted beam due to absorption in the fuel plate are used as a measure of fuel density. The unit automatically scans the plates with overlapping paths until the entire plate is scanned.

[1]B. E. Foster, S. D. Snyder, and R. W. McClung, Continuous Scanning X-Ray Attenuation Technique for Determining Fuel Inhomogeneities in Dispersion Core Fuel Plates, ORNL-3737 (Jan. 1965).

Calibration standards are provided at each end of the fuel plate for automatically setting new trigger levels for the specified tolerance limits at any point of the fuel cross section. The tolerance limits can be changed by using calibration standards based on other specified limits.

An x-y plot of the plate being inspected is produced by a pneumatic printer with four colors of ink. A different color is sprayed on the graph paper to indicate an "out of tolerance" condition. Absence of any mark within the "plate area" on the x-y plot indicates that the plate is within tolerance.

A strip-chart recorder continuously records the value of the attenuated x-ray beam when the scan speed is less than 64 in./min. This record can be correlated to fuel content.

The necessity for a 100% nondestructive test of HFIR fuel plates was based on the requirement that there must be a uniform generation of heat within the plate.

1.1.2 Circuitry

The interconnections between the major portions of the circuitry are shown in Fig. 4. The integrate and hold circuits are set by the function control which detects the location of a standard that has been moved into the beam by the scan control. The standards are machined from selected 6061 aluminum by the use of an empirically determined relationship between the uranium oxide of the fuel plates and the aluminum. The zero detectors and gates are opened in the following combinations: No Fuel, +30% and +10%, and +30% and ±10% for the no fuel outline, maximum outline, and minimum outline, respectively. Each of the out-of-tolerance signals (+30%, +10%, -10%, and No Fuel) opens a color channel (black, green, red, or blue) to the plotting head of the pneumatic printer.

1.1.3 Percentage of Fuel Variation Per Chart Division

The percentage of fuel per chart division for the range of 30 to 80 chart divisions is shown in Fig. 5.

1.1.4 Average Limit Accuracy

The accuracy of determining the plus and minus 10% average limits is shown in Figs. 6 and 7 for the output range on the recorder from 30 to 90 chart divisions, calibrated as described in Sect. 2.8.1. The data points in these figures are for a single pass at each point plotted except for the points enclosed by a square, which indicates that the value plotted is the average of fifteen scans at the same point on the standards. The variation of the data was within ±1 division of the standard and -0.4 and +0.6 division for the trigger level from the average.

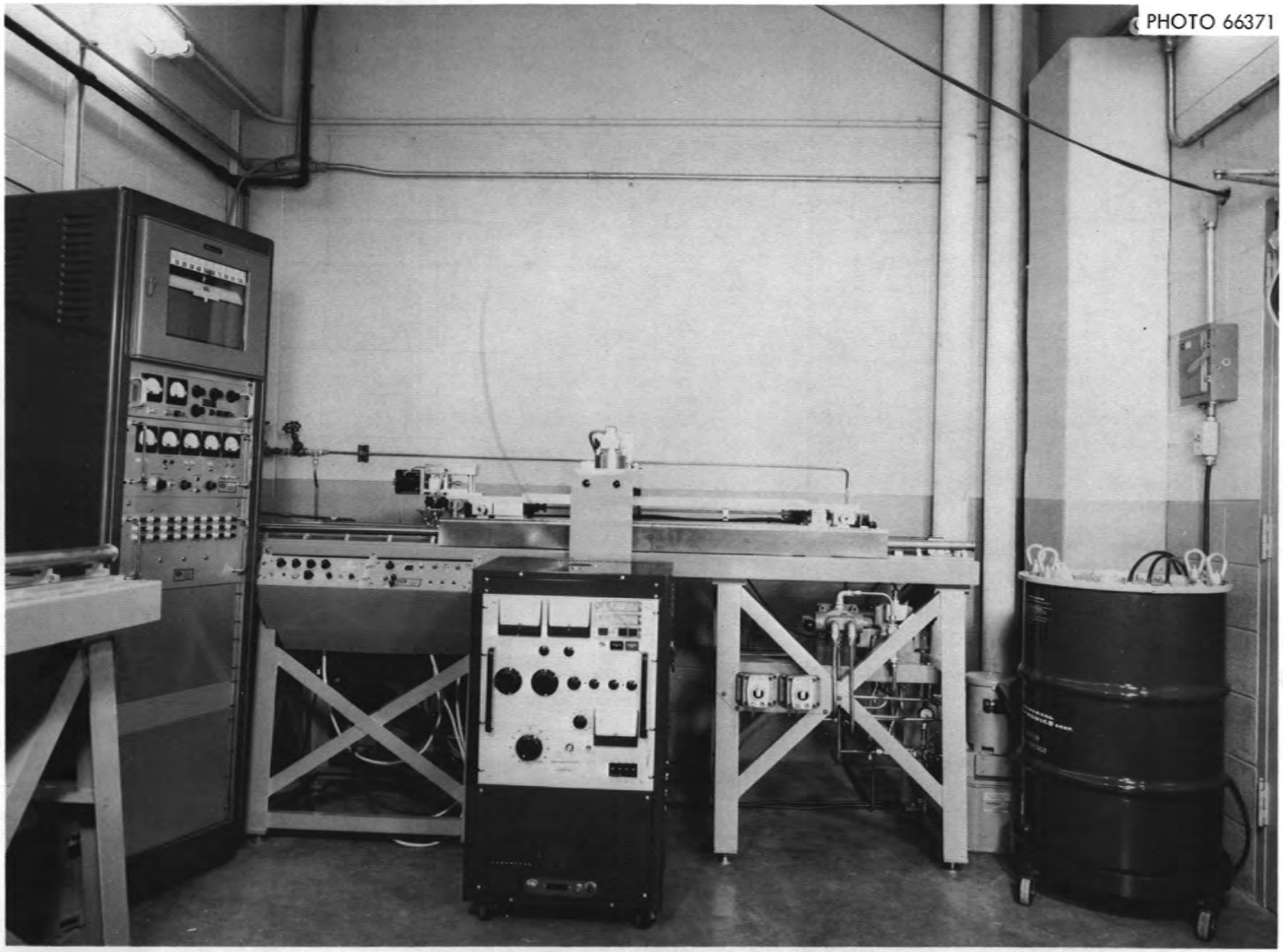

Fig. 1. HFIR Homogeneity Scanner.

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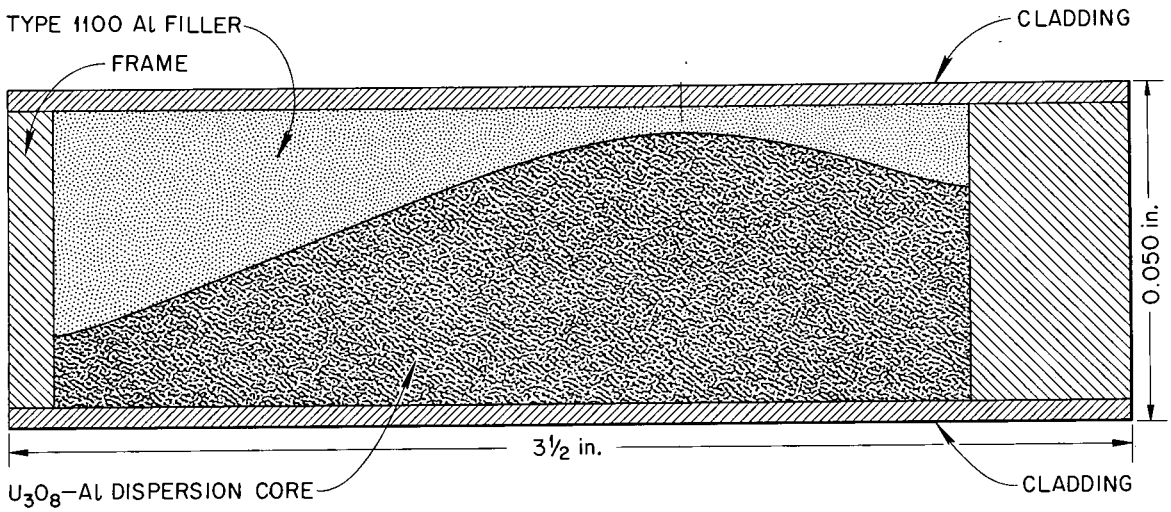

Fig. 2. HFIR Fuel Plate Cross Section.

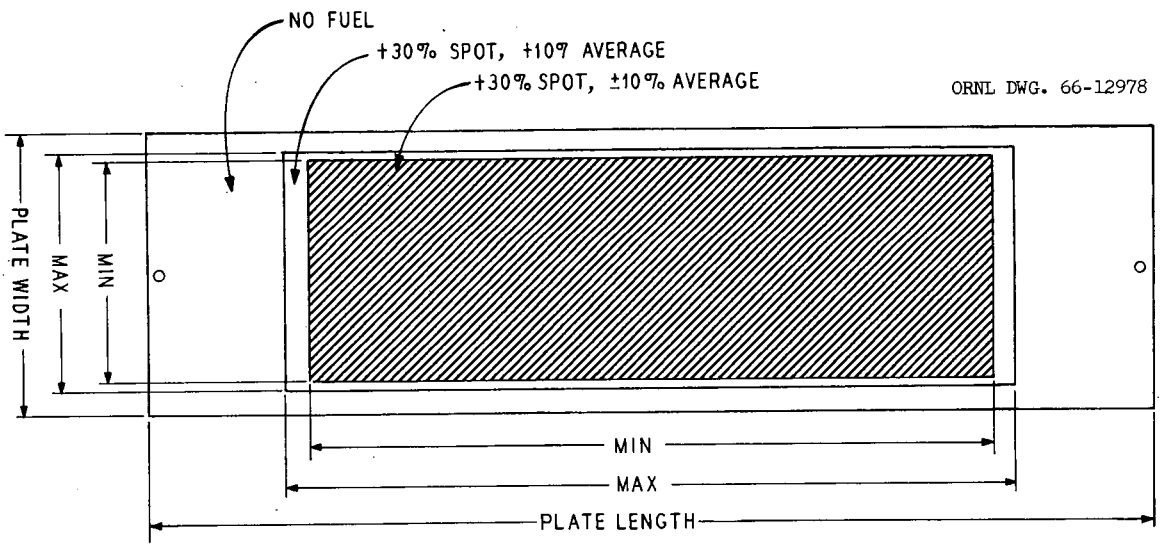

Fig. 3. Fuel Plate Area Outlines.

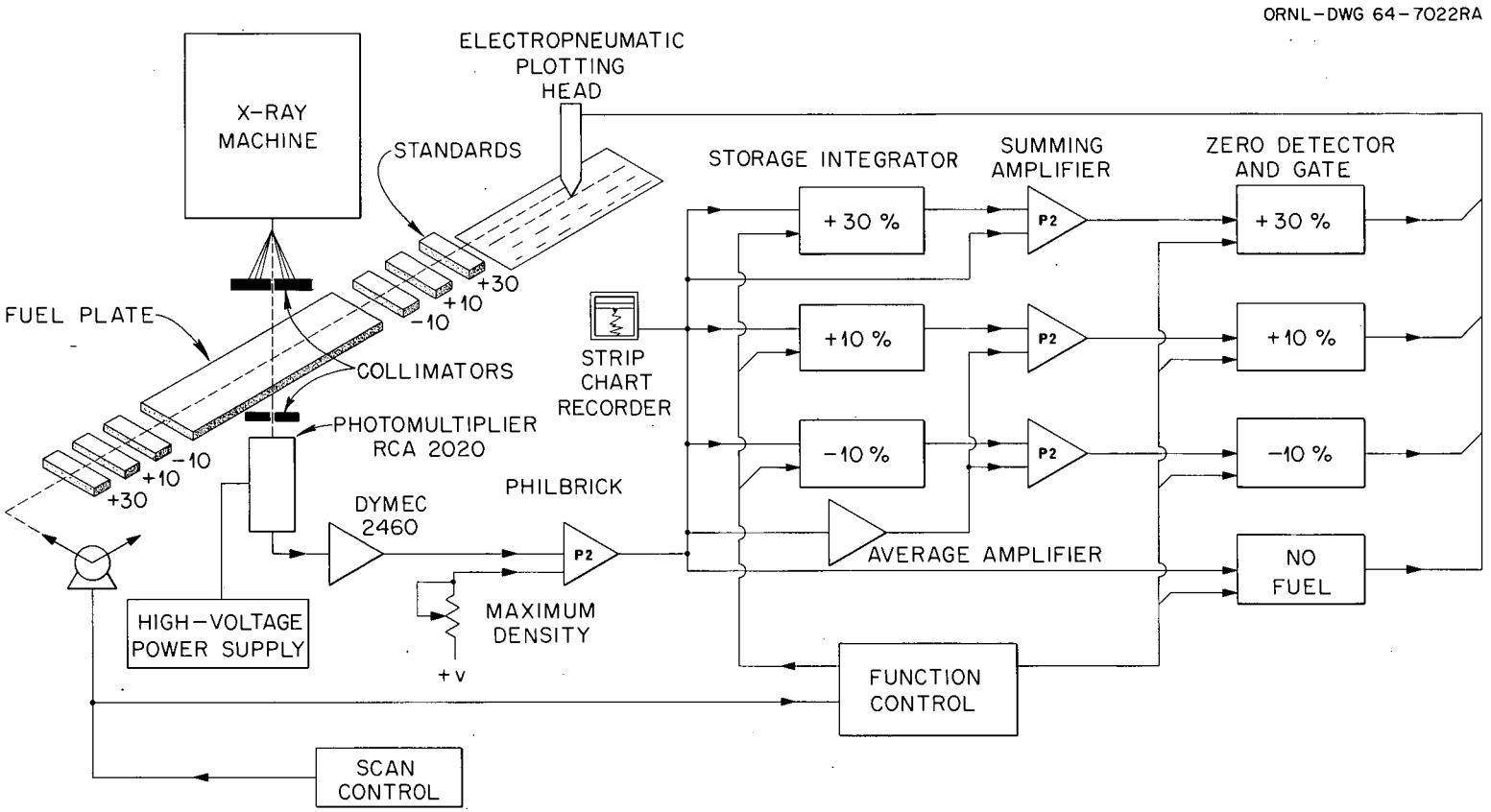

Fig. 4. Diagram of HFIR Homogeneity Scanner.

ORNL DWG. 66-12979

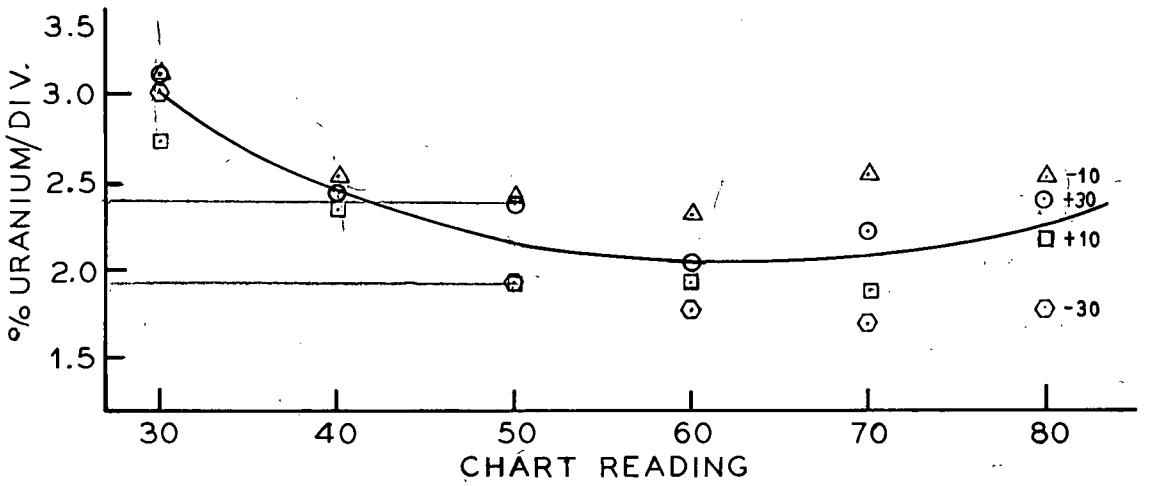

Fig. 5. Percentage of Uranium Oxide per Division for the Range of Recorder Ouputs. Data by B. E. Foster.

ORNL DWG. 66-12980

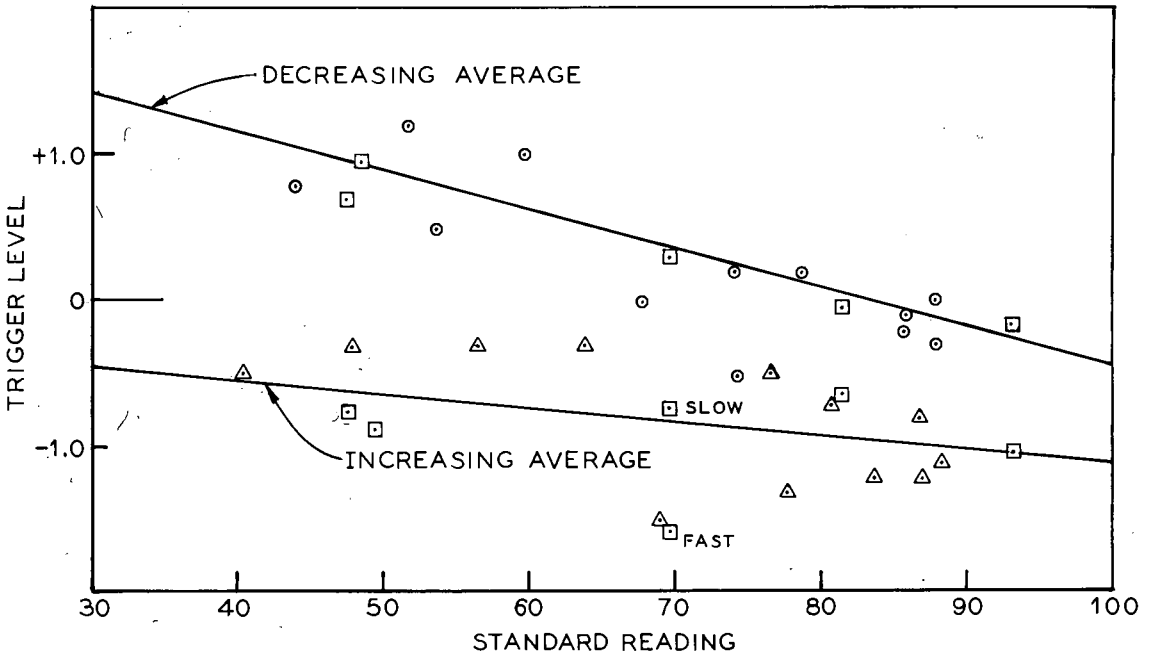

Fig. 6. Plus 10%.

ORNL DWG. 66-13038

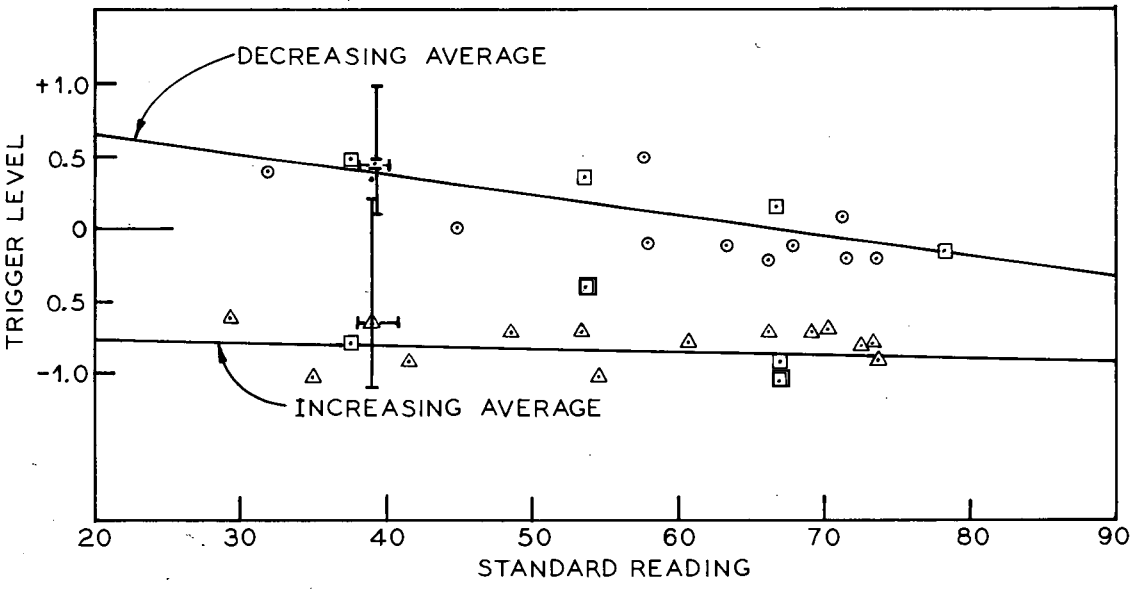

Fig. 7. Minus 10%.

The data plotted in Figs. 6 and 7 were obtained by pulsing the average signal displayed on the recorder with the "beyond tolerance limit" signals triggering the x-y plotter. Figure 8 shows a typical recorder output with the data points indicated. The hysteresis of the tolerance limit triggering was verified at a chart reading of 40, 60, and 80. The hysteresis for any level can be read from Figs. 6 and 7.

ORNL DWG. 66-12981

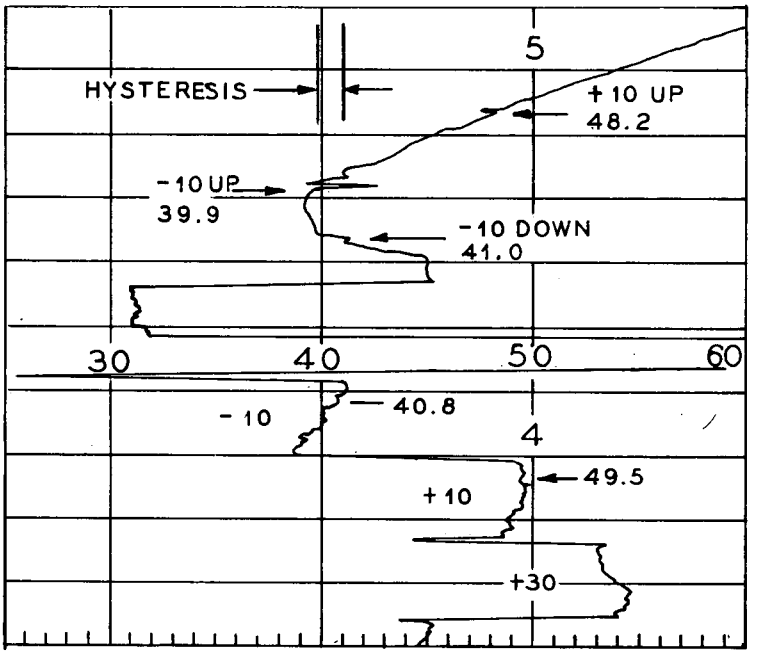

Fig. 8. Typical Output of Brown Recorder for Trigger Data.

1.1.5 Spot Limit Accuracy

The accuracy of the spot limit checking has not been accurately determined. However, the data indicate that a 100% no alarm occurs two divisions (0.2 v) below the standard, and a 100% alarm occurs one division (0.1 v) above the standard.

1.2 Controls

1.2.1 Gauging Chassis

Meters. -- The Spot, +30% Limit, +10% Average, Plate Average, and -10% Average signals are displayed on five meters. Each of the meters has a diode in series with it for reverse polarity protection.

Below each of the meters is a test point for that particular signal and the output of the checking amplifier for that limit. Any of these test points can be used to drive an auxiliary recording or sampling device. The meter indication will be approximately 0.2 v less than the recorder indication because of the diode voltage drop.

AC Power Switch. -- The ac power for a ±15 v dc-regulated power supply, Philbrick model PR-300C (whose output supplies the operational amplifiers, Philbrick model P2), is controlled by a toggle switch labeled AC Power. A 0.5-amp fuse on the connector apron at the rear of the chassis provides overload protection.

Maximum Density Potentiometer. -- The Maximum Density potentiometer controls the amount of bucking current supplied to the spot amplifier. It adjusts the signal level from the Dymec amplifier, model 2460A, so that the minimum to maximum density can be displayed in the range from 0 to 10 v.

Recorder Switch. -- The spot signal is displayed when the switch labeled Recorder is set at the "spot" position. With the switch set at the "average" position, the average signal is displayed during the traverse of the maximum area, and the spot signal is displayed outside this area.

Limit Test Selector Switch. -- This switch allows any of the limits (+ 30%, ±10%, and No Fuel) to be selected for test. The switch is set at the "off" position if an x-y plot is not desired.

Test Pushbutton. -- This pushbutton is for testing the operation of the limits as selected by the Limit Test Selector switch.

Alarm Reset Pushbutton. -- When the Alarm Reset pushbutton is depressed, it releases the alarm that had been locked in by exceeding the + 30% Limit.

Scan Speed Switch. -- The plate-average time constant for the scan speeds of 16, 64, 128, and 240 in./min is selected by this switch. With the switch set at the "test" position any time constant can be set through the use of test jacks.

Test Jacks. -- The test jacks allow selection of any time constant at any speed. The normal time constant is chosen by the formula RC = 40/speed, where the value of R is fixed at 1 megohm, C is in microfarads, and the speed is in inches per minute.

1.2.2 Function Control Chassis

AC Power Switch. -- The AC Power switch connects ac power through 1-amp fuses (located on the connector apron at the rear of the chassis) to the ±12 v dc-regulated power supplies, Technipower models 12.0-0.75 and 12.0-1.5, and to the -100 v and ±6.5 v dc zener regulated supplies.

DC Power Switch. -- The DC Power switch disconnects the dc power supplies from the load and allows the + 12 and -12 v power supplies to regulate before the load is applied.

Position Potentiometers. -- The 24 potentiometers select the "off" and "on" locations of the standards and the area outlines (see Sect. 2.5).

1.2.3 Scan Control Chassis

Auto Out-Manual-Auto In Selector Switch. -- Either automatic control or manual control can be selected with this switch. In the automatic mode, two positions are used for selection of the width index direction. Normal operation of the unit will alternate between "auto out" and "auto in." With the switch set at "auto out," the plate will be moved toward the front of the scanner.

Maximum Edge Index Switch and Indicator. -- This switch selects the number of mils of transverse motion between length scans when the beam is outside the maximum outline or when it is ready to cross the maximum outline. The switch is operational when the indicator is on. If the indicator is out, the normal index set on the Slo-Syn Preset Indexer is used (see Sect. 1.2.4).

Maximum Edge Index Disabling Switch. -- This switch removes the control from the maximum edge index. The normal index (Sect. 1.2.4) is substituted.

Width Out and In Limit Indicator. -- These indicator lights are turned on when the width drive is manually operated beyond the width of the inner or outer fuel plates or when a malfunction occurs. The microswitch that controls these lights will also interrupt ac power to the Slo-Syn Preset Indexer (Sect. 1.2.4). These indicators are not used during normal operation.

Width Stop Pushbutton. -- The Stop pushbutton has a toggle action; that is, it locks when in the "off" or "on" position. The button must be pushed again to turn the Slo-Syn Indexer on after it has been used to stop. The pushbutton contact is in series with the Out and the In microswitch contacts.

AC Power Switch. -- With this switch, power is supplied to the solenoid valves on the length motion and directly to the Slo-Syn Preset Indexer. Overload protection is provided by 1-amp fuses mounted next to the switch.

Left Length Pushbutton. -- This pushbutton operates a relay that energizes a solenoid valve to control the length motion to the left. The pushbutton should be held depressed for manual control.

Stop Length Pushbutton. -- This pushbutton interrupts the holding path to either of the length motion control relays.

Right Length Pushbutton. -- This pushbutton operates a relay that energizes a solenoid valve to control the length motion to the right. The pushbutton should be held depressed for manual control.

1.2.4 Slo-Syn Preset Indexer

The operation of all controls of the preset indexer is described in the Slo-Syn instruction folder.

Forward-External-Reverse. -- This selector switch should be set to "external" for automatic operation.

Preset Index. -- The number of mils set on the switches is used as the normal index for automatic operation except when the Maximum Edge Index indicator is on (Sect. 1.2.3).

2. OPERATING INSTRUCTIONS

2.1 Startup

After the equipment has been installed or has been shut down, the procedures for energizing all components are described in the following sections.

2.1.1 X-Ray Machine Power

Turn on the following switches in the order given:

a. stabilizer switch,
b. main breaker switch,
c. filament Variac fully counterclockwise (turn on the filament switch),
d. primary switch,
e. control switch.

2.1.2 Instrument Cabinet

Turn on the power switches in the following order:

a. AC power on the high voltage power supply (be sure that the dc switch is off).
b. AC power on the gauging chassis (set the maximum density potentiometer to approximately 500).
c. AC power on the function chassis.
d. DC power on the function chassis.
e. AC power on the Sorensen regulator (24 v dc to the plotting solenoids).

f. DC power on the high voltage power supply (set at approximately 950 v).
g. AC power on the Brown recorder (in rear). Chart drive off.

2.1.3 Scan Control

Turn the power switch on at both the scan control chassis and the Slo-Syn Preset Indexer chassis.

2.1.4 Photomultiplier Tube Dymec Amplifier

Turn the power switch on. (The amplifier is located at the rear of scanner table.)

2.1.5 X-Ray Machine High Voltage

a. Set the six control knobs for correct kilovoltage.
b. Set the Hi-Lo switch on "lo" for an x-ray tube current of approximately 11 ma.
c. Turn on the cooling water.
d. Turn on the key switch.
e. Turn the kv Variac to "end of travel" counterclockwise.
f. Push the High Voltage On switch.
g. Turn the kv Variac slowly clockwise until the Not Reg warning light goes out at the end of travel.
h. Turn the MA fine adjustment to the maximum clockwise position.
i. Turn the Brown recorder chart drive on, and turn the recorder signal switch at the gauging chassis to "spot."
j. Turn the filament Variac clockwise. Do not allow the recorder signal to oscillate. If it does, stop the oscillation by turning the fine MA adjustment counterclockwise.
k. Continue step j until a setting of approximately 60 is reached on the filament Variac.
l. Reset the fine MA adjustment to a maximum clockwise position with no oscillation.
m. Turn the fine MA adjustment counterclockwise to reduce the MA to the next lower division mark on the MA meter, i.e., approximately 11 ma.

2.2 Operation

The operating conditions listed below are fully explained later in this manual. The explanations should be read before the scanner is operated.

2.2.1 Operation Check List

The following list gives the conditions which must be met prior to fuel plate scanning:

a. Appropriate standards installed.
b. Regulator valves adjusted for proper scan speed.
c. Pneumatic printer ink and solenoid shift properly adjusted.
d. Pneumatic printer air supply on.
e. Chart paper (5401) installed in Brown recorder.
f. Brown recorder power switch set at "on" (switch is located at the rear of recorder).
g. Scan speed selector switch at proper setting to select the correct time constant.
h. Hydraulic pump on.
i. Proper kilovoltage setting.
j. Proper milliampere setting.
k. Correct values for the Slo-Syn preset (normal) index and the maximum edge index settings.
l. Slo-Syn selector switch set at "external."
m. X-Y plot paper advanced.
n. Width position indicator setting of either 1860 or 8490 for inner plates or 1695 or 8675 for outer plates (this will put the bridge in the Pre-Scan position for automatic scanning, Figs. 9 and 10).
o. Maximum Edge Index light on.
p. Plate Width lamp lit.
q. Maximum and Minimum Width lamps out.
r. Proper tool steel (0.006 and 0.018 in.) calibration (after calibration, the tool steel push rod should be pushed in to clear the x-ray beam).
s. Scanning table in the extreme right or left position.
t. Fuel plate correctly installed.
u. Brown recorder chart drive switch on if a strip chart recording is being made.
v. Recorder signal selector switch at "off" if a recording is not being made.
w. Pneumatic printer test selector limits switch in "on" position.

After the conditions listed are satisfied, scanning may proceed.

2.2.2 Normal Operation

In the following discussion, the directions "right, left, out, and in" are referenced as follows: With the operator standing in front of the x-ray collimator and shield assembly and facing the machine, "right" and "left" are to the operator's right and left. "Out" means that the fuel plate will be moved toward the operator, and "in" means that the fuel plate will be moved away from the operator.

The scanning table should contain a fuel plate (either an inner or an outer plate) and should be at the extreme left position. The normal operating steps follow.

a. The scanning operation is started by depressing the pushbutton labeled Right on the scan control chassis and holding the pushbutton depressed. The scanning table will move to the right.
b. Set the switch labeled Auto Out-Manual-Auto In to "auto out" and release the Right pushbutton.
c. The scanning table will move to the right until it is automatically stopped by the right limit switch. The table will move out 80 mils, and the Maximum Width indicator lamp will light.
d. The table will begin to move to the left, and the Maximum Edge Index indicator lamp will go out. The table will move to the left until it is stopped by the left limit switch, after which the table will move out 61 mils and the Minimum Width indicator lamp will light.
e. The scanning table will move to the right, stop, move out, move to the left, stop, move out, and so on until the Minimum Width indicator lamp goes out.
f. The scanning table will move toward the left until stopped by the left limit switch. The Maximum Edge Index indicator lamp will light. The table will move out 80 mils, move to the right until stopped by the right limit switch, and move out 80 mils. Operation of the table will stop.
g. Turn the Auto Out-Manual-Auto In switch to "manual." Remove the x-y plot, change the fuel plate, and restart the scanning operation by switching from "manual" to "auto in." The scanning table will move "in" 80 mils and then move toward the left limit, repeating all scanning steps previously described, but moving "in" on the transverse motion.

2.2.3 Operational Tests

The operating condition of the scanning unit should be checked periodically, as described in the following paragraphs.

Width Position Indicator. -- Verify that the scanning table is in the correct position at the completion of the scan of every plate. This position should also be the starting point for the next plate.

Amplitude Calibration. -- Insert the tool steel into the x-ray beam immediately before a plate is to be scanned. Readjust the "maximum density" and the "fine" settings if the amplitude of the Brown recorder is more than one-half division from either of the specified calibration points.

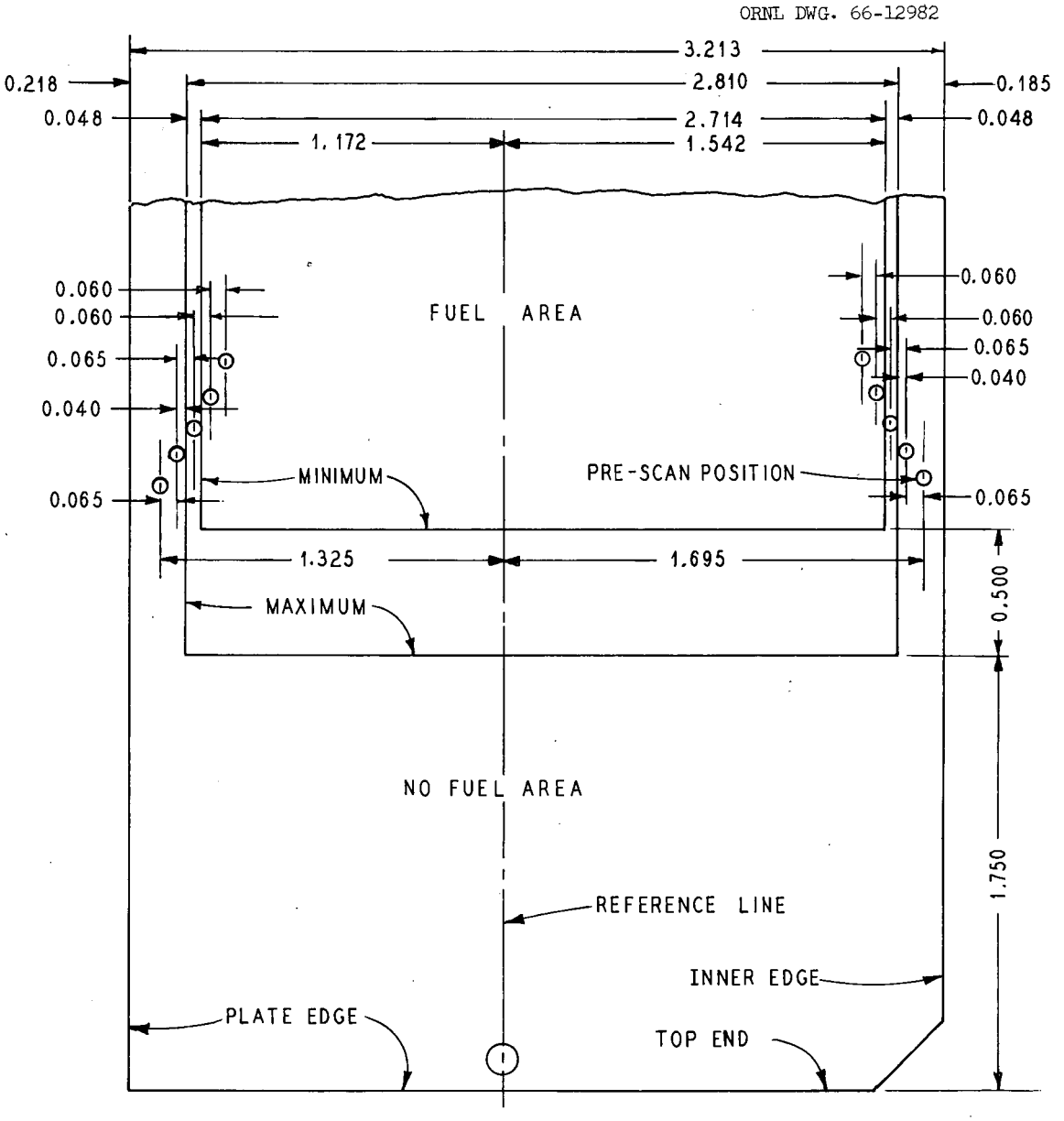

Fig. 9. Outer Fuel Plate Dimensions and Scan Pattern.

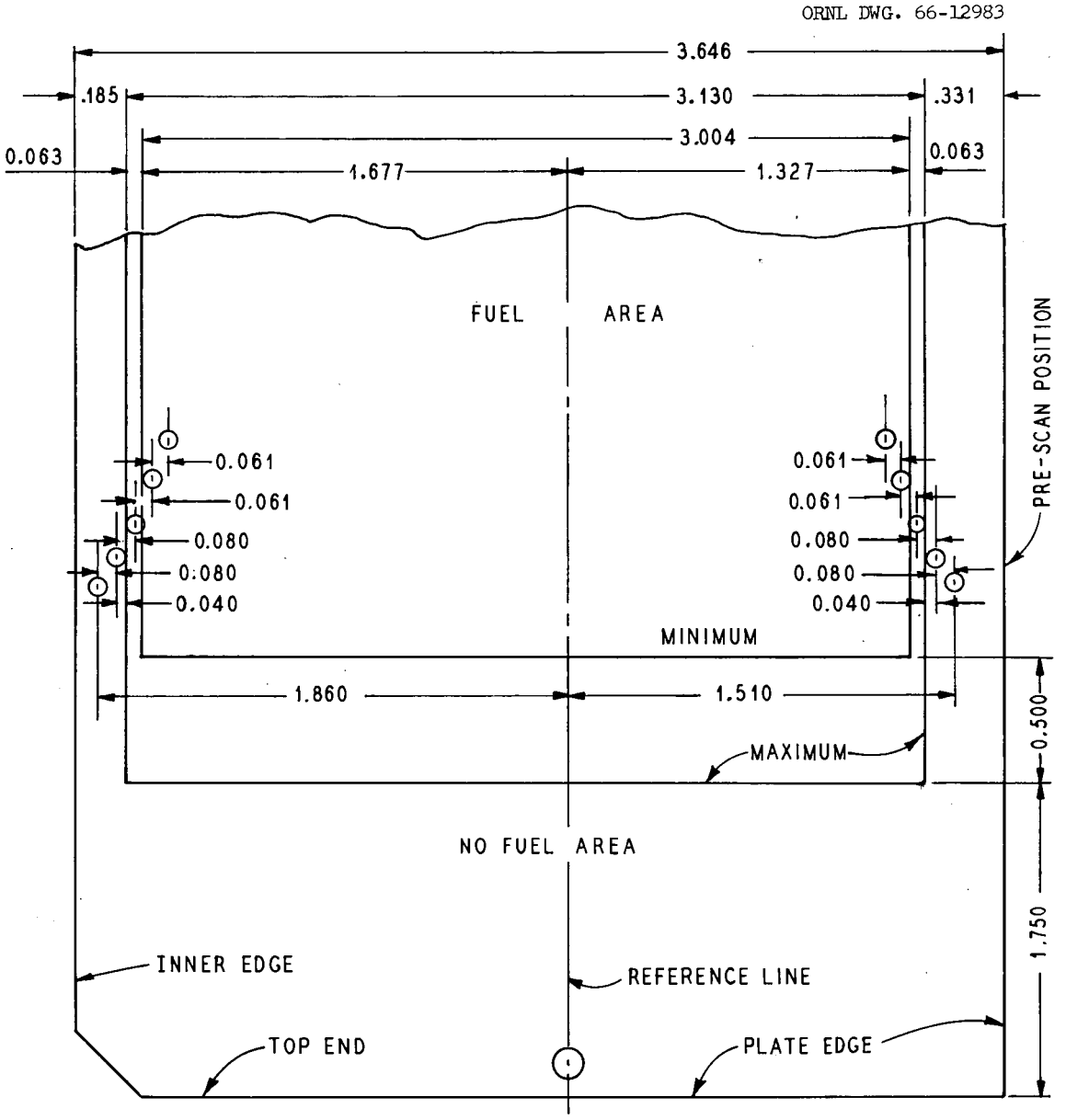

Fig. 10. Inner Fuel Plate Dimensions and Scan Pattern.

Standard plate. -- The standard plate should be scanned in accordance with Sect. 2.8.2 at the beginning of each day that fuel plates are to be inspected. The operating conditions to be tested with the standard plate are spot response and average response.

Max - Min Potentiometer Settings. -- The potentiometer settings for energizing the indicator lights for the maximum and minimum fuel outline on both width and length should be adjusted each week or whenever a setting error is suspected.

Alarm Trigger Levels. -- The +30% and ±10% trigger levels should be checked each week. This is done by scanning across the calibration standards to set the alarm levels. Note the values of the standards recorded by the Brown recorder. With the x-ray beam at the empty plate holder, slowly insert the tool steel calibration strips into the beam until the solenoid for -10% is actuated to turn off the -10% alarm. Locate the level at which the solenoid is intermittently actuated by "noise" signals. This is the alarm trigger level for -10%, and it should agree closely with the recorder value for the -10% calibration standard.

Insert the tool steel farther into the beam until the +10% level is indicated. Locate the trigger level for +10% as described for the -10% standard.

Repeat the calibration procedure for +30% alarm level. If the alarm level determined by use of tool steel does not agree with the calibration standard within ±1 division for the midpoint between 100% alarms and infrequent alarms on any of the three standards, instrument repair is needed.

"Average-Spot" Response. -- With sufficient material in the x-ray beam to produce an indication of approximately half scale on the Brown recorder, set the recorder signal switch alternately to "spot" and "average." The recorder pen should not move more than 0.1 chart division when the switch setting is alternated. The deviation should be uniform over the entire range of the recorder. Pen movement in excess of this indicates that instrument repair is needed. This test should be conducted each week.

Recorder Adjustment. -- The response of the recorder should be checked each week if it is being used routinely or prior to its use if it has not been used for more than one week. The standard plate is scanned at a speed of 64 in./min with the Recorder Signal switch set on "spot." The recorder trace is examined at the ends of the pen excursion in both upward and downward directions when the plate is being scanned across the +15% to -15% steps and back. The "corners" of the steps should not be round, and the overshoot of the pen should not be more than three chart divisions.

2.3 Operation of the Scanning Table

2.3.1 Width Movement

Control. -- The width (or in and out) movement of the scanning table is powered by a Slo-Syn stepping motor which is controlled either by the Slo-Syn controller or by an external signal. The external signal is generated in the scan control chassis and is transmitted to the step motor whenever the Maximum Edge Index indicator lamp is on.

Manual Control. -- When manual control of width movement (indexing) is desired, turn the Maximum Edge Index Disabling switch to the "off" position to remove the external signal. Select the desired index distance on the Slo-Syn Preset Indexer by setting the four switches. The distance traveled will be the sum of the four values indicated from left to right: inches, 100 mils, 10 mils, 1 mil. Select the desired index direction on the Slo-Syn Selector switch and push the Index pushbutton. The scanning table will move the selected index distance and stop. An emergency stop can be made at any time by pushing the Width Stop pushbutton. This is a latching switch which must be pushed again to make the width controls operable.

Automatic Control. -- When automatic indexing is desired, switch the Maximum Edge Index Disabling switch to the "on" position and the Slo-Syn selector switch to the "external" position. (With this switching combination the indexing motor will be controlled by the Slo-Syn Preset Indexer values when the Maximum Edge Index indicator lamp is out and by the Maximum Edge Index values when the indicator lamp is on.) Select the index distance to be used in the fuel area of the plates on the Slo-Syn Preset Indexer (60 mils for outer plates and 61 mils for inner plates) and the index distance to be used outside the fuel area on the scan control Maximum Edge Index switches (65 mils for outer plates and 80 mils for inner plates).

Set the Scan Control Selector switch to "auto-in" or "auto-out." The bridge will index when the switch is turned, will move to the end of the length travel, and will automatically index to the next scan.

If the Maximum Edge Index indicator lamp does not light after the x-ray beam has crossed the minimum line when moving from the fuel area toward the plate edge with the Maximum Edge Index Disabling switch "on," proceed as follows:

a. Turn the Maximum Edge Index Disabling switch to "off."
b. Turn the Scan Control Selector switch to "manual."
c. Set the Slo-Syn Selector switch in the direction ("out" or "in") that will move the fuel area toward the beam.
d. Increase the setting of the Slo-Syn Preset Indexer by 200 mils so that the distance traveled will put the center of the beam across the minimum fuel line.

e. Push the Index pushbutton.
f. Turn the Slo-Syn Selector switch to reverse the direction so that the bridge will return to its original position.
g. Push the Index pushbutton.
h. Turn the Maximum Edge Index Disabling switch to "on." The Maximum Edge Index indicator lamp should light.
i. Return the Slo-Syn Selector switch to "external." Return the Slo-Syn Preset Indexer to the original value.

2.3.2 Length Movement

Control. -- The length movement of the bridge is hydraulically powered and can be controlled either with a two-way manually operated valve or with pushbutton switches on the scan control chassis. The scan control chassis provides for either manual or automatic operation.

Manual Control. -- For manual operation, the selector switch must be in the "manual" position. The bridge can then be moved to the right or left by pushing the appropriate start pushbutton on the Scan Control and holding the button down. The bridge movement will stop when the button is released.

Automatic Control. -- When being operated automatically, the bridge stops, indexes, and automatically starts in the opposite direction at the end of each scan. Automatic operation stops when a width limit switch is actuated. The length travel can be stopped at any time by switching to "manual."

When a width index is desired before the first scan starts, with the bridge at the end limit of travel:

a. Set the Slo-Syn Selector switch to the "external" position.
b. Turn the Scan Control Selector switch to the desired index direction.

The length travel will start immediately and continue in the automatic operation.

When a width index is not desired before the first scan starts:

a. Set Slo-Syn Selector switch to the "external" position.
b. Set the Scan Control Selector switch to the "manual" position.
c. Push one of the Length start pushbuttons and hold it in.
d. Turn the selector switch to "auto-in" or "auto-out."
e. Release the Length start pushbutton.

2.4 Installation of Standards

Each set of calibration standards consists of two groups of four standards. Insert a group into each end of the fuel plate holder in such a manner that the 100% standard is at the outer end of the holder and the

scribed reference line is aligned with the scribed line on the holder. When installed in this manner, the sequence across the standards will be 100, 130, 110, and 90% as read from either end toward the center of the plate holder.

2.5 Function Setup

2.5.1 General

The length and width positions are set by the use of two potentiometers and an indicator light for each location. The length positions are set, starting at the left end of the plate holder with the holder moving to the left, in the following order: +30L, +10L, -10L, Plate, Maximum, Minimum, -10R, +10R, and +30R. The Maximum and Minimum length positions are located within the Plate length. The width positions (Plate, Maximum, and Minimum) are located similar to the locations on the length scan (Fig. 3). The left and right positions, L and R, are set with the scanner approaching the setting position in the corresponding direction. This reduces the hysteresis that would be present in the right settings if they were set while approaching from the left. The function of each of the locations +30L, +10L, -10L, -10R, +10R, and +30R is to produce a control signal for the storage integrator circuits. On the other hand, the function of the Plate, Maximum, and Minimum locations, after combining the length and width positions to select an area, is to gate the inputs of the null detectors to the plotting head.

2.5.2 Adjustment of Length Potentiometers

Each position has two 10-turn potentiometers for setting the On and Off locations. The minimum dial setting occurs when the bridge is at the extreme left of the machine. One division of the dial is approximately 0.04 in. The approximate location for each dial is given in Table 1. With the calibration standards and the standard plate (see Sect. 2.8.2) in the plate holder, proceed to adjust the length potentiometer.

Table 1. Approximate Values for Setting the Length Potentiometers

Length Position	On	Off
+30L	100	130
+10L	135	165
-10L	170	200
Plate	205	785
Maximum	250	750
Minimum	260	740
-10R	840	810
+10R	875	845
+30R	915	885

Standards at the Left End. -- The adjustment procedure is as follows:

a. Move the bridge to the right until the center of the beam is approximately 1/8 in. from the left edge of the 130% standard.
b. Adjust the + 30L On potentiometer until the indicator lamp flickers.
c. Move the bridge to the left until the center of the beam is approximately 1/4 in. from the right edge of the 130% standard.
d. Adjust the + 30L Off potentiometer until the indicator lamp flickers.
e. Move the bridge to the left until the beam is at the 110% standard and approximately 1/8 in. from the left edge. Adjust the + 10L potentiometer.
f. Continue setting the potentiometers for the standards (left positions) as described in steps a to e, moving the bridge in the left direction.

Plate Length. -- After setting the position lights for the left calibration standards, continue moving the bridge to the left to make the following plate settings.

a. Left Plate End: with the beam at the end of the plate, adjust the Plate On potentiometer until the indicator lamp flickers.
b. Left Maximum: with the beam over the standard plate reference notch representing Maximum fuel length, adjust the Max On potentiometer.
c. Left Minimum: with the beam over the reference notch representing the Minimum fuel length, adjust the Min On potentiometer.
d. Right Minimum: repeat step c at the Minimum notch at the right end of the standard plate, adjusting the Min Off potentiometer.
e. Right Maximum: repeat step b, adjusting the Max Off potentiometer.
f. Right Plate End: repeat step a, adjusting the Plate Off potentiometer.

Standards at the Right End. -- The adjustment procedure is as follows:

a. After adjusting the plate positions, continue moving the bridge to the left until the center of the beam is approximately 1/8 in. from the right edge of the 130% standard.
b. Adjust the + 30R On potentiometer until the indicator lamp flickers.
c. Move the bridge to the right until the center of the beam is approximately 1/4 in. from the left edge of the 130% standard.

d. Adjust the +30R Off potentiometer until the indicator lamp flickers.
e. Continue setting the standards, moving toward the right until all the right end standards have been set.

Readjustment. -- After the adjustments have been made to both left and right standards, move each group of standards through the beam in their respective directions at a speed slow enough to visually check the location of the point at which the indicator lamps operate. Readjust the potentiometer settings if necessary.

The indicator lamp corresponding to a specific standard should light after 1/8 in. of the standard enters the x-ray beam, and it should go off when 1/4 in. of the standard remains before leaving the beam, when the direction of travel is moving the fuel plate toward the beam.

The length potentiometer setting for the Plate, Maximum, and Minimum can best be rechecked by measuring the distance through which the bridge travels with the appropriate indicator light on. The Plate light should remain on for a distance of 24.000 in., the Maximum light for 20.580 in., and the Minimum light for 19.500 in. The accuracy of settings should be within 1/32 in.

The lights should be turned off at each end in similar locations with respect to the plate end. The x-ray beam should be entirely outside the maximum fuel area when the Max light goes off, and centered on the minimum outline when the Min light goes off (1.710 in. from the maximum to the plate end and 2.250 in. from the minimum to the plate end).

2.5.3 Adjustment of Width Potentiometers

Each position has two 10-turn potentiometers for setting the On and Off locations. The minimum dial setting occurs when the width table is to the rear edge of the machine (In). One division of the dial is approximately 0.005 in. The approximate location for each dial for the inner and outer fuel plates is given in Table 2.

Table 2. Approximate Values for Setting the Width Potentiometers

Width Position	Inner		Outer	
	On	Off	On	Off
Plate	130	780	160	750
Maximum	160	757	189	722
Minimum	168	746	195	715

A mechanical digital readout attached to the width drive shaft indicates the position in mils with an accuracy of 1 mil while moving in the same direction. Backlash in the gearing causes an error of 3 mils.

Location of Reference Line. -- The procedure for setting the reference line (Fig. 11) is as follows:

a. Turn the Maximum Edge Index Disabling switch to "off."
b. Place the standard plate in the fuel plate holder and locate the reference line. This is done most accurately by centering over the plate positioning pins in the plate holder and by using the strip chart recorder to locate the point where equal movements in and out will produce equal readings.
c. Adjust the width position indicator (counter) to 0000.

Width Potentiometer Setting. -- The adjustment procedure is as follows:

a. Set the Slo-Syn Preset Indexer to 1677 (1.677 in.) for inner plates or 1542 (1.542 in.) for outer plates (see Fig. 11).
b. Set the Slo-Syn Selector switch to "in."
c. Push the Slo-Syn Index button. Wait for the drive to stop. Check the width position indicator (should read 1677 for inner plates or 1542 for outer plates).
d. Adjust the Minimum Width On potentiometer to a setting which causes the Min indicator lamp to flicker.
e. Set the Slo-Syn Preset Indexer for 63 mils for inner plates or 48 mils for outer plates.
f. Push the Slo-Syn Index button. Wait for the drive to stop.
g. Adjust the Maximum Width On potentiometer to a setting which causes the Max indicator lamp to flicker.
h. Set the Slo-Syn Preset Indexer for 40 mils.
i. Push the Slo-Syn Index button. Wait for the drive to stop.
j. Connect the appropriate limit switch cable for inner or outer plates (located on the extreme right of the bridge). Adjust the switch position if necessary to give a slight compression contact on the operating arm.
k. Set the Slo-Syn Selector switch to "out."
l. Set the Slo-Syn Preset Indexer to 3.107 in. for inner plates or 2.802 in. for outer plates.
m. Push the Slo-Syn Index button. Wait for the drive to stop. Check the width position indicator (should read 8.673 for inner plates or 8.828 for outer plates).
n. Adjust the Minimum Width Off potentiometer.
o. Set the Slo-Syn Preset Indexer to 63 mils for inner plates or 48 mils for outer plates. Push the Slo-Syn Index button and wait for drive to stop.

p. Adjust the Maximum Width Off potentiometer.
q. Set the Slo-Syn Preset Indexer for 40 mils, index, and wait for the drive to stop.
r. Adjust the limit switches as in step j.
s. Set the Plate Width Off and On potentiometers to 780 and 130 respectively for inner plates or to 750 and 160 for outer plates.

2.6 Adjustment of Scan Speed

The scan speed is controlled by two Vickers control valves. The valve on the right controls the speed to the right, and the valve on the left controls the speed to the left. The hydraulic oil pressure regulator should be adjusted to 150 psi on the gauge at the pump, with the bridge at the extreme right or left. For final settings the travel should be timed.

2.7 Adjustment of Pneumatic Printer

To adjust the ink to the x-y plot, proceed as follows:

a. Move the bridge until both the minimum width and minimum length indicator lamps come on.
b. Adjust the air pressure to the printer to 20 psig.
c. Fill the ink reservoirs to 75% capacity with filtered ink.
d. Adjust the bridge travel to operating speed.
e. Set the Limits Selector switch on the circuit to be tested.
f. Start the bridge travel.
g. Push the test button and hold it down while the bridge is moving.
h. Adjust the ink supply until the desired contrast is obtained at the operating speed.
i. Repeat steps e through h for each color.
j. Turn the Limits Selector to the "off" position after the adjustments are completed.

2.8 Instrument Calibration

2.8.1 Amplitude

Amplitude is calibrated by inserting tool steel of two different thicknesses (0.006 and 0.018 in.) into the x-ray beam and observing the response on the Brown recorder. The procedure for calibration and adjustment is as follows:

a. Install chart paper (5401) in Brown recorder and turn the Chart Drive switch "on."

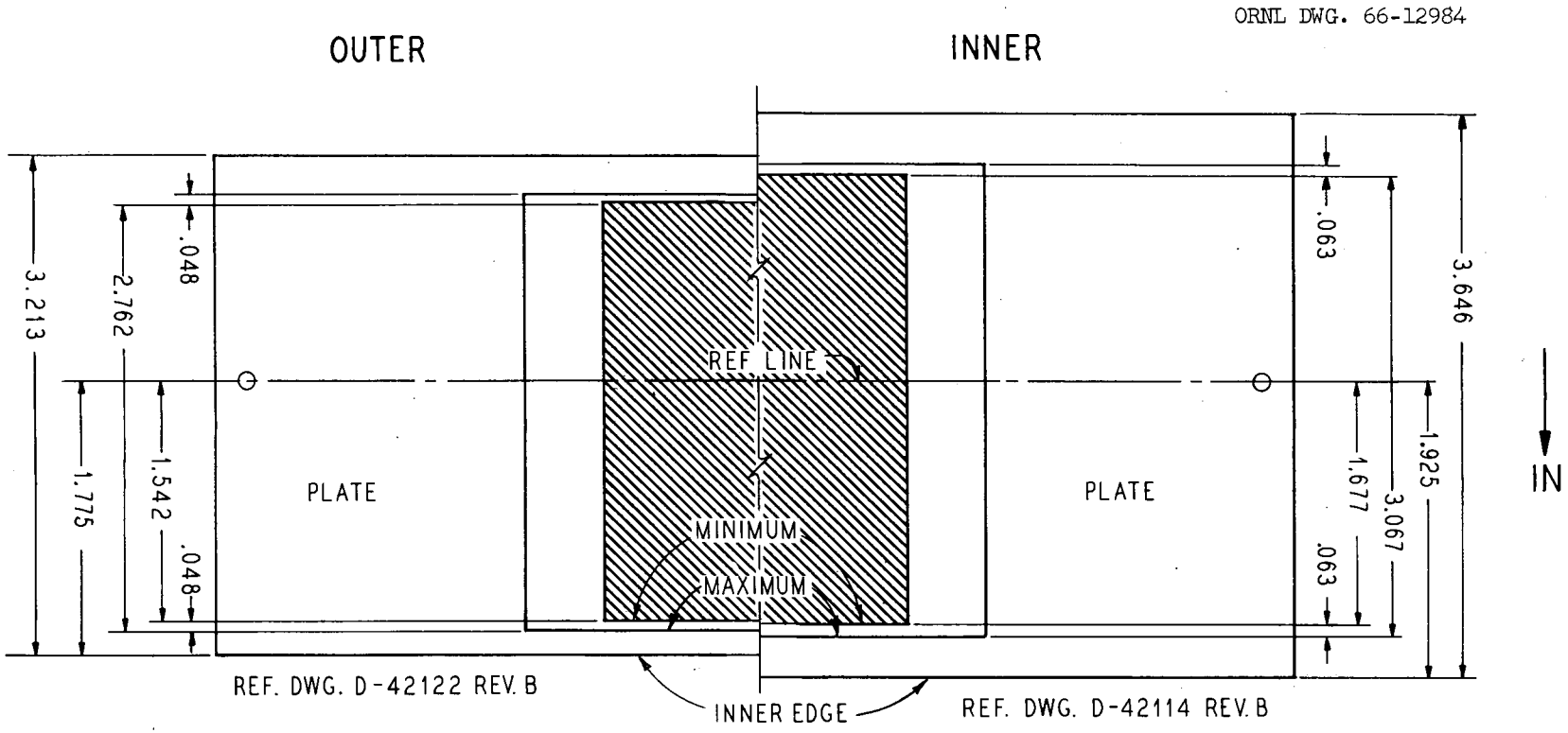

Fig. 11. Fuel Plate Dimensions.

b. Pull the tool steel control rod until the first detent is engaged. This will bring the 0.006-in. tool steel into the x-ray beam. The control rod is located at the front of the x-ray tube support channel.
c. Adjust the Fine voltage control of the photomultiplier high-voltage supply until the Brown recorder indicates 9-1/2 chart divisions.
d. Pull the control rod out until the second detent is engaged. This will bring the 0.018-in. tool steel into the x-ray beam. Adjust the Maximum Density potentiometer, located on the gauging control chassis until Brown recorder indicates 76 chart divisions.
e. Repeat steps b, c, and d until both adjustments are correct. Rapid adjustment can be achieved by setting the Maximum Density potentiometer as many divisions above or below 76 as it was below or above before step c was repeated.

2.8.2 Standard Plate

A layout for a standard plate is shown in Fig. 12, and details of construction are shown on ORNL dwg. No. 10940S041D. The standard plate should be scanned once per week to test that the performance of the scanner is acceptable. The x-y plot should have a predetermined color and location pattern.

3. ELECTRONIC MAINTENANCE

3.1 X-Ray Tube Alignment

Mechanically align the upper collimator M39 (on Dwg. 10940S026) and the holder M33 to be at right angles to the bridge top M2. Align the upper collimator and the lower collimator M57 by shifting the shield with respect to the bridge top or by shifting the bridge top with respect to the bridge bottom. Center the adjustment M15 of the adjusting pad M6 along the axis of the x-ray tube. Place the x-ray tube on the adjusting pad and center it with respect to the shield by shifting the tube and adjusting at M3. Use the rotation adjustment on the x-ray tube to align the clamp ring of the tube with the shield. Clamp the x-ray tube to the adjusting pad. Check the centering. Adjust the upper collimator to clear the plate holder by 1/32 in.

After applying high voltage to the x-ray tube, shift the tube with respect to the collimator by using the adjustments at M3 and M15. A minimum signal on the recorder is desired. Center the adjustments within the minimum for each motion. CAUTION! Do not allow your hands to enter the x-ray beam.

The spot size, about 0.080 in. diam at the fuel plate surface, can be checked for uniformity of intensity and for a circular pattern by

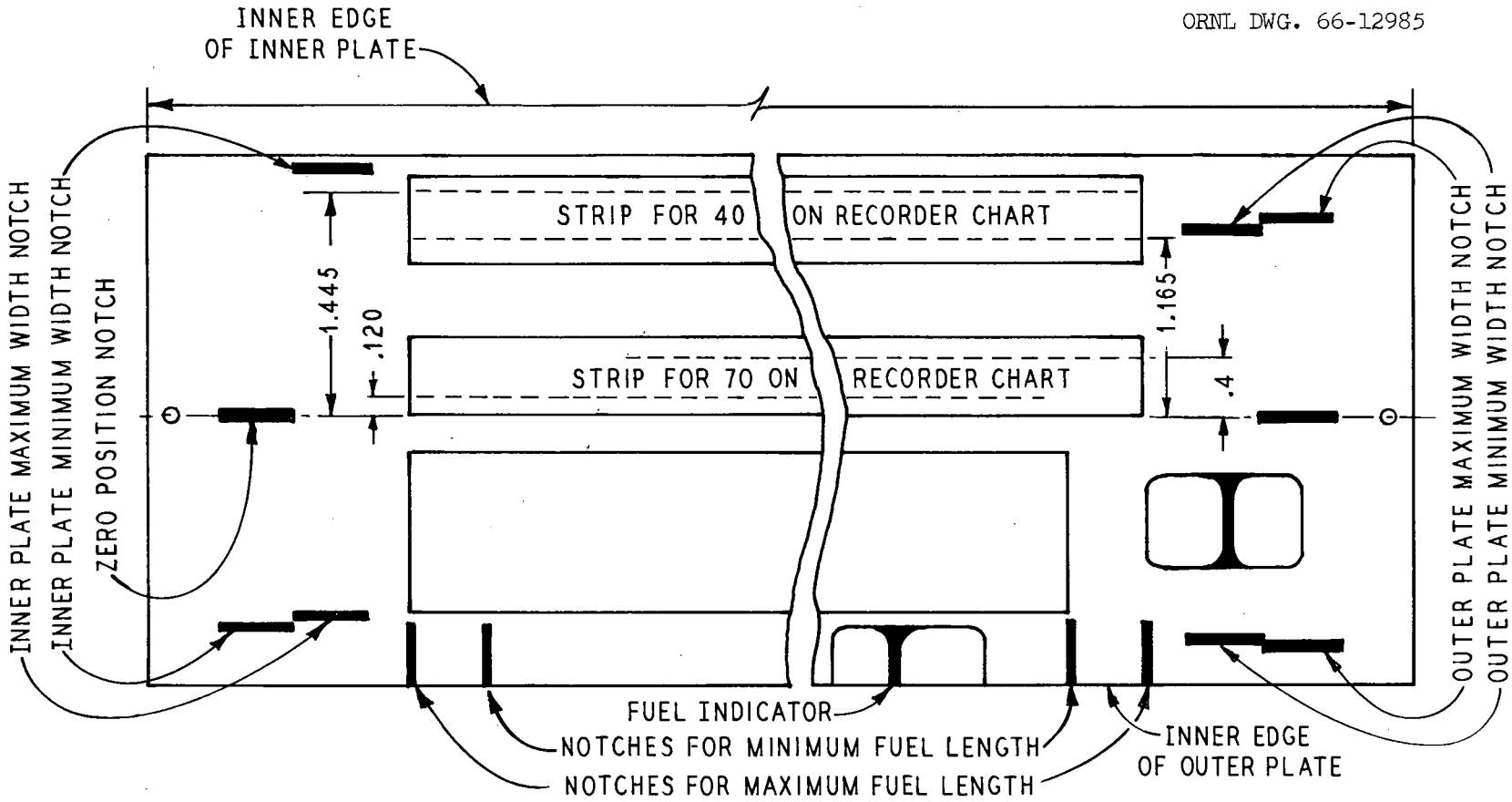

Fig. 12. Standard Plate Dimensions.

exposing a piece of x-ray film, very fine grain (Kodak type M), with a 0.005-in. lead filter on top of the film, for 15 sec.

The amplitude should be calibrated before the scanner is placed in production (see Sect. 2.8.1).

3.2 Pneumatic Printer

Air pressure at the printer should be set at 30 to 35 psig. The F-1 assembly should be cleaned weekly by soaking in acetone for 8 hours. The ink reservoirs should be cleaned monthly by flushing with warm water. If the ink has dried, use acetone on metallic parts. Do not use acetone on the vinyl plastic tubing.

3.2.1 Ink

The ink must be filtered through a lintless nylon cloth, ORNL Stores No. 06-880-2222 (Southern Press and Filter Media Co., or equal). The reservoirs should be filled to 75% capacity. The ink used is a stamp pad type as follows:

a. black, FSN7510-161-4237 GSA, Class 1, ORNL Stores No. 10-354-4675,
b. red, FSN7510-161-4240 GSA, Class 1, ORNL Stores No. 10-354-4715,
c. green, FSN7510-161-4238 GSA, Class 1, ORNL Stores No. 10-354-4695,
d. blue, FSN7510-161-4236 GSA, Class 1, ORNL Stores No. 10-354-4685.

3.2.2 Paasche F-1 Assembly

The F-1 assembly, by the Paasche Airbrush Co., Chicago, is used to adjust the color of the output by a screwdriver adjustment shown in Figs. 13 and 14. Turn the adjustment clockwise for a darker color or counterclockwise to shut off or lighten the color.

The F-1 assembly can be removed by disengaging the ink supply with a slight pull and rocking motion at point A on Fig. 13 and by removing two 4-40 socket head screws. After being removed from the base, the upper and lower end of the F-1 assembly can be removed from its support bracket.

To install the F-1 assembly, reverse the removal procedure. Be sure that the needle guide bushing, located inside the lower tapered piece of the F-1 assembly, is screwed all the way in. The tapered piece should also be snug against the needle. CAUTION! Do not overtighten.

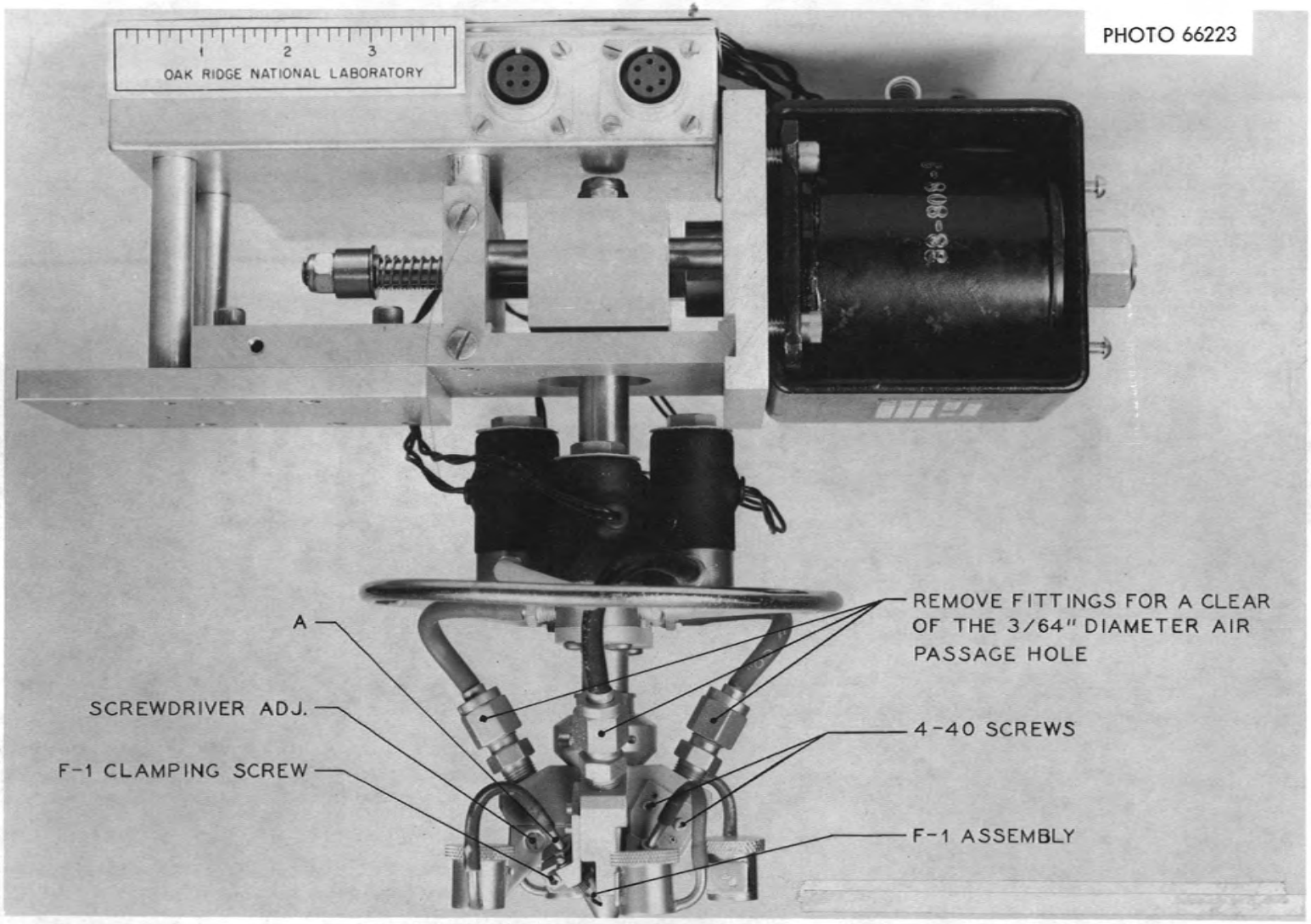

Fig. 13. Pneumatic Printer, Side View.

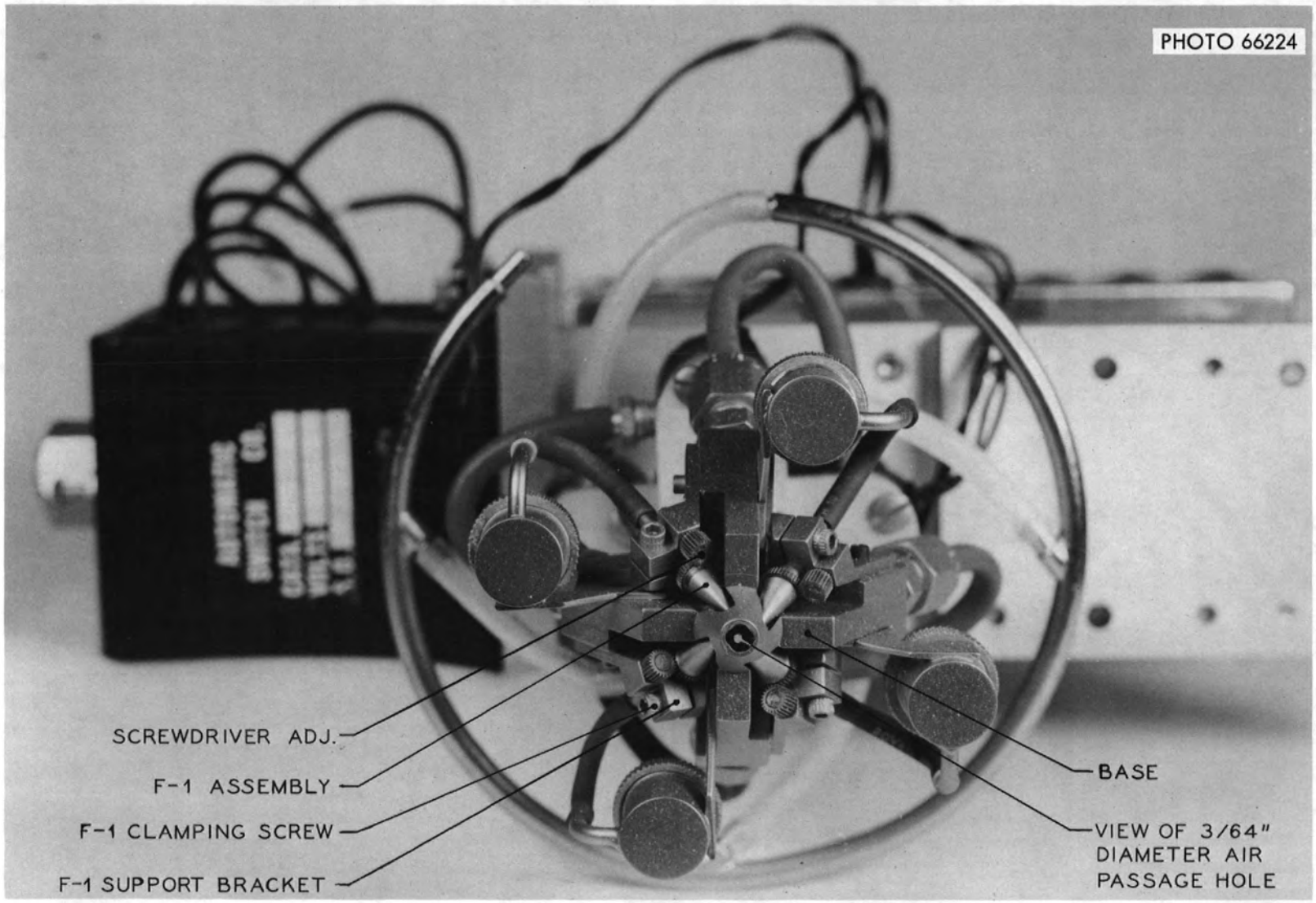

Fig. 14. Pneumatic Printer, Bottom View.

The needle assembly must be centered within the 3/64-in. diam air-passage hole (Fig. 14) in the base of the pneumatic printer. The apex of the F-1 assembly is adjusted to the center of the 3/64-in. diam hole by moving it up or down after loosening the clamping screw. Tighten the screw when the adjustment is completed.

3.2.3 Shift Adjustment

The solenoid operated shift adjustment compensates for the electrical and pneumatic time delays of the printing system; therefore, an adjustment is required whenever the speed of scanning is changed. The adjustment is made as follows: (a) attach a piece of No. 18 copper wire to a fuel plate across the width of the plate at right angles to the direction of travel; (b) run the scanner in an automatic mode; (c) check the pattern of dots when the scanner passes over the wire; (d) if the dots are staggered on alternate scans, adjust the amount of shift to bring them into alignment; and (e) tighten the locknut on the shift adjustment.

3.3 Description of Functional Operation

3.3.1 Scan Control

The scan control chassis (ORNL dwg. Q-2744-3) contains the components for controlling the programmed motion of the scanner: four dpdt relays, a two-decade index switch, a gating circuit for the Maximum Edge or Normal Index, four pushbuttons (Right, Left, Stop Length, and Stop Width), and a three-position (Auto Out-Manual-Auto In) selector switch for automatic or manual control. The parts of the scan control external to the chassis are a Slo-Syn indexer and motor and eight limit switches. Two limit switches are used in the length motion (right and left) and six limit switches are used in the width motion: two for maximum travel limits, two for inner fuel plate limits, and two for outer fuel plate limits. The length and width limit switches are connected through connectors SL and SW.

The sequence of operation under normal use is the following. The right relays K3 and K4 will be energized through the interlock contact K1A and the right pushbutton PB3 in manual operation or the left limit switch LL in automatic operation. Manual operation is terminated by the Stop pushbutton PB1. In the following discussion automatic operation Auto Out is assumed. The left relays K1 and K2 are locked out by the opening of the normally closed contact K3A when K3 is energized. The normally open contact K4A will seal in relays K3 and K4 through the right limit switch RL, the In or Out limit switches IL1 or OL1, the Auto Out or Auto In positions of the Auto Out-Manual-Auto In Selector switch, the normally open contacts of the Slo-Syn Preset Indexer relay, and the Stop pushbutton PB1. (The Slo-Syn Preset Indexer relay is energized except when counting.) AC power is supplied to the right solenoid valve through fuses F1 and F2 and contacts K3C and K4C. The scanner table will move to the right until the right limit switch RL is operated.

The opening of the normally closed contact of RL opens the holding path to relays K3 and K4. This allows the normally closed contact K4B to energize the Slo-Syn Preset Indexer start circuit through the Auto Out side of the three-position selector switch and the start transistor Q3. The + 12 v level at pin K of the printed circuit card will cause transistor Q3 to switch. The collector of Q3, pin H, will change from + 4.5 v to ground. The signal change at capacitor C31 is from -3 to + 4 v. The indexer relay will be de-energized for the counting period as set on the Slo-Syn Preset Indexer or on the scan control chassis if the Maximum Edge Index indicator lamp is on. Control signals to the indexer are routed through connector SI.

At the completion of the counting period, the indexer relay energizes. The operating path to relays K1 and K2 is completed through the normally open contact of RL which is operated by the scanner table. Relays K1 and K2 are sealed in through the normally open contact K2A. The normally closed contact K1A, now open, prevents the operation of the right relays. The scanner table will move to the left because of the ac power applied to the left solenoid through K1C and K2C. It will move left until the left limit switch LL is operated. The control will again index and reverse its direction of motion through K2B, the Slo-Syn Indexer count relay, and the left limit switch LL.

The motion sequence (right, index, left, index, right, etc.) will continue until the out limit switch OL1 is operated. This will prevent K1 and K2 or K3 and K4 from operating through RL or LL, and the scanner will stop. Moving the Auto Out-Manual-Auto In switch to "auto in" will cause the Slo-Syn Preset Indexer to start the sequence for motion toward the In Limit switch IL1.

The Stop Width pushbutton has a latching action for stopping in the middle of an index. The limit switches IL2 and OL2 are used as a crash stop and are located at the points of maximum travel of the width. Each switch controls an indicator that is turned on if the limit is operated. In order to resume normal operation after operating IL2 and OL2, the ac power cord to the Slo-Syn Preset Indexer should be connected to a source of power other than the scan control chassis. CAUTION should be exercised in backing off the limits IL2 and OL2.

The Maximum Edge Index and Normal Index circuits require a signal level of approximately 0 v at the collectors of Q1 and Q2 for control of indexing to take place by the Maximum Edge Index switches on the scan control chassis or the Normal Index switches on the Slo-Syn Preset Indexer. The signal levels at the anodes of the selection diodes are 0 v selected and + 10 v not selected. The signal level at pin D of the printed circuit board (ORNL drawing Q-2744-11) is a negative pulse from + 10 v to ground. The Maximum Edge Index switch is connected to the indexer through cable SI.

3.3.2 Function Control

The function control chassis (ORNL drawing Q-2744-2) selects the operation to be performed by the gauging circuits through the use of twelve position circuits. Each circuit contains two potentiometers, two voltage comparators, and an Exclusive-Or gate. These outputs are then combined for the control functions. The details of operation follow.

A reference voltage for the "on" or "off" location of a position is obtained from the wiper of a 10-kilohm, 10-turn potentiometer. The potentiometer has a zener regulated supply voltage of -6.5 v at one end and +6.5 v at the other end. The "right" and "out" directions are clockwise on the potentiometers. These same voltages are also routed to the location sensing slide wires through connector FL. (See ORNL drawing Q-2744-13 for connector terminations.)

Movement of the scanning table to the right will result in an increasing positive voltage at the wiper of the slide wire, pin 2 of $T\text{-}113_{A1}$ (see Sect. 4 for numbering and symbols). The emitter-follower output, pin 7 of $T\text{-}113_{A1}$, is routed to pin 2 of the 18 voltage comparators (T-172) for the length position detection. Whenever the voltage on pin 2 of a comparator exceeds the potentiometer reference voltage on pin 4, the output pin 7 of the comparator will switch from -11 to -3 v. In a similar manner, the width sensing uses emitter follower $T\text{-}113_{76}$ to control six voltage comparators.

The outputs of the On and Off comparators are the inputs to an Exclusive-Or gate T-423. This gate has a -3 v output if the two inputs are different, i.e., one at -3 v and the other at -11 v, and a -11 v output if the inputs are the same. The -3 v signal is present during the time the scanner moves from the "on" to the "off" position, as set by the reference voltage from the potentiometers.

The three setting signals (Set + 30% Limit, Set + 10% Limit, and Set -10% Limit) are generated by similar circuits. For instance, the +30% Left and +30% Right signals from pins 7 and 8, respectively, of $T\text{-}423_{12}$ are combined in an OR gate $T\text{-}406_{22}$. The "true" or "1" output of the gate is -3 v, and -11 v is the "false" or "0" output. The OR gate output, pin 7 of $T\text{-}406_{22}$, controls relay driver $T\text{-}135_{A2}$, which controls a setting relay K8 at the input to the +30% Limit amplifier, ORNL dwg. Q-2744-1. The output of the relay driver, pin 8 of $T\text{-}135_{A2}$, is at -12 v for a -11 v input (relay released) and at 0 v for a -3 v input (relay operated).

The signals from the "plate," "maximum," and "minimum" positions for fuel plate length and width are combined to form "Inspect No Fuel," "Inspect Maximum," "Inspect Minimum," and "Allow Less than Nominal." Inspect Maximum and Inspect Minimum are formed by combining the width and length signals in an AND gate $T\text{-}404_{62}$ and $T\text{-}404_{25}$ respectively. Inspect Minimum is inverted in squaring amplifier T-10666 to form Allow Less than Nominal through an emitter follower, pin 8 of

T-11376. Inspect Minimum is also routed through an emitter follower, pin 7 of T-11376. Inspect No Fuel is an Exclusive Or combination of Plate area, pin 8 of T-40462, and Inspect Maximum, pin 7 of T-40462. The Inspect No Fuel output is pin 7 of T-42382.

The remaining control signals are those used to select the Normal Index or the Maximum Index. Normal Index is set each time the Maximum Width changes from a "0" to a "1", -11 v to -3 v. The squaring amplifier T-10656 and one-shot multivibrator T-10564 are used as a time delay to allow completion of the Maximum Edge Index operation before the control signal is removed. Similarly, the one-shot multivibrator T-10565 is used to set the flip-flop T-10354 to the Maximum Edge Index state when the Minimum Width signal changes from -3 v to -11 v.

The interconnections to the scan control and gauging chassis from the function control chassis are routed through two cables, function to gauging (FG) and function to scan control (FS). (See ORNL drawing Q-2744-13 for the individual pins.)

3.4 Description of Gauging Circuits

3.4.1 Spot Signal

The spot, or transmitted x-ray beam signal, is obtained in the following manner (see ORNL drawing Q-2744-1). The transmitted x-ray beam is absorbed in a plastic phosphor coupled to an RCA 2020 photomultiplier with Dow Corning 200 fluid. The photomultiplier is operated at a gain of approximately 4000, with 1075 on the dynode resistor string. The anode current is fed to the input of a Dymec model 2460A amplifier. A model 2461A-M4+1 plug-in is modified to contain a 10-megohm feedback resistor in parallel with 100 pf. The resulting signal is +7.55 v for an unattenuated beam, +4.0 v for 6-mil-thick tool steel in the beam, and +1.55 v for 20-mil-thick tool steel in the beam (see Sect. 2.8.1 for calibration).

The output of the Dymec amplifier feeds a 250-kilohm resistor at the input of the level-shifting amplifier No. 7. The current at the summing junction is combined with an adjustable bucking current of 14 to 20 a (Maximum Density) so that increasing density increases the signal. The signal level at the output of the level-shifting amplifier TP-7 is dependent upon the settings of the maximum density potentiometer and the gain-setting, fine voltage control of the photomultiplier. The approximate voltage level for an unattenuated beam is -10.45 v, for 6-mil-thick tool steel in the beam it is +0.95 v, and for 18-mil-thick tool steel in the beam it is +7.60 v.

3.4.2 Plate Average Signal

The plate average signal is generated by routing the spot signal to the averaging amplifier No. 4 and then to the inverting amplifier No. 5.

The RC time constant in the feedback path of amplifier No. 4 is used to adjust the averaging time for the selected scan speeds of 16, 64, 128, and 240 in./min. The time constant is determined from the formula RC = 40/scan speed, where the scan speed is in inches per minute, R is in megohms, and C is in microfarads. A "test" position allows C to be any value. R is fixed at 1 megohm. A 330-kilohm resistor at the input to the averaging amplifier is used to adjust the average output outside of the minimum fuel outline. The output of the inverting amplifier TP-5 is used as one of the inputs to the ±10% checking amplifiers No. 3 and No. B, respectively, and as one input of the hold-nominal average amplifier No. 6.

The signals from the ±10% limit amplifiers Nos. 2 and A and the average inverting amplifier No. 5 are summed in the hold amplifier No. 6. Unity gain is used for the ±10% inputs, and a gain of 2 is used for the inverted plate average input. The resulting output is zero volts if the plate average is at nominal, a negative voltage if the plate average is above nominal, and a positive voltage if the plate average is below nominal. In the area between the maximum and minimum fuel outlines a voltage comparator $T\text{-}1726$ checks for a positive signal. The detection of the below-nominal signal causes a positive signal to be fed back through contacts of relay K4 to the input of the averaging amplifier. The resulting shift in the negative direction at the output of the hold amplifier turns off the feedback. The periodic output of the hold amplifier can be changed by varying the size of R43 and C61. An AND gate $T\text{-}40422$ turns off the nominal hold circuit when the beam is within the minimum outline.

3.4.3 +30% and ±10% Limit Circuits

All of the three limit circuits are identical in operation. The operation of the +30% circuit is typical. As the scanner moves into the Set +30% Limit area, relay K8 operates, connecting the spot signal to the +30% limit set and hold amplifier[2] No. 8. The 32-msec time constant in the feedback path of amplifier No. 8 allows the output voltage to approach the input voltage in approximately 160 msec. Since the beam is moving at a maximum speed of 20 msec per beam diam of 80 mils, any fluctuation of the signal will be smoothed out. Relay K8 releases at the end of the Set +30% Limit signal. The output of amplifier No. 8 TP-8 will remain at the level set except for a slow discharge due to leakage from the capacitor. The discharge rate is about 0.2 mv/sec. Relay K2 controls the setting of the +10% average amplifier No. 2, and relay KA controls the -10% average amplifier No. A.

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[2]G. A. Korn and T. M. Korn, "D-C Analog Computers with Automatic Programming Features," p. 384 in Electronic Analog Computers, 2d ed., McGraw-Hill, New York, 1956.

3.4.4 +30% Checking

The +30 limit voltage from amplifier No. 8 is summed with the spot signal from amplifier No. 7 in the +30% spot check amplifier No. 9. The output of amplifier TP-9 is positive for a signal within tolerance and negative for an out-of-tolerance signal. A voltage comparator $T\text{-}172_9$ is used to detect an out-of-tolerance condition. The output of the comparator is standardized to -3 v and -11 v in a squaring amplifier $T\text{-}106_8{}_1$ for the out-of-tolerance and in-tolerance signals respectively. The squaring-amplifier output, pin 7 of $106_8{}_1$, drives a one-shot multivibrator $T\text{-}105_7{}_1$ and one input of an OR gate, pin 5 of $T\text{-}406_5{}_1$. The second input of the OR gate, pin 4, is connected to the output of the multivibrator through an emitter follower, pins 3 and 8 of $T\text{-}113_6{}_1$. The multivibrator changes a narrow pulse from the comparator to a 20-msec-wide pulse. This pulse is of correct width to provide resolvable ink spots at the plotter at scanning speeds of 240 in./min. The output of the OR gate, pin 8 of $T\text{-}406_5{}_1$, is gated by the inspect maximum signal in AND gate $T\text{-}404_4{}_1$. The output of the AND gate, pin 7 of $T\text{-}404_4{}_1$, drives two relay drivers $T\text{-}135_1{}_2$ and $T\text{-}139_9{}_1$. These relay drivers control the +30% alarm circuit and the black ink solenoid valve of the plotter assembly. The alarm circuit contains two relays KD and KE and a buzzer. Relay KD locks itself and KE in through the Alarm Reset pushbutton S6. Relay KE supplies 110 v ac to the buzzer. The +30% tolerance is indicated by black ink.

3.4.5 "No Fuel" Checking

The "No Fuel" reference point is at approximately 70 mils of aluminum or -80% of the minimum fuel thickness. The reference point is zero volts, but it can be changed by returning a 1-megohm resistor from the input of amplifier No. 1 to a negative reference voltage. The in-tolerance and out-of-tolerance signals are positive and negative respectively. The circuitry from the comparator $T\text{-}172_1$ to the relay driver $T\text{-}139_{A2}$ is similar to the +30% spot check with the exception of the gating signal. It is "Inspect No Fuel" to AND gate $T\text{-}404_8{}_2$. "No Fuel" is indicated by blue ink.

3.4.6 +10% Average Checking

The +10% average check is similar to the +30% spot check. The +10% check amplifier No. 3 sums the signals from the +10% set and hold amplifier No. 2 and the inverting amplifier No. 5. The output TP-3 is positive for an in-tolerance signal and negative for an out-of-tolerance signal. The circuit from the comparator $T\text{-}172_3$ to the relay driver $T\text{-}139_{A1}$ is similar to the +30% path. The +10% average is indicated by green ink.

3.4.7 -10% Average Checking

The -10% average check is the same as the +10% average check with one exception. The out-of-tolerance signal is positive and the in-tolerance signal is negative TP-5; therefore, an inverter is not required

to standardize the output from comparator $T\text{-}172_B$. Its plotter output, red ink, is controlled by the inspect maximum signal through AND gate $T\text{-}40482$.

4. DRAWING SYMBOLS

The symbols shown on the following pages represent the 9-pin plug-in transistor units used in this instrument. The numbers beside the symbols represent the manufacturer's[3] type number and serve to identify the unit; i.e., 105 is a one-shot multivibrator, 106 is a squaring amplifier, etc. The subscripts on these numbers indicate the socket locations for that particular unit in matrix notation. Viewing the chassis from the wiring side with the connectors at the bottom, the rows of sockets are numbered from top to bottom 1, 2, 3, 4, 5, 6, 7, 8, 9, A and the columns left to right 1, 2, 3, 4, 5, 6, 7, 8, 9, A. All possible locations of sockets are numbered.

The subscript is written with the row number first and the column number second, always viewing the chassis from the wiring side. Thus, 105_{15} is a one-shot multivibrator in the first row, the fifth column from the left.

The small numbers beside each input and output are pin numbers according to standard tube socket numbering.

These symbols are used throughout the system diagrams to make the system more understandable and signal flow more easily followed. Only that circuitry not included in the plug-in package is shown.

Normal signal levels through the system are approximately -3 v (signal present) and -11 v (signal absent). The exceptions are the outputs of packages 135 and 139 as noted in the following pages.

5. DRAWING LIST

The following drawings are on file in the Engineering Graphics Group of the Instrumentation and Controls Division. The main title of the following drawings is HFIR Homogeneity Scanner, Production Model.

1. Q-2744-0, Cables and Wire Parts.
2. Q-2744-1, Gauging Circuit.
3. Q-2744-1A, Gauging Parts List.
4. Q-2744-2, Function Control Circuitry.

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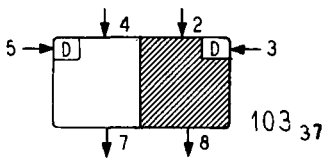
[3]Engineered Electronics Co., Santa Ann, Calif., T-Series Digital Circuit Modules.

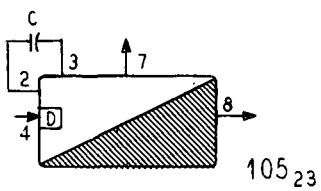
5. Q-2744-2A, Function Control Parts List.
6. Q-2744-3, Scan Control Circuit.
7. Q-2744-3A, Scan Control Parts List.
8. Q-2744-4, Gauging Metalphoto Panel.
9. Q-2744-5, Gauging Chassis.
10. Q-2744-6, Function Control Metalphoto Panel.
11. Q-2744-7, Function Control Chassis.
12. Q-2744-8, Scan Control Metalphoto Panel.
13. Q-2744-9, Scan Control Chassis.
14. Q-2744-10, Scan Control Side Bracket.
15. Q-2744-11, Width Index Drive Printed Circuit.
16. Q-2744-12, -100 and ±6.5 Zener Supply Printed Circuit.
17. Q-2744-13, Connector Terminations.
18. Q-2744-14, Modified Preset Indexer Circuit, Model SP250-4.
19. Q-2744-19, Spare Parts List.
20. Q-2744-20, Four Color Pneumatic Printer.
21. Q-2744-20A, Pneumatic Printer Parts.
22. Q-2744-21, Pneumatic Printer Details.
23. Q-2744-22, Pneumatic Printer Details.
24. Q-2744-23, Pneumatic Printer Details.
25. Q-2744-24, Pneumatic Printer Details.
26. Q-2744-25, Pneumatic Printer Details.
27. Q-2744-26, Pneumatic Printer Assembly Circuit.

The main title of the following drawings is HFIR Production Model Scanner. The drawing series is numbered 10940S001 through 10940S042.

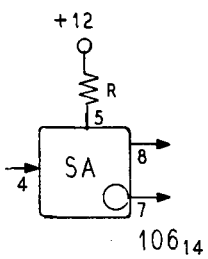
1. 10940S004E, Assembly Drawing.
2. 10940S026D, X-Ray Detection Equipment.
3. 10940S041D, Standard Plate.



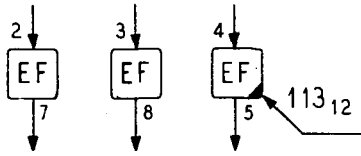
103 - Flip Flop
Pins 2 and 4 - D.C. reset and set inputs
Pins 3 and 5 - differentiated reset and set inputs
Pins 7 and 8 - D.C. outputs



105 - One-shot Multivibrator
Pins 2 and 3 - Timing capacitor
C = 50 (t-2) t in microseconds (μs)
C in picofarads (μμf)
Pin 4 - differentiated input
Pin 5 - D.C. Input (not shown)
Pin 7 - In-phase pulse output for time t
Pin 8 - Inverted pulse output for time t

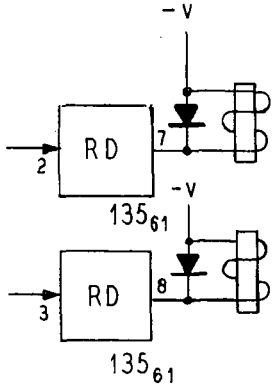


106- Squaring Amplifier (Schmitt Trigger)
Pin 2 - A.C. input (not shown)
Pin 4 - D.C. input
Pin 5 - Trigger level adjustment
Pin 7 - Inverted output
Pin 8 - In-phase output



113 - Triple PNP Emitter Follower
Pins 2, 3, and 4 - D.C. inputs
Pins 7, 8, and 5 - D.C. outputs

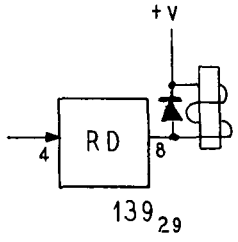
Indicates a wire to an indicator



135 - Dual Relay Driver (0 to -35V)
Driver 1 Pin 2 - D.C. input
Pin 7 - D.C. output

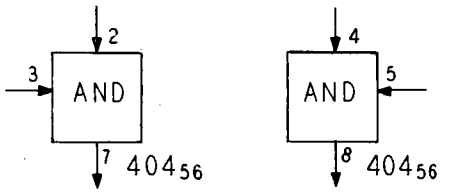
Driver 2 Pin 3 - D.C. input
Pin 8 - D.C. output

Output levels are -V = "0" and 0V = "1"



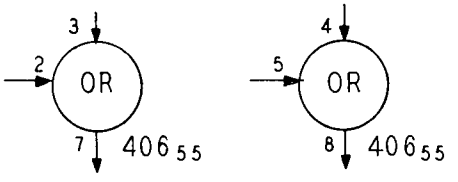
139 - Relay Driver (0 to +40 V)
Pin 4 - D.C. input

Pin 8 - D.C. output (0V = "1", -V = "0")
+V is a maximum of 40 volts



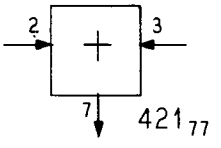
404 - Dual Two Input "And" Gate
Gate 1 Pins 2 and 3 - D.C. inputs
Pin 7 - D.C. output

Gate 2 Pins 4 and 5 - D.C. inputs
Pin 8 - D.C. output

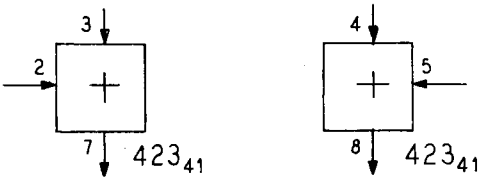


406 - Dual Two Input "Or" Gate
Gate 1 Pins 2 and 3 - D.C. inputs
Pin 7 - D.C. output

Gate 2 Pins 4 and 5 - D.C. inputs
Pin 8 - D.C. output



421 - Exclusive "OR" Gate
Pins 2 and 3 - D.C. inputs
Pin 7 - D.C. output



423 - Dual Exclusive "OR" Gate
Gate 1 Pins 2 and 3 - D.C. inputs
Pin 7 - D.C. output

Gate 2 Pins 4 and 5 - D.C. inputs
Pin 8 - D.C. output

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