

**ACU-RITE®**

# **ACU-RITE® II**

## **DIGITAL MEASURING SYSTEM**

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**OPERATOR'S MANUAL**

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## THE ACU-RITE WARRANTY

### GENERAL INFORMATION

Your new ACU-RITE II digital measuring system is manufactured and warranted by BAUSCH & LOMB.

The ACU-RITE system has been designed and tested to exacting specifications to provide years of trouble-free service. If you experience any problems with your system notify the authorized Bausch & Lomb ACU-RITE dealer from whom it was purchased. Please unpack your system carefully, and check the items received against those listed on the packing slip. Be sure the items are what you ordered. For your future warranty service or ordering reference, please record the following information in the spaces provided:

ACU-RITE II Serial No. \_\_\_\_\_  
Scale Assembly(ies) \_\_\_\_\_

Model \_\_\_\_\_ Serial No. \_\_\_\_\_

Model \_\_\_\_\_ Serial No. \_\_\_\_\_

Model \_\_\_\_\_ Serial No. \_\_\_\_\_

Date of Purchase \_\_\_\_\_

ACU-RITE Dealer \_\_\_\_\_

Dealer Address \_\_\_\_\_

Dealer Telephone \_\_\_\_\_

### BAUSCH & LOMB INSTRUMENTS & SYSTEMS DIVISION WARRANTY TO THE USER

1. ACU-RITE II digital measuring system parts and labor are warranted against defects in material and workmanship to the consumer for a period of 12 months from date of purchase.
2. This warranty covers all parts, except lamps and other consumable items. It applies only to instruments and accessories which have been installed and operated in accordance with instructions in our reference manuals, have not been tampered with in any way, misused, suffered damage through accident, neglect or conditions beyond our control, and have been serviced only by our authorized dealers or Instruments & Systems Division service personnel.
3. Bausch & Lomb is not responsible for loss in operating performance due to environmental conditions, such as humidity, dust, corrosive chemicals, deposition of oil or other foreign matter, spillage, or other conditions beyond our control.

There are no other warranties expressed or implied, and Bausch & Lomb shall not be liable under any circumstances for consequential damages.

## SECTION 1 INTRODUCTION

Your ACU-RITE II digital measuring system has been designed and manufactured by Bausch & Lomb to be used primarily on machine tools and for other coordinate-measuring applications. This easy-to-use system has been proven reliable for precision metal-working operations while decreasing scrap and increasing productivity. As you use the system, you'll find that the accuracy already built into your machine tool will be remarkably enhanced.

### 1.1. SYSTEM DESCRIPTION

The system, as shown in Figure 1-1, includes two basic components: the ACU-RITE II digital position readout (DRO or console), for control and display, and ACU-RITE scale assemblies installed on one or more axes of your machine to detect and measure table movement. The pushbutton DRO, available in one-, two-, or three-axis units, contains the solid-state electronics for coordinate presetting, tool offsetting, absolute and incremental locating, and readout.

Console construction is durable and highly resistant to dirt, oil and other shop contaminants. Likewise, scale assemblies are built to be durable and provide long-lasting service. Available in three models—A-R/5, A-R/1 and Mini-Scale—scale assemblies consist of a Bausch & Lomb chrome-line glass scale, protective housing and electronic reading head (also called a "transducer"). A cable from the reading head is connected to the rear of the console. See respective installation procedures in separate manuals for A-R/1, A-R/5 and Mini-Scale assemblies. The OPERATION section, Section 3, describes in detail how the system functions.

### 1.2. FEATURES YOU SHOULD KNOW ABOUT

Below are descriptions of many of the standard features that come with your system. In addition,

optional features, which you may not have on your system, are also described.

#### 1.2.1. Absolute/Incremental Measurement Modes

The ABS key allows the system to be operated in an incremental mode, for point-to-point measuring, or in an absolute mode, for keeping track of total incremental table movement in each axis. When the ABS key is lit you're in the absolute mode; when it's not lit, you're in the incremental mode.

#### 1.2.2. Inch-to-Millimeter Direct Conversion

Allows you to machine in either inch or millimeter dimensions and, with a flick of the INCH-mm switch on the DRO console, convert from one to the other without losing your zero reference or preset values.

#### 1.2.3. Pushbutton Preset

You can preset your coordinate dimensions into the memory and recall them to the display at any time, using the PRESET key. Subtract from or add to coordinates at any time without presetting again.

#### 1.2.4. Machine Tool Geometry (Abbé) Error Compensation

Every machine tool is subject to geometric error due to the force of gravity, particularly when machining heavy or overhanging workpieces. The ACU-RITE II system can compensate for certain types of errors in increments of  $\pm 15$  parts per million, up to about  $\pm 230$ ppm.

#### 1.2.5. Large Scale Integrated (LSI) Circuitry

We've incorporated all of the complex electronic circuitry into two identical LSI chips. The ACU-RITE II DRO has completely interchangeable printed-circuit boards and modules that can eliminate unnecessary service calls and wasteful downtime.

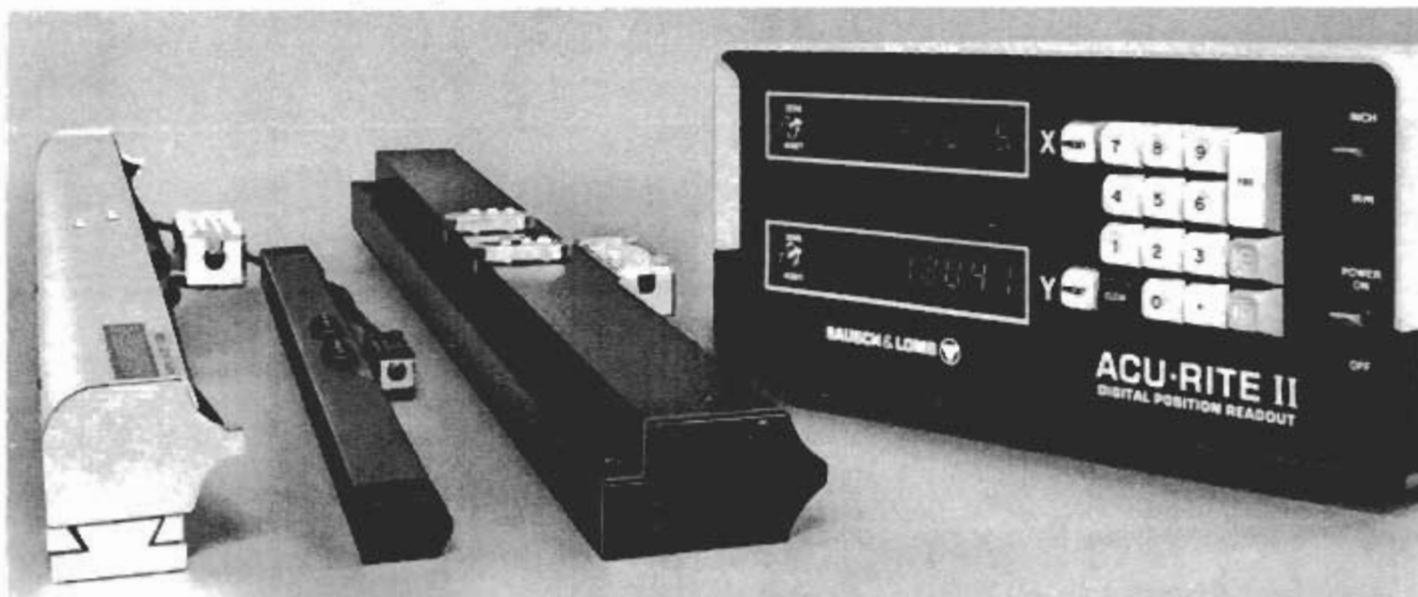


Figure 1-1. ACU-RITE Digital Position Readout and Scale Assemblies: .0005", Mini-Scale and .0001"

### 1.2.6. Bright L.E.D. Display

Our light-emitting diode display has big, bright red numbers. The seven-decade (and plus/minus sign) display is visible within a 120-degree viewing angle and is easy to see at 20 feet or more. As you turn the controls on your machine, the numbers change instantaneously to indicate the exact position.

### 1.2.7. Auto Reset (optional)

When the auto reset feature is activated it responds to a trigger signal at a designated position reference mark on a special scale. When the mark is reached, the console and display are reset to zero.

### 1.2.8. BCD Output (optional)

A BCD (binary coded decimal) output enables your system to be interfaced with an external system, such as a computer terminal, machine tool control, printer, or N/C feedback system.

### 1.2.9. Other Features

A fault indicator, a lighted mark in the sign display indicates a power interruption or an improper signal to the console (e.g., excessive slew speed). Also, the console faceplate withstands years of grease and dirt - you can restore its finish with the wipe of a cloth.

There are full operating descriptions of all these features elsewhere in this manual.

## 1.3. HOW TO USE THIS MANUAL

This manual has been prepared to familiarize you with all parts of the system and the various operating procedures you'll need to use. Other sections of the manual include:

2. Installation - How to install the console and check out the system. To install A-R/1, A-R/5 and Mini-Scale assemblies, see respective manuals.
3. Operation - How to use the console controls and operate the system, with examples and detailed procedures.
4. Machine Error Compensation - What machine geometry errors are, and how to determine and correct them. Plus how to use the system to calibrate a machine tool. Functions of internal switches are also described.
5. Maintenance - The nature of system problems and how to correct them using a troubleshooting table and other procedures. Also includes reading head replacement procedures for A-R/1 and A-R/5 scale assemblies.

Refer to the table of contents for locating specific procedures. You will not find information on electronic parts replacement or repair in this manual. In case of malfunctions in the electronic network that cannot be remedied using the troubleshooting guide contact your ACU-RITE dealer service representative.

## 1.4. SPECIFICATIONS

### 1.4.1. Console

Display Full 7 decades of 7 segment LEDs, long life, readable to over 20 feet at 120° viewing angle, plus and minus sign and power fail indication.

|                         |                                                                                                                               |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Circuitry               | Integrated Circuitry, including LSI.                                                                                          |
| Capacity                | One, two or three axes of 7 decades each.                                                                                     |
| Inputs                  | TTL compatible quadrature square waves (input noise filtered by signal sampling technique).                                   |
| Front Panel Controls    | ON/OFF switch, ZERO RESET buttons, mm-INCH selector switch, PRESET keys, digit keyboard, Plus-Minus keys, CLEAR key, ABS key. |
| External Connections    | One, two or three signal inputs. Optional BCD output.                                                                         |
| Diameter/Radius Display | Selectable diameter or radius display.                                                                                        |
| Fault Indicator         | Power interruptions and excessive count rate are flagged in the display                                                       |

Linear Correction Output count can be modified in increments of  $\pm 15$  parts/million up to a maximum of  $\pm 457$  parts/million to compensate for some types of machine or temperature error.

Power 115 VAC  $\pm 10\%$ , .6A, 50-60 Hz, convertible to 100V, 220V, 240V.

Ambient Temperature  $0^{\circ}\text{C}$  ( $23^{\circ}\text{F}$ ) to  $40^{\circ}\text{C}$  ( $104^{\circ}\text{F}$ ).

Resolution DRO is usable (without modification) and internally switch-settable for the following scale resolutions:  
.0005"/.01mm/.005mm,  
.0001"/.002mm (specify),  
.00025" (opt. for dia. readout).

Dimensions W34.2cm x H14cm x D25.4cm (W13.5" x H5.5" x D10")

Weight (net) 5.9kg (13 lbs.)

### 1.4.2. Scale Assemblies

|                             | A-R/5                                                             | A-R/1                                                              | Mini-Scale                           |
|-----------------------------|-------------------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------|
| Resolution                  | .0005"<br>.01mm                                                   | .0001"<br>.002mm                                                   | .0005"<br>.00025"<br>.005mm<br>.01mm |
| Accuracy                    | $\pm .0005''$ in<br>any 40"<br>$\pm .01\text{mm}$ in<br>any meter | $\pm .0002''$ in<br>any 40"<br>$\pm .005\text{mm}$ in<br>any meter | Same as<br>A-R/5                     |
| Repeatability               | $\pm .0003$<br>(.007mm)                                           | $\pm .0001$<br>(.0025mm)                                           | $\pm .0002$<br>(.005mm)              |
| Lengths Available (min/max) | 4"/120"<br>100/3050<br>mm                                         | 4"/72"<br>100/1525<br>mm                                           | 2"/40"<br>50/1000<br>mm              |
| Light Source (typical)      | light-emitting diodes                                             |                                                                    |                                      |
| Sensing Elements (typical)  | photo-transistors                                                 |                                                                    |                                      |

## SECTION 2 INSTALLATION

### 2.1. INSTALLATION OF CONSOLE

#### 2.1.1. General

This section includes complete installation instructions for the ACU-RITE II system. Console installation procedures consist of locating the console on one of two types of stands: machine-mounted or floor-mounted. Procedures for making electrical connections and internal switch settings are also described. Separate installation instructions for the A-R/1, A-R/5 and Mini-Scale are packaged with the scales. These instructions include procedures for checking out the system with your machine tool in preparing for operation.

#### 2.1.2. Console Location

When selecting the proper location for the console, be sure of the following for safety and convenience:

- The operator can easily reach the panel controls.
- The console is mounted at eye level for comfortable reading of the display and controls.
- There is no interference with operation or loading of the machine tool.
- The console is located away from coolant splash and flying chips.

#### 2.1.3. Column-Mounting Kit Assembly

This kit is installed on the ram or column of the machine tool. Parts are provided for installation on either top or side surfaces. Install the kit as follows (refer to Figure 2-1):

- a. Drill and tap two holes (5/16-18 x 5/8")-deep at the mounting location as shown.
- b. Attach the mounting bracket (1) to the machine with the two 5/16-18 x 2-3/4"-long socket head cap screws (2) and two 5/16" I.D. steel washers (3).
- c. Insert the spacer (4) into the end of the bracket arm, making sure that the 1-11/16"-diameter hole

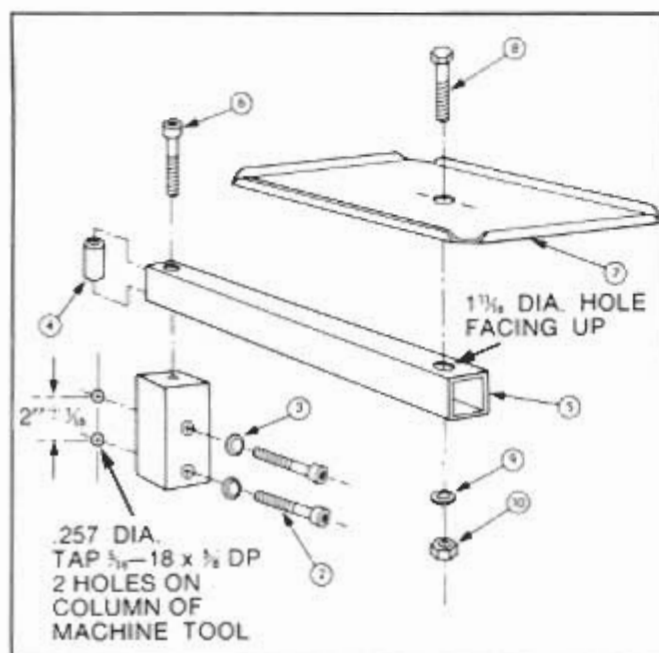


Figure 2-1. Column-Mounted Console Bracket Kit

at the opposite end is up as shown. Attach the mounting bracket to the machine with the 1/2-13 x 2-3/4"-long socket cap screw (6).

- d. Place the dimple (center) of the tray (7) into the 1-11/16"-diameter hole in the bracket arm and assemble, using the 1/2-13 x 2-1/2"-long hex head cap screw (8), washer (9) and 1/2-13 hex nut (10).
- e. Tighten all nuts and screws securely.

#### 2.1.4. Floor Stand Assembly

The floor stand should be located behind and to one side of the machine where it will not be bumped and does not obstruct table travel or routing of cables, etc. Assemble the floor stand as follows (refer to Figure 2-2):

- a. Attach four rubber feet to the bottom of the base (1). (Feet have adhesive backing.)
- b. Attach the lower support tube (2) to the base with a 1/2-13 x 1-1/4" hex head cap screw (3).
- c. Attach the upper support tube (4) to the console tray (5) with a 1/2-13 x 1-1/4" hex head cap screw (3).
- d. Slide the upper support tube into the top of the lower support tube.
- e. Start two 5/16-18 x 1/2" socket head cap screws (6) in the tapped holes at the top of the lower support tube, and, while holding the tray at the desired height, tighten the screws.

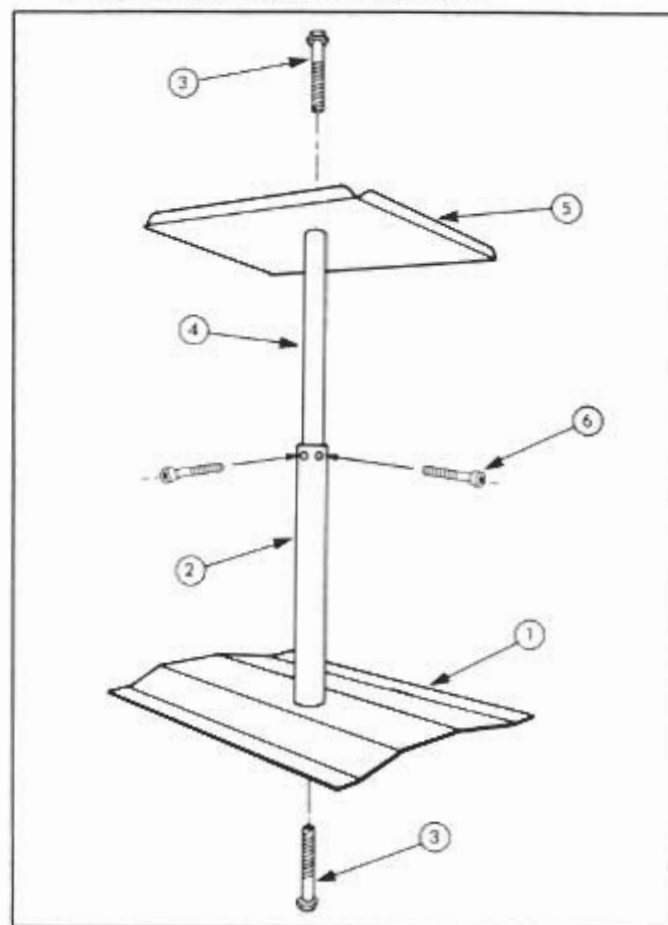


Figure 2-2. Console Floor Stand Kit

### CAUTION

Make sure that all screws are tight and that the floor stand is rigid before placing the console on the tray.

#### 2.1.5. Electrical Connections

### CAUTION

Do not operate the system with a supply voltage other than that marked on the console nameplate. Incorrect voltage can damage the system.

- Refer to Figure 2-3. Connect a heavy-gauge braided ground strap or copper wire from the thumb-screw terminal on the rear of the console to a convenient point on the machine base. Check that the ground wire is a minimum length and routed so that it will not be pulled or rubbed during machine operation. Ground the machine base by connecting it to a cold-water pipe or other solid earth ground. A metal stake driven several feet into the ground will suffice if no other ground is available. (No special ground is required for scale assemblies.)
- Plug the console power cord into a properly grounded outlet of the correct voltage.
- Turn the console on and check that the fault indicator at the left of the display lights. If the fault indicator does not light, check the line voltage connection to be sure there is power to the outlet.

If the fault indicator still will not light, refer to System Troubleshooting in Section 5.

#### 2.1.6. Internal Switch Settings

There are up to three identical printed-circuit axis/display boards (one for each axis) stacked at the left inside the console. A typical board is shown in Figure 2-4. On each board there are two switch assemblies: Nine-switch assembly S1 (toward the rear on the console), and four-switch assembly S2 (toward the front). On each board the individual switches in assemblies S1 and S2 must be set in accordance with your particular system and installation. Instructions for setting switches 1 through 5 and switch 9 on S1 are given in the Error Correction Procedure in Section 4. Set the remaining switches as indicated in Table 2-1.

### NOTES

- The switches in your console have been set for .0005" scales on all axes. Check the settings and change if required.

- Some consoles have internal switches with slightly different labelling. For these switches "open" corresponds to OFF.

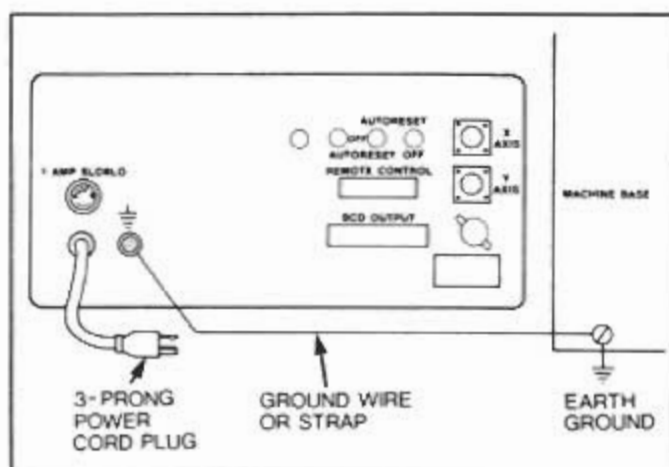


Figure 2-3. Console Electrical Connections

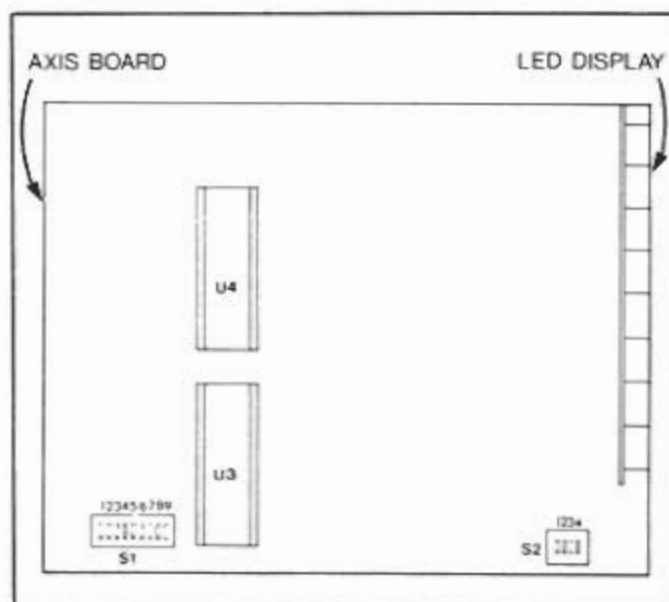


Figure 2-4. Internal Switch Locations on Axis/Display Board

Table 2-1. Internal Switch Settings

| Scale Resolution | S1 Switch Settings |   |   |   |   | S2 Switch Settings |     |     |     |
|------------------|--------------------|---|---|---|---|--------------------|-----|-----|-----|
|                  | 1                  | 2 | 3 | 4 | 5 | 6                  | 7   | 8   | 9   |
| .0005"           | See                |   |   |   |   | OFF                | OFF | OFF | ON  |
| .00025"          | Error              |   |   |   |   | OFF                | OFF | OFF | ON  |
|                  | Correction         |   |   |   |   |                    |     |     |     |
| .0001"           | in                 |   |   |   |   | ON                 | OFF | OFF | OFF |
| .01mm            | Section 4          |   |   |   |   | ON                 | OFF | ON  | ON  |
| .002mm           |                    |   |   |   |   | OFF                | ON  | ON  | OFF |
| .005mm (linear)  |                    |   |   |   |   | OFF                | OFF | ON  | OFF |
| .005mm**         |                    |   |   |   |   | ON                 | OFF | ON  | ON  |

\* The .00025" Mini-Scale is used for diameter measurement only. It reads out in .0005" increments.

\*\* When the .005mm scale is used for diameter measurements, it reads out in .01mm increments.

#### a. Round-off

1. Whenever you use an English scale in the INCH mode or a metric scale in the mm mode, the least significant display digit (farthest to the right) will indicate multiples of the scale resolution (.01mm resolution scales will provide multiples of 1, .002mm resolution scales will provide multiples of 2, etc.). If you select diameter readout, the least significant display digit will indicate multiples of twice the scale resolution (e.g., .01mm resolution scales provide multiples of 2), except for .002mm resolution scales, which will be rounded to multiples of 5.
2. When you use an English scale in the mm mode, the Acu-Rite II performs exact multiplication (25.4mm/inch) rounded to the nearest least significant digit.
3. When you use a metric scale in the INCH mode, displayed numbers will be rounded for your convenience. In this case, the rounding will apply both to direct conversion and conversion with Diameter Readout selected (as shown in Table 2-2).

#### b. Diameter Readout Selection

In certain machining operations, such as movement

on the cross-feed of a lathe, a doubling of the measured dimensions is often desired for diameter display. To select this function, S1 switches 1, 2, 3, 4, and 9 must be on and switch 5 must be off (refer also Table 4-3). Switch S2 is still set for the resolution of the scale per Table 2-1.

There are two applications in which you must proceed in a slightly different manner to obtain Diameter Readout.

1. If, for instance, you use the .00025" scale you will note that it employs the same S1 switch 6, 7 and 8 off selection as the .0005" scale (see Table 2-1). Reading will thus automatically be doubled, providing Diameter Readout.
2. If you use the .005mm scale in Diameter Readout mode, you must establish S1 switch 6, 7, 8 settings according to .01mm resolution per Table 2-1.

Note that in both above cases, no additional Diameter selection must be performed. S1 switches 1, 2, 3, 4 and 9 need not all be on, but should be selected in accordance with error compensation requirements (see Table 4-3).

Table 2-2. Round-off in mm/Inch Conversion

| Scale Resolution | Rounded Conversion Increment |                              |
|------------------|------------------------------|------------------------------|
|                  | Direct Conversion            | With Diameter Readout        |
| .002mm           | None                         | .0000", .0002", .0004", etc. |
| .005mm           | .0002", .0004", etc.         | None*                        |
| .01 mm           | .0005", .0010", .0015", etc. | .0005", .0010", etc.         |

\* Instead of Selection Diameter Readout, select .01mm Resolution according to Table 2-1.

## SECTION 3 OPERATION

### 3.1. GENERAL

Operating your machine tool will be much easier with a digital measuring system once you see what you can do with the system - and what it can do for you. As you move your machine table a chosen distance, the system tracks the movement and displays it on the DRO console, clearly showing when the table has traveled the exact distance. You and your machine are in constant communication so that table position is always known, within the tolerances you're working to, down to .0001" (.002mm) or .0005" (.01mm) depending on your system's resolution.

This section contains all of the descriptions and procedures you'll need to operate the ACU-RITE II system. Modes of Operation, paragraph 3.2., is a functional description of how measuring information is obtained; Control Panel Description, paragraph 3.4., identifies the operating features on the front of the console, what each control does, and how to include tool offset in the measurement; Operating Procedures, paragraph 3.5., is a step-by-step instruction of how to operate the DRO as part of the machining process and provides examples to demonstrate how you, your machine, and the system work together.

#### NOTE

A soil-resistant, laminated operator's card is provided with this manual to be attached to your machine tool. After thoroughly reading and understanding this section, use the card for convenience.

### 3.2. MODES OF OPERATION

The system measures in two ways, or modes: the *incremental* measurement mode and the *absolute* measurement mode. You select either mode on the console by pushing the ABS key. When the ABS key is lit, the console is in the absolute mode, and when the ABS key is not lit, the console is in the incremental mode.

The incremental mode is used when you want the system to measure and display point-to-point table positions. After you've moved the table from one point to another, just reset to zero and continue to the next step. The *preset* function, used only in the incremental mode, allows you to preset your console to any value. Preset is also used for tool offset (radius or diameter) by adding the preset value to or subtracting it from the incremental measurement. At any time (when the ABS key is not lit), you can recall the preset or offset dimension to the display by pushing (lighting) the PRESET key again. The associated sign indicates whether you added (+) or subtracted (-) the preset value the last time you used an offset.

In the absolute mode, the system keeps track of the distance the table has moved in a given axis from the original zero starting position, no matter how many incremental steps you've made. This absolute distance is displayed the instant you push (lighting) the ABS key.

Full operating descriptions follow in this section under Operating Procedures.

### 3.3. AUTO RESET FEATURE (OPTIONAL)

Auto reset is an optional convenience feature that establishes a permanent zero reference for your machine table travel. It's handy for either of the two following situations: (See also How To Use Auto Reset, paragraph 3.6, at the end of this section.)

- When machining identical production parts, using a fixture, auto reset provides a distance reference to your first machining operation so your location is exact each time. This saves time, eliminates positioning errors and also eliminates the need to use a surface of the part as a reference location.
- On occasion, a part may have to be left on the machine overnight or through the weekend. Auto reset keeps you from losing your place. Simply move the table back to the closest zero location, then move the known distance to your next machining location according to dimensions on your workprint.

Marks are placed on the scale at 8-inch intervals, the first one being anywhere from 0" to 8" from the end of the scale (depending on mark location when the glass scale is cut). When the reading head senses this mark, a fiducial trigger output (FTO) pulse is produced that causes the console to zero and display all zeros on the specific axis. These FTO marks are sensed when the AUTO RESET switch on the rear console panel is in the AUTO RESET position. Otherwise, the system functions normally.

The reading head includes a separate LED and photo-transistor for sensing the FTO mark, and the display will indicate when the reading head passes over the mark from either direction. However, to avoid possible errors in display readings, the system has been designed to reset properly only when approached from the positive-going direction.

A console with the auto reset option can be used with scales having no FTO marks, and vice versa. In both cases, normal measurements will take place, but the auto reset feature will not be usable unless both scale and console are equipped for it.

### 3.4. CONTROL PANEL DESCRIPTION

Control panel features are shown in Figure 3-1.

#### 3.4.1. Fault Indicator

When you turn the console on, the display shows a fault indicator at the left of each axis window (otherwise blank). This vertical mark will not appear during normal system operation; but if it lights during operation (and the display blanks), you'll know that shop or system power has been momentarily interrupted or that the table has been moved too fast (excessive slew rate). This indication guards against false measurements on the display that may go unnoticed. In either case, you'll have to restart your operation procedures.

#### 3.4.2. LED Display

- Shows measured absolute distance when in the absolute mode (ABS key lit).
- Shows measured incremental position when in the incremental mode (ABS key and PRESET key not lit).

- Shows value entered in preset memory when in the incremental mode and PRESET Key is pushed (PRESET key is lit, ABS key not lit).
- When in either the incremental or the absolute mode, the plus or minus sign at the left of the display indicates the direction from the zero reference point (polarity of table travel). However, when the value in the preset memory is being displayed, it is always an absolute number (no sign), and the plus or minus sign tells you whether you last added or subtracted that value.

#### 3.4.3. ZERO RESET Button

Pushing the ZERO RESET button in each axis resets the display to zero in either the absolute mode (ABS key lit) or the incremental mode (ABS key not lit). The display shows all zeros, unless the preset value is displayed (ABS key not lit, PRESET key lit). In that case, the incremental mode is still zeroed, but the preset value continues to be displayed.

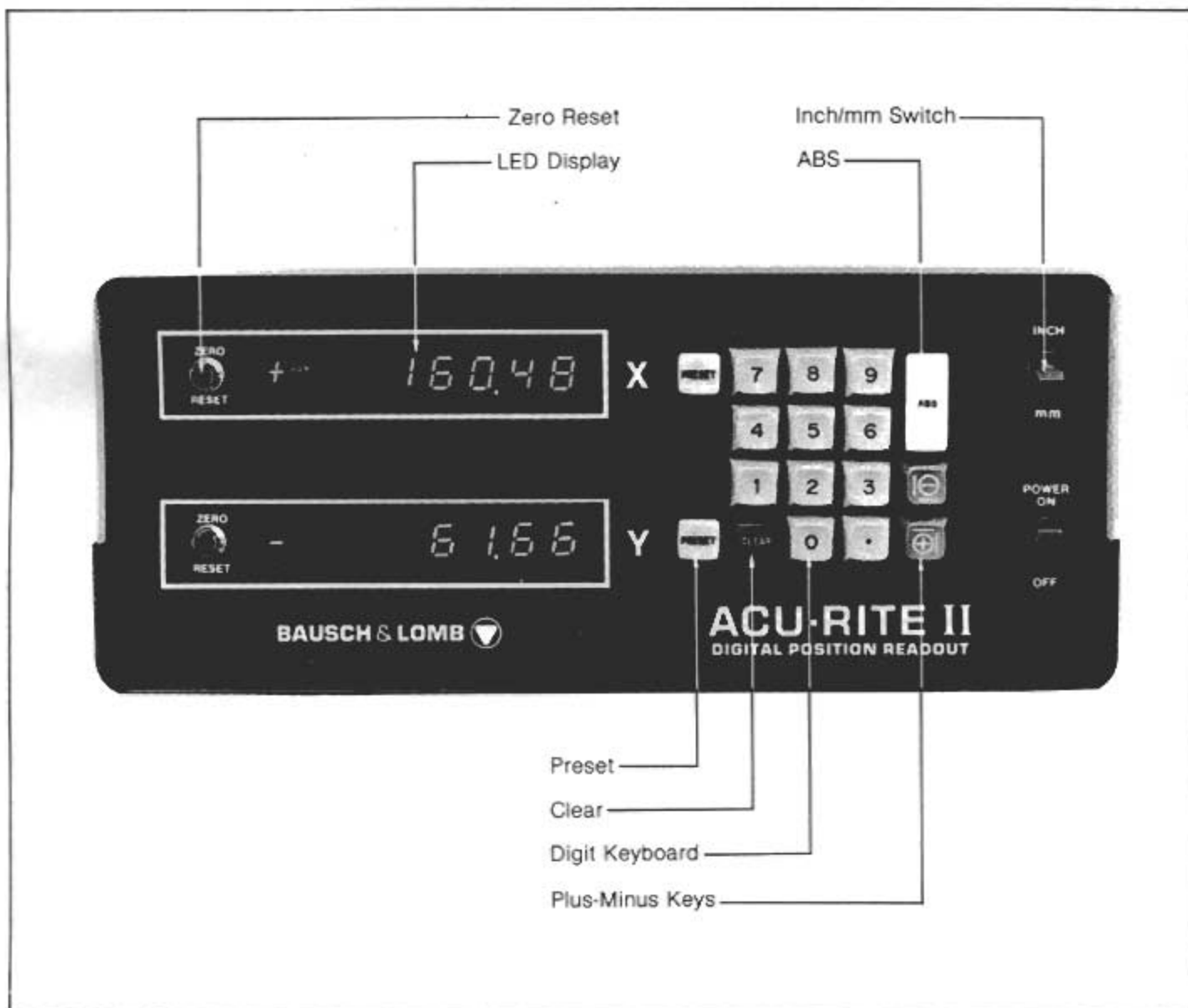


Figure 3-1. Panel Controls

### 3.4.4. INCH-mm Switch

Instantly converts incremental or absolute mode measurement from inches to millimeters, and vice versa. Does not convert value in preset memory even though decimal place will change.

### 3.4.5. PRESET Key

When lit:

- Changes the display from the incremental measurement to the value in the preset memory when in the incremental mode (ABS key not lit).
- Activates the preset keyboard functions (CLEAR, digit, and plus and minus keys).
- Both measurement modes still measure machine table coordinates, but only the preset value is displayed (ABS key not lit).
- Push to return to the incremental mode when not adding or subtracting the preset value.

#### NOTE

If the ABS key is lit, the display will not show the preset entry, though entry *does* take place.

### 3.4.6. CLEAR Key

Functional only when the PRESET key is lit.

- Clears the value in the preset memory. (The display will blank except when the ABS key is lit.)
- Enables entry of new value into preset memory.

### 3.4.7. Digit Keyboard

Used to enter a new value into preset memory when the PRESET key is lit and the CLEAR key has been pushed. Leading and trailing zeros do not have to be entered; e.g., for 0.2300, enter: decimal point, 2, and 3.

### 3.4.8. Plus-Minus Keys

Keys are functional immediately following a digit keyboard entry or immediately after pushing the PRESET key if reusing an established preset value.

- When used to enter preset - PRESET light goes out when either key is pushed indicating that the plus or minus preset value has been entered into the preset memory. The display will then be returned to the incremental mode and will display the new measurement (equal to the incremental measurement, plus or minus the value entered in the preset memory).
- When used for tool radius/diameter offset - adds or subtracts the radius/diameter dimension (plus or minus) from the incremental measurement. For easy reference, the circle represents the tool, the tangent lines represent the workpiece surface to be machined (see Including Tool Offset Dimensions, paragraph 3.4.11., below, and for examples, see Operating Procedures, Tool Offset Operation).

### 3.4.9. ABS Key

When lit, this key switches the display from the incremental mode or preset value to the absolute mode, and displays the absolute measurement (total movement of the table from zero measured in any one axis).

### 3.4.10. AUTO RESET Switch (Optional)

Located on the rear console panel, this optional switch

controls the use of a fiducial trigger output (FTO) pulse. An FTO pulse is generated when the reading head passes a mark on the glass scale. When the AUTO RESET switch is in the OFF position, the console functions normally. When the switch is placed in the AUTO RESET position and the mark is passed, the console will automatically reset to zero and display all zeros on the related axis. If the switch is left in this position, the console will reset to zero at each mark. See How To Use Auto Reset, paragraph 3.6., at the end of this section.

### 3.4.11. Including Tool Offset Dimensions

Use of the digit keys and the plus and minus keys make the console capable of arithmetic calculations. You can add a dimension to or subtract it from the incremental measurement in the display at any time. Usually, this capability is used for including a tool offset (diameter or radius) into the print dimension to be machined.

In the diagram on the plus and minus keys (see Figure 3-2), the circle represents the top view of the tool, while the vertical and horizontal lines represent the workpiece reference surfaces to be machined.

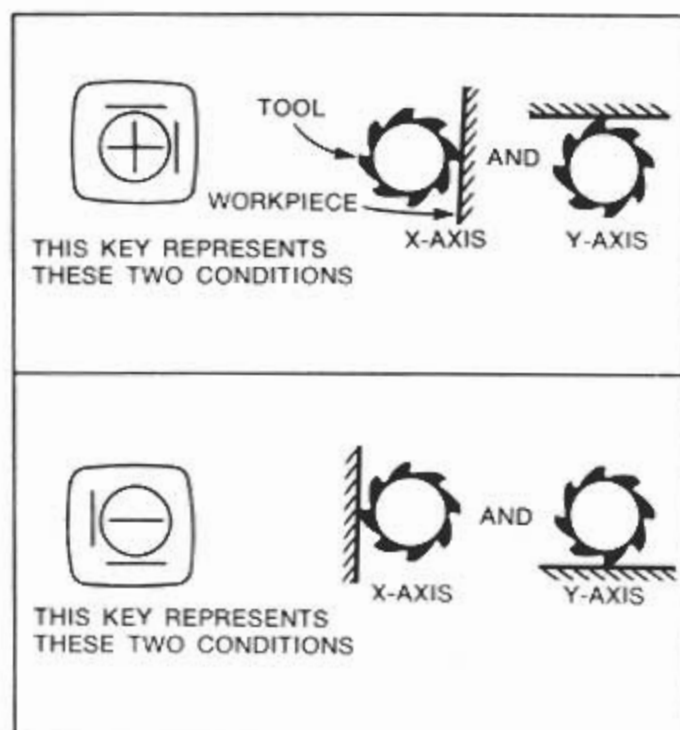
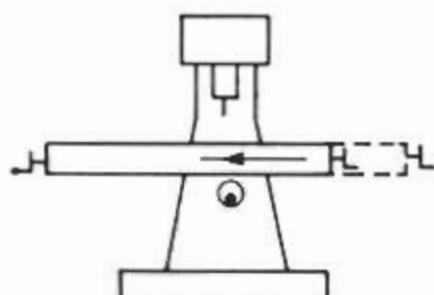


Figure 3-2. Representation of Tool Offset Symbols (Plus/Minus Keys)

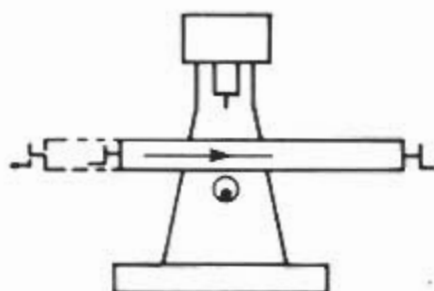
These symbols show the relative location of the tool with respect to the workpiece surface, and indicate the offset direction.

Before the tool offset function can be used effectively, the polarity of the machine tool table travel must be established. Refer to the system check-out procedure in the separate installation instructions.

Machine tool table travel polarities, in accordance with International Standard ISO 841, are illustrated for a typical milling machine in Figure 3-3.



Longitudinal table movement from right to left should display (+) directional count on "X" axis



Longitudinal table movement from left to right should display (-) directional count on "X" axis



Cross feed table movement from front to back should display (-) directional count on "Y" axis



Cross feed table movement from back to front should display (+) directional count on "Y" axis

Figure 3-3. Table Travel Polarities (Direction)

### 3.5. OPERATING PROCEDURES

The following is a series of procedures for setup and operation of the system for machining. Examples are provided for each procedure to demonstrate the use of the DRO in practice. Most examples show the X-axis only, but apply to the Y- or Z-axis as well.

#### 3.5.1. Setup

##### NOTE

If your console has an AUTO RESET switch on the rear panel, the switch must be in the OFF position before proceeding. See Auto Reset Feature, paragraph 3.3., and/or AUTO RESET Switch, paragraph 3.4.9., in this section for an explanation of this optional feature.

- Place the workpiece in position and move the table to the location of your zero coordinates (starting point).
- Flip the console POWER switch to ON (see Figure 3-4). Both the ABS key and the fault indicator(s) at the left of the display(s) will light and the display(s) will be blank, indicating that the fault circuits are working properly in the absolute mode.

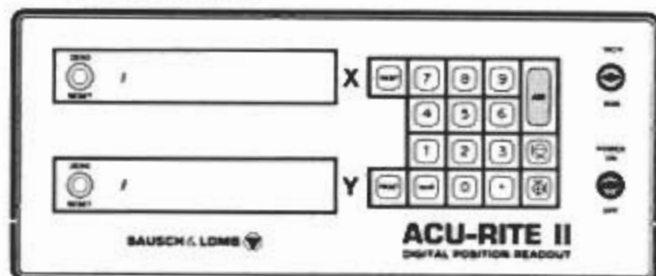


Figure 3-4. Console Status: Power On

- Push the ZERO RESET button for each axis to zero the absolute mode. Plus zeros will be displayed (see Figure 3-5).

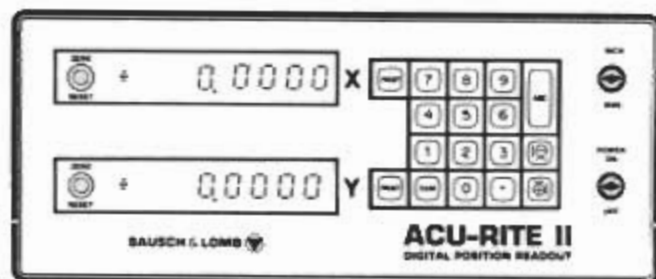


Figure 3-5. Console Status: Zero Reset

- Push the ABS key (see Figure 3-6). The light will go out, changing the console to the incremental mode. The fault indicator(s) will light again, indicating that the fault circuits are working properly in the incremental mode.
- Push the ZERO RESET button for each axis again to zero the incremental mode, and plus zeros will be displayed (see Figure 3-5).
- Make proper selection on the INCH-mm switch (see Figure 3-6) to be certain that measurements will be made and displayed in the correct dimensions (inches to millimeters).

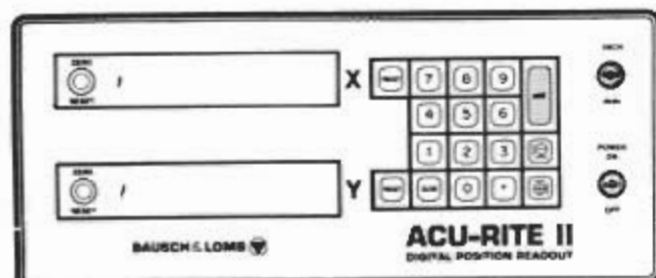


Figure 3-6. Console Status: Fault Indicator

#### NOTE

The display will read 0.0000 in INCH measurement or either 0.00 or 0.000 in mm measurement, depending on the resolution of the system.

Your ACU-RITE II system is now ready to use.

#### 3.5.2. Incremental Mode Operation

When you use the ACU-RITE digital measuring system, normal operation of your machine tool (for simple jobs like drilling a few holes or slot-milling) is done in the incremental mode. In other words, the system is measuring and displaying the table travel incrementally, or point-to-point (hole-to-hole, start-to-finish, etc.). Figure 3-7 represents an example of a job to be machined in the incremental mode; that is, to locate and drill holes A, B and C. Here is the procedure for system operation using the ZERO RESTART button to re-zero the X-axis display at the start of each point-to-point dimension:

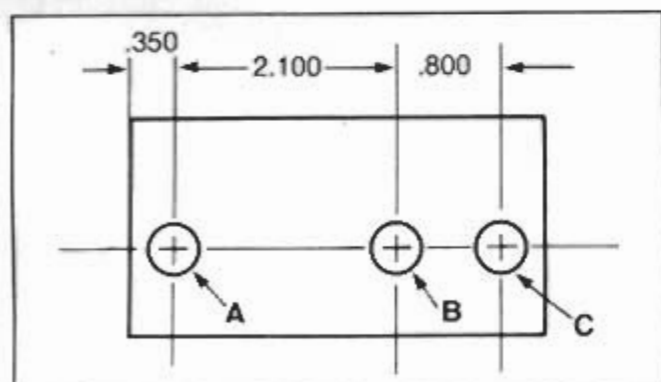


Figure 3-7. Workpiece for Incremental Procedure

- Locate and drill hole A.
- Push the ZERO RESET button on the X-axis.
- Move the table to the left until the display reads +2.1000, and drill hole B.
- Push the ZERO RESET button again.
- Move the table to the left until display reads +0.800, and drill hole C.

#### 3.5.3. Preset Operation

When in the incremental mode, the preset function permits you to enter the coordinate dimension into the memory as well as to display it. Therefore, as the table is moved the display changes incrementally from the dimension to zero, just opposite of normal incremental operation. To preset the incremental mode with a specific dimension, proceed as follows:

- Push the ZERO RESET button on the desired axis to zero the incremental mode display.
- Push the PRESET key on the desired axis (see Figure 3-8). The key will light up, and the display will indicate the value in the preset memory (zero or any previously entered number).

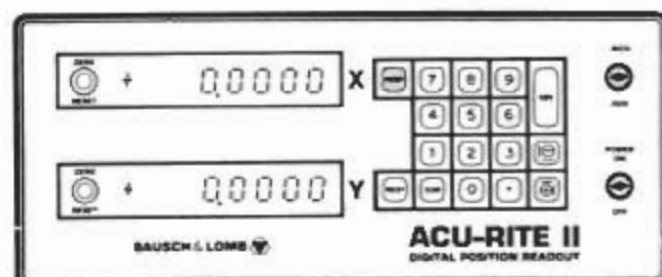


Figure 3-8. Console Status: Preset Value Display

#### NOTE

When the PRESET key is lit, the system will still measure the machine coordinates, but not display them.

- Push the CLEAR key to clear any previous number from the preset memory. The display will blank out except for the decimal point (see Figure 3-9).

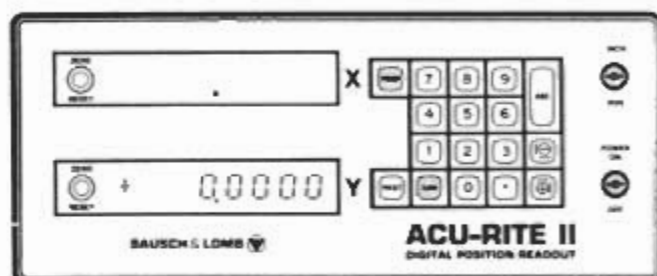


Figure 3-9. Console Status: Clearing Preset and Display

- Enter the preset value by pushing the appropriate digit keys, including the decimal point (see Figure 3-10). If an error is made, push the CLEAR key and start again.

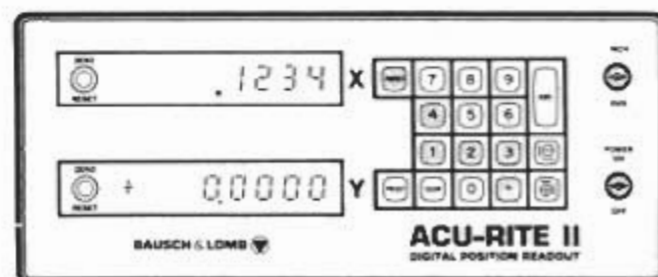


Figure 3-10 Console Status: Digit Display

- To preset the incremental mode to the above value, push the plus or minus key, depending on whether the preset value is to be positive or negative (see Figure 3-11). The PRESET light will go out and the display will now indicate the preset machine coordinates.

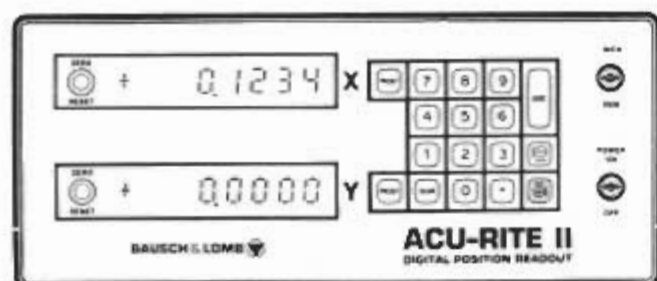


Figure 3-11. Console Status: Preset Entry, Incremental Mode

#### NOTE

The preset value may be recalled at any time by simply pushing (lighting) the PRESET key. To return to the incremental mode, push the PRESET key again (light out).

#### 3.5.3.1. EXAMPLE PROCEDURE A

Figure 3-12 represents the same job as the one done under Incremental Mode Operation, paragraph 3.5.2., (locate and drill holes A, B and C), except that the following procedure uses the preset function rather than re-zoning for each point-to-point dimension.

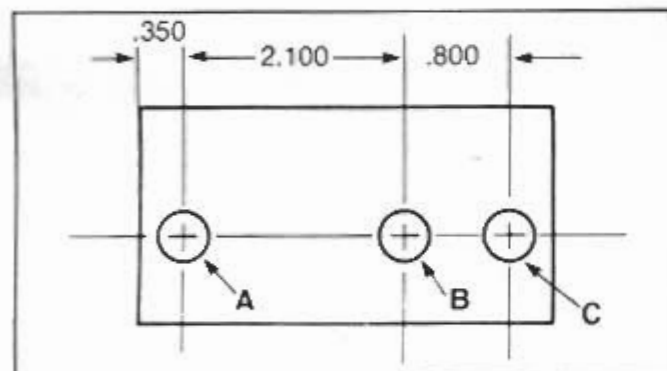


Figure 3-12. Workpiece for Preset Procedure A

- Locate and drill hole A.
- Push the ZERO RESET button on the X-axis.
- Push the PRESET key on the X-axis.
- Push the CLEAR key (display will blank).
- Push the digit keys for the value being entered onto the preset memory: 2, decimal point, and 1.
- Push the minus key. The display will read -2.1000 and the PRESET light will go out.
- Move the table to the left until the display reads +0.0000, and drill hole B.
- Push the PRESET key again.
- Push the CLEAR key (display will blank).
- Push the digit keys for the new preset value: decimal point and 8.
- Push the minus key. The display will read -0.8000, and the PRESET light will go out.
- Move the table to the left until the display reads +0.0000, and drill hole C.

#### NOTE

When presetting, each tangent line on the plus and minus keys will represent the current reference surface from which you move the tool toward the next operation. For the:

X-axis, use the plus key if next hole location is to the left.

Y-axis, use the plus key if next hole location is toward the operator.

X-axis, use the minus key if next hole location is to the right.

Y-axis, use the minus key if next hole location is away from operator.

#### 3.5.3.2. EXAMPLE PROCEDURE B

Figure 3-13 represents another example of machining operation, this time using the preset function for drilling a series of equally-spaced holes, A, B, C and D. The procedure is as follows:

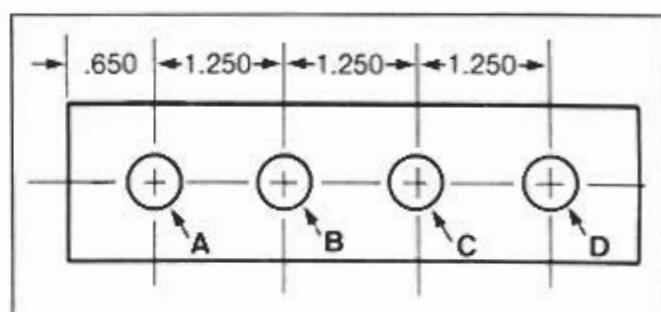


Figure 3-13. Workpiece for Preset Procedure B

- Locate and drill hole A.
- Push the ZERO RESET button on the X-axis.
- Push the PRESET key (it will light) on the X-axis.
- Push the CLEAR key (display will blank).
- Push the digit keys from the value being entered into the preset memory: 1, decimal point, 2, 5.
- Push the minus key. The display will read -1.2500 and the PRESET light will go out.
- Move the table to the left until the display reads +0.0000, and drill hole B.
- Push the PRESET key (it will light) on the X-axis. The display will show the value in the preset memory to be -1.2500.
- Push the minus key to display the preset value (-1.2500) in the incremental mode.
- Move the table to the left until the display reads +0.0000, and drill hole C.
- Push the PRESET key again on the X-axis.
- Push the minus key. The display will read -1.2500.
- Move the table to the left until the display reads +0.0000, and drill hole D.

#### 3.5.4. Tool Offset Operation

As stated previously under Including Tool Offset Dimensions, paragraph 3.4.11., you can machine a workpiece using the offset by simply adding the tool

diameter or radius to (or subtracting it from) the value in the preset memory. There are no pencil calculations needed for this technique. The following procedures, A through D are four examples (two for diameter, two for radius) that will give you a good working knowledge of how to use the preset function of the system for tool offset operation. Understand that in each procedure, setup has already been done (see Setup, paragraph 3.5.1., earlier in this section).

#### 3.5.4.1. EXAMPLE PROCEDURE A

The workpiece (see Figure 3-14) is to be machined on surfaces A and B with a .250-inch diameter tool, using surface D as a reference. Offset will be the tool diameter, and table movement will be in the X-axis. Here is the procedure:

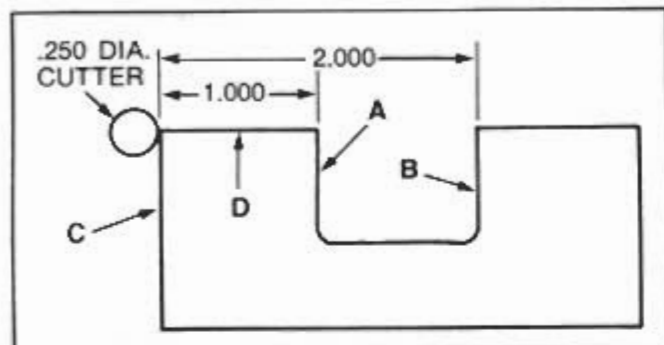


Figure 3-14. Workpiece for Tool Offset Procedure A

- Locate the tool against surface C.
- Push the ZERO RESET button on the X-axis.
- Push the PRESET key (it will light) on the X-axis.
- Push the CLEAR KEY.
- Push the digit keys for tool diameter: decimal point, 2 and 5.
- Push the minus key to:
  - Enter the tool diameter into the preset memory.
  - Shift the datum line (reference) from surface C to the left of the tool.
  - Display the tool diameter (0.2500) in the incremental mode.
- Move the table to the left, with the tool parallel to but not touching surface D, until the display reads +1.0000, and machine surface A.
- Push the PRESET key (it will light) on the X-axis. The display reads -0.2500 in the preset memory.
- Push the plus key to:
  - Shift the datum line (reference) back to the right face of the tool.
  - Display +1.2500 in the incremental mode.
- Move the table to the left until the display reads +2.0000, and machine surface B.

#### 3.5.4.2. EXAMPLE PROCEDURE B

The workpiece (see Figure 3-15) is to be machined on surfaces A and B with a .250-inch diameter tool, using surface D as a reference. Offset will be the tool diameter, and table movement will be in the Y-axis. Here is the procedure:

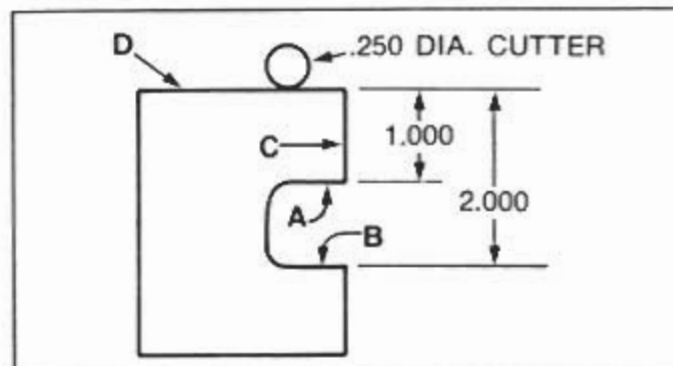


Figure 3-15. Workpiece for Tool Offset Procedure B

- Locate the tool against surface D.
- Push the ZERO RESET button on the Y-axis.
- Push the PRESET key (it will light) on the Y-axis.
- Push the CLEAR key.
- Push the digit keys for the tool diameter: decimal point, 2 and 5.
- Push the plus key to:
  - Enter the tool diameter into the preset memory.
  - Shift the datum line (reference) from surface D to the back surface of the tool.
  - Display tool diameter (+0.2500) in the incremental mode.
- Move the table to the rear (away from you) with the tool parallel to but not touching surface C, until the display reads -1.0000. Machine surface A.
- Push the PRESET key (it will light) on the Y-axis. The display reads +0.2500 in the preset memory.
- Push the minus key to:
  - Shift the datum line (reference) to the front surface of the tool.
  - Display -1.2500 in the incremental mode.
- Move the table to the rear until the display reads -2.0000, and machine surface B.

#### 3.5.4.3. EXAMPLE PROCEDURE C

The workpiece (see Figure 3-16) is to be machined on surface A with a .500-inch diameter tool, and drilled for hole B. Offset will be the tool radius, and table movement will be in the X-axis. (Though Y-axis movement would normally take place, it is omitted for simplicity.) Here is the procedure:

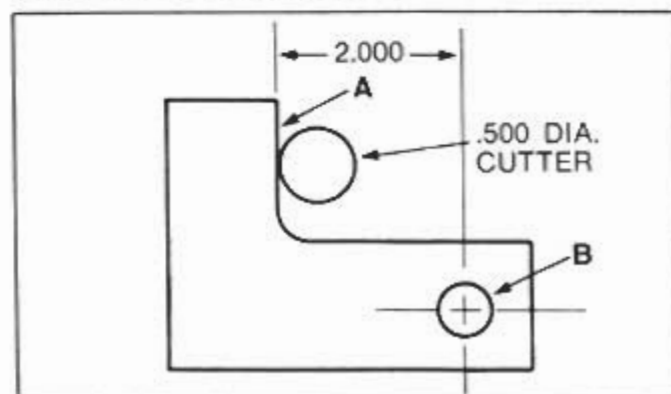


Figure 3-16. Workpiece for Tool Offset Procedure C

- Machine surface A with the tool positioned as shown.
- Push the ZERO RESET button on the X-axis.
- Push the PRESET key (it will light) on the X-axis.
- Push the CLEAR key.
- Push the digit keys for the tool radius: decimal point, 2, 5, and 0.
- Push the plus key to:
  - Enter the tool radius into the preset memory.
  - Shift the datum line (reference) to the right and to the centerline of the tool.
  - Display the tool radius (+0.2500) in the incremental mode.
- Move the table to the left until the display reads +2.0000. Insert the correct drill and drill hole B.

#### 3.5.4.4. EXAMPLE PROCEDURE D

The workpiece (see Figure 3-17) is to have holes A and B drilled, using a .200 diameter edge finder for workpiece referencing. Offset will be the radius of the edge finder, and table movement will be in the X-axis. Here is the procedure:

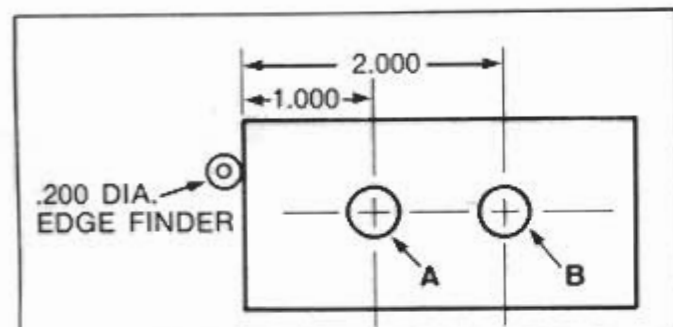


Figure 3-17. Workpiece for Tool Offset Procedure D

- Put the edge finder against the left face of the workpiece.
- Push the ZERO RESET button on the X-axis.
- Push the PRESET key (it will light) on the X-axis.
- Push the CLEAR key.
- Push the digit keys for the edge finder radius: decimal point, 1.
- Push the minus key:
  - Enter the edge finder radius into the preset memory.
  - Shift the datum line (reference) to the left, i.e., to the centerline of the edge finder.
  - Display the radius (-0.1000) in the incremental mode.
- Move the table to the left until the display reads +1.0000, and drill hole A.
- Move the table to the left until the display reads +2.0000, and drill hole B.

#### 3.5.5. Absolute Mode Operation

In this manual, the term "absolute" (used with "mode" or "measurement") refers to the distance from present table position in a specific axis to the

original (starting) zero reference point. The absolute measurement is, therefore, normally the total of the incremental measurements in a given axis. However, both the absolute mode and the incremental mode can be combined and used to machine (see Combined-Mode Operation, paragraph 3.5.6.). You should be familiar with the following additional points on the use of the absolute mode:

- When the console is turned on, the ABS (absolute) key lights. Also, the fault indicator lights in the display (otherwise blank) indicating that the fault circuitry is working properly in the absolute mode. Push the ZERO RESET button on each axis display to zero the absolute mode; then push the ABS key (light will go out) to select the incremental mode (see Incremental Mode Operation, paragraph 3.5.2.).
- To switch to the absolute mode during an incremental machining operation, push the ABS key to light it. The display will instantly change to the measurement in the absolute mode (without losing the incremental measurement).
- To re-zero the absolute mode when in the incremental mode, push the ABS key (it will light), and push the ZERO RESET button(s); then push the ABS key again (light will go out) to return to the incremental mode.
- When in the absolute mode, pushing the PRESET key will not display the preset value, but you can still use the preset function as you would normally.
- The absolute mode can be used just like the incremental mode for operations that do not require presetting or offsetting between steps. As a rule, however, the absolute mode should be used as in step "b" above or for machining in combination with the incremental mode.

#### 3.5.6. Combined-Mode Operation

When you machine using both incremental and absolute modes, you are operating the system as through it were two separate DROs: one to measure movement between successive cutting locations, and the other to measure the distance a cutting location is from the zero reference location. The part drawing you're working with will determine when to use the combined mode operation; specifically, when at least one machining dimension is referenced to the zero surface of the workpiece, and one or more successive incremental operations precede it, as is the case shown in Figure 3-18. The following is a typical example of a combined-mode procedure.

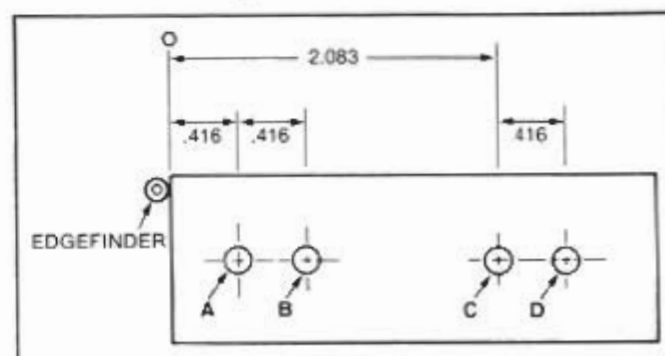


Figure 3-18. Workpiece for Combined Mode Procedure

In this example, the workpiece (see Figure 3-18) is to be drilled at four locations along the X-axis. The zero reference is established at the left surface of the workpiece. Notice that the dimension for hole C (2.083) is referenced from the zero point. This lets you know that you will be using the absolute mode to drill that hole (the size of the drill is arbitrary for this example). You will be using the radius offset of an edge finder to establish the centerline at the zero reference point. Here is the procedure (perform Setup procedure, paragraph 3.5.1., first):

- a. Locate the edge finder against the left surface of the workpiece.
- b. Push the PRESET key (it will light) on the X-axis.
- c. Push the CLEAR key.
- d. Push the digit keys for the edge finder radius offset.
- e. Push the minus key to:
  1. Enter the offset into the preset memory.
  2. Shift the datum line (reference) from the left surface of the workpiece to the centerline of the edge finder.
  3. Display the edge finder radius in the incremental mode.
- f. Move the table to the left until the display reads +0.0000.
- g. Push the ABS key to change to the absolute mode. The display will read the radius of the edge finder.
- h. Push the ZERO RESET button on the X-axis to re-zero the absolute mode, then push the ABS key again to change back to the incremental mode.
- i. Insert the drill and move the table to the left until the display reads +0.4160, then drill hole A.
- j. Push the ZERO RESET button on the X-axis to re-zero the incremental mode.

- k. Move the table to the left again, until the display reads +0.4160, and drill hole B.
- l. Push the ABS key to change to the absolute mode. The display will read +0.8320.
- m. Move the table to the left until the display reads +2.0830, and drill hole C.
- n. Push the ABS key to change back to the incremental mode. The display will read 1.6670.
- o. Push the ZERO RESET button on the X-axis to re-zero the incremental mode.
- p. Move the table to the left until the display reads +0.4160, and drill hole D.
- q. Push the ABS key to change to the absolute mode and check your absolute dimension. The display will read +2.4990.

### 3.6. HOW TO USE AUTO RESET

- a. Place the AUTO RESET switch (on back of console) in the AUTO RESET position.
- b. Approach the point to be measured in the positive direction (lower number to higher number). The display will automatically reset after passing the FTO mark closest to the point being measured.
- c. When the console resets, place the AUTO RESET switch in the OFF position.
- d. Center the tool (endmill, dial indicator, etc.) at the point to be measured. The distance displayed on the console indicates the measured distance between the FTO mark and the point location. For future reference, record the measured distance.
- e. To relocate this point at any time, follow steps "a" through "d" until you come back to your recorded measurement.

## SECTION 4

### MACHINE TOOL ERROR COMPENSATION

#### 4.1. WHY ERRORS OCCUR

In every machining operation, there is always some degree of error or inaccuracy due to at least one of the following machine tool deficiencies:

- Gravity causes deflections in the machine tool structure (see Figure 4-1), particularly when a heavy workpiece is placed on a machine with overhanging table or ways. A result of these deflections is commonly called Abbé error. (The following paragraphs provide further explanation.)
- The fit between mating surfaces is loose, because of either manufacturing tolerances, subsequent wear, or improper gib adjustment.
- The ways are not scraped straight or are not aligned perfect at assembly.
- Driving and cutting forces deflections, since no material is totally rigid.
- Temperature gradients can distort machine geometry.

In addition, machine tables and ways can be forced out of alignment if you use the locks improperly. Tables that are not completely locked in position can be caused to shift from the forces of machining and eventually wear.

Abbé error is a progressive fault occurring in machine tool tables or beds. Gibs and table ways can wear due to an increase in pressure at the edge of the machine way, on both the knee and at the center of the table. This causes increased wear at these points as the weight of the table moves to increase the overhang.

Because the increase of weight is gradual as a table moves from center, so is the wear. The result is the formation of an arc shape along the table and knee, concave to the ways. Pressure of the gib against the way causes the gib to wear. Often when a short travel is used, retightening the gib causes localized wear of the way.

The scale attached to the table measures its horizontal motion with respect to the fixed reader head. A worn table, however, follows the curvature of the arc, resulting in an error in the movement of the workpiece relative to the cutter. In the case of the milling machine, the workpiece is moving too far.

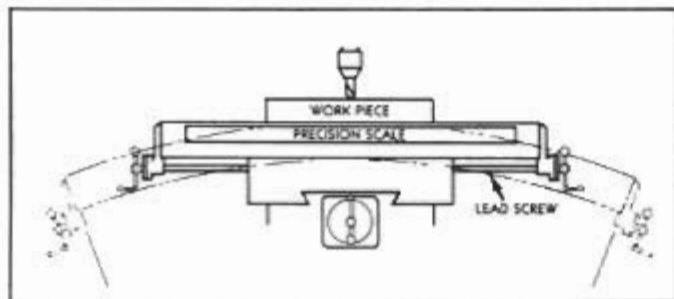


Figure 4-1. Exaggerated Abbé Error Curve of Table Travel on a Milling Machine with an Overhanging Table

#### 4.2. HOW TO MEASURE ERRORS

Most errors resulting from the preceding conditions can be measured with a simple step-by-step procedure. You will need an accurate indicator and a recently calibrated measuring standard. Procedures vary slightly from one machine to another, but the concept remains the same.

- Take measurements at the height above the machine surface where tooling is normally located.
- Locate the standard on the machine table at the height where most machining takes place. Joe blocks, a step gage, a laser interferometer or other standards can be raised on parallels to meet this requirement.
- When using a step gage or similar standard (with the indicator located in the spindle), take measurements along the standard at 2- to 6-inch intervals. All measurements should be taken in the same direction of table motion.
- If the standard selected has not been recently calibrated, have the standard inspected to establish current length.

Below are two specific procedures for measuring machine table errors. The first (4.2.1.) is relatively simple, and sufficient for shorter-length measurements on small mills, jig borers, etc. The second (4.2.2.) is a bit more detailed and dependent upon availability of the step gage standard required (permits maximum accuracy). Also, see "Note" under 4.3., Error Correction Procedure.

##### 4.2.1. Simplified Procedure

- Select (and support on parallels) Jo blocks, gage rods, or other standards preferred for accurate length measurement.
- Take measurements of the standard on (or near) the table centerline (X-axis) starting at table height. Raise the standard 2" or 4" and repeat the measurement. Then raise to 6" to 8" as desired, and take the third measurement.
- Determine the error by noting the difference between each of the measurements and averaging the results.
- Correct the error according to 4.3., Error Correction Procedure.

##### NOTE

The same procedure as above can be used at three table surface locations on the Y-axis of the table. This will determine any horizontal error.

##### 4.2.2. Step Gage Procedure

The following is an example procedure using a step gage as the measuring standard (see Figure 4-2).

- Set up the step gage on the table at a height and position that coincides with that of a typical workpiece.

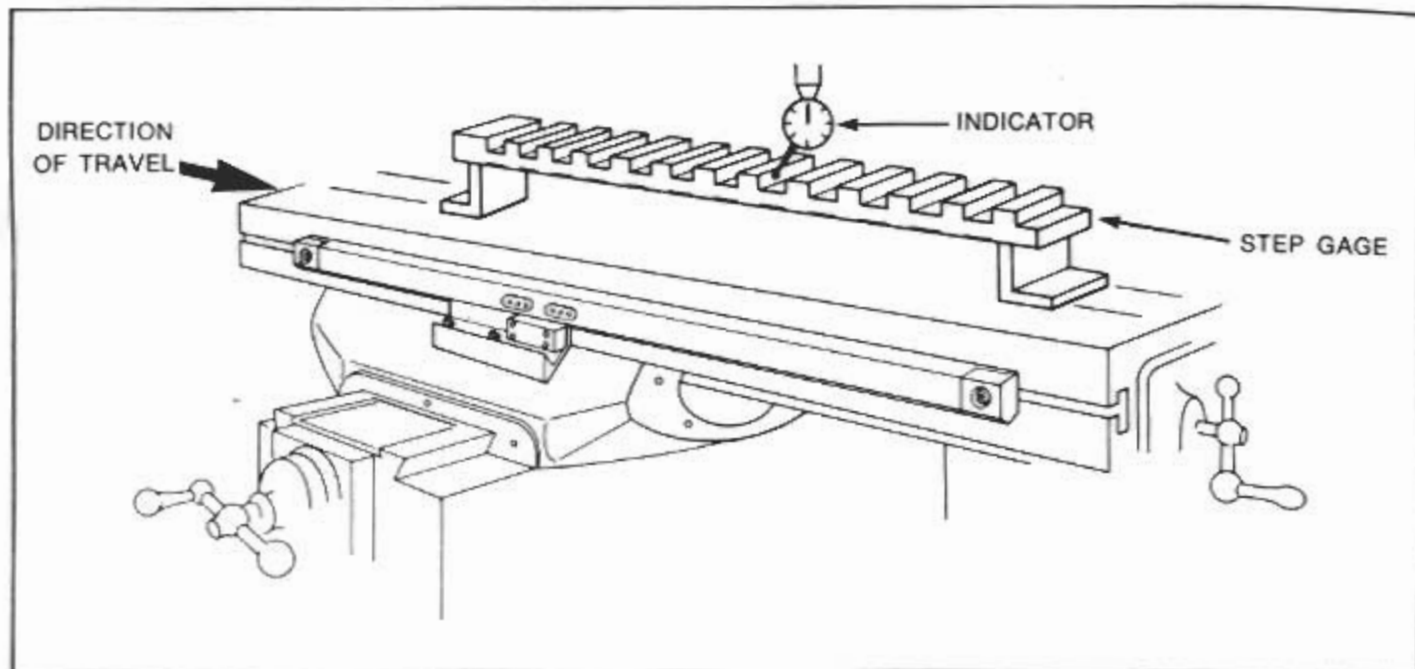


Figure 4-2. Example of Measurement Set-up Using Step Gage as a Standard

- b. Insert a dial indicator into the spindle and lower it until the indicator can contact the first reference surface of the gage.
- c. Set the dial indicator to zero.
- d. Turn on the console and reset it to zero (refer to Setup under Operating Procedures, paragraph 3.5.).
- e. Raise the spindle and move the table until the next reference surface is close to the dial indicator.
- f. Lower the spindle and carefully move the table until the indicator contacts the gage surface and registers zero.
- g. Record the distance moved as measured by the standard and as measured by the system and displayed on the console. Then record the difference between the two measurements.

**NOTE**

Make sure that each measurement reading is repeatable.

**Table 4-1. Standard and Displayed Measurements (Inch)**

| Distance Measured by Standard | Measurement Displayed on Readout | Difference Between Measurements |
|-------------------------------|----------------------------------|---------------------------------|
| 0.0000                        | 0.0000                           | 0                               |
| 3.0000                        | 3.0000                           | 0                               |
| 6.0000                        | 5.9995                           | -.0005                          |
| 9.0000                        | 8.9995                           | -.0005                          |
| 12.0000                       | 11.9990                          | -.0010                          |
| 15.0000                       | 14.9990                          | -.0010                          |
| 18.0000                       | 17.9990                          | -.0010                          |
| 21.0000                       | 20.9985                          | -.0015                          |
| 24.0000                       | 23.9985                          | -.0015                          |
| 27.0000                       | 26.9985                          | -.0015                          |
| 30.0000                       | 29.9980                          | -.0020                          |

- h. Repeat steps "c" through "g" until you have moved the length of the standard.

Table 4-1 is an example of a set of recorded measurements from the standard and the display taken at 3" intervals over a 30" travel. The difference between these measurements can be plotted on a graph to determine what compensation is required to minimize the apparent error.

Figure 4-3 is a graph using the standard measurements to represent one coordinate, and the range of apparent error to represent the other coordinate. By plotting coincident points on the graph, a best-fitting straight line "C" can be drawn through the approximate center of the points plotted.

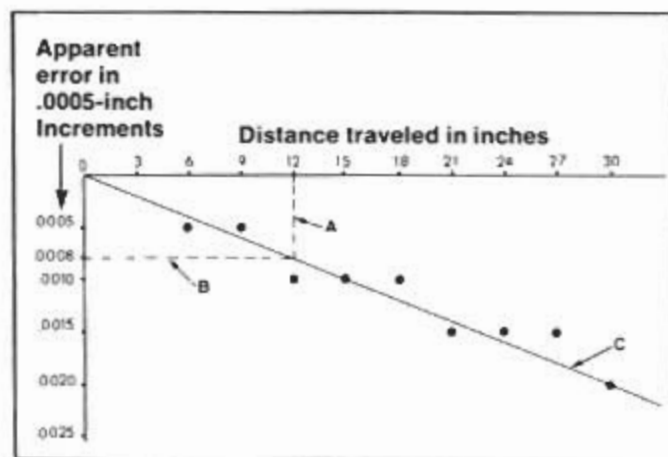


Figure 4-3. Error Slope Plotted in Inches

Drawing a vertical line "A" at any of the selected distance measurements and a horizontal line "B" where "A" intersects line "C", we determine the amount of correction necessary to reduce the total error. The following formula is used to compute the error:

$$\begin{aligned}\text{Error} &= \frac{B}{A} \\ &= \frac{-.00080 \text{ in.}}{12 \text{ in.}} \\ &= -.0000667\end{aligned}$$

Moving the decimal point 6 places to the right, the resultant correction (or compensation) factor for the error is 66.7 parts per million. Error Correction Procedure, paragraph 4.3., explains how to use this number. Below, Table 4-2 and Figure 4-4 repeat the same examples for determining error in metric measurements.

**Table 4-2. Standard and Displayed Measurements (Metric)**

| Distance Measured by Standard (mm) | Measurement Displayed on Readout (mm) | Difference Between Measurements (mm) |
|------------------------------------|---------------------------------------|--------------------------------------|
| 0.0                                | 0.00                                  | 0                                    |
| 76.2                               | 76.200                                | 0                                    |
| 152.4                              | 152.388                               | .013                                 |
| 228.6                              | 228.588                               | .013                                 |
| 304.8                              | 304.775                               | .026                                 |
| 381                                | 380.975                               | .026                                 |
| 457.2                              | 457.175                               | .026                                 |
| 533.4                              | 533.362                               | .038                                 |
| 609.6                              | 609.562                               | .038                                 |
| 685.8                              | 685.762                               | .038                                 |
| 762                                | 761.950                               | .051                                 |

#### 4.3. ERROR CORRECTION PROCEDURE

##### NOTE

Sometimes error corrections are made based on a particular workpiece weight. When there is a weight deviation, a new error factor will be introduced. Therefore, additional measurements will be required, followed by a recorection of the error.

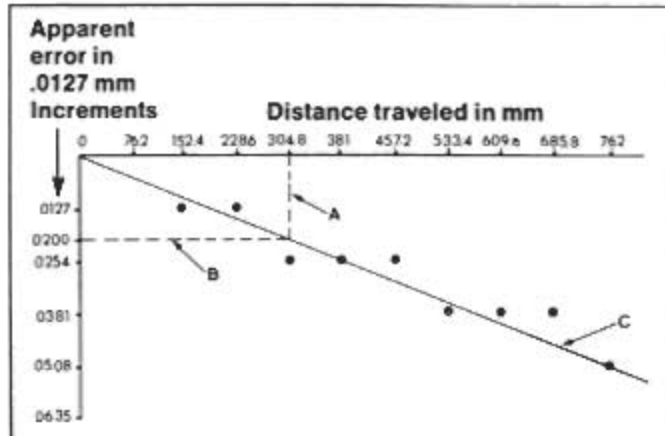
After computing the error, select the nearest available correction factor from the list provided in Table 4-3 (61.04 ppm in this case). Remove the cover from the console; you will note that each axis/display board contains two sets of switches, S1 and S2. Switch set S1 contains nine individual switches. Switches 1 through 5 control the transfer (machine tool) error correction factor. Use these switches on each axis/display board to make linear corrections according to position selection in Table 4-3. Be sure that the sign (+ or -) of the correction switch (#5) is chosen correctly. Since in this case the readout is displaying a shorter measurement than the standard, the procedure is to add a correction factor to make them equal.

##### Caution

Check the readout display. A mistake here will double instead of cancel the error; therefore, the mistake can be very easily recognized and corrected by repositioning the sign switch (#5).

##### NOTES

1. When switch #5 is off (+) forward pulses are added to forward motion, and reverse pulses added to reverse motion. Switch #5 on (-) will add reverse pulses to forward motion and forward pulses to reverse motion.



**Figure 4-4. Error Slope Plotted in mm**

Cross check by repeating the calibration procedure (steps "c" through "h" above) after the switches have been set. If the measurement data is not sufficiently reproducible, it is a sign of inadequate machine geometry, loose or excessive local wear on ways, or too much gravity-induced deflection, particularly on large machines. Your machine tools must be thoroughly checked for misalignments.

2. Some consoles have switches with slightly different labeling. For these switches, the "open" position corresponds to OFF.

**Table 4-3. Switch Assembly S1, Settings for Error Correction and Diameter Readout Selection**

| Correction Factor (ppm) | #1  | #2  | #3  | #4  | #9  | #5                         |
|-------------------------|-----|-----|-----|-----|-----|----------------------------|
| No Correction           | off | off | off | off | off | (Either off (+) or on (-)) |
| +/- 15.26               | on  | off | off | off | off | off/on                     |
| +/- 30.52               | off | on  | off | off | off | off/on                     |
| +/- 45.78               | on  | on  | off | off | off | off/on                     |
| +/- 61.04               | off | off | on  | off | off | off/on                     |
| +/- 76.29               | on  | off | on  | off | off | off/on                     |
| +/- 91.55               | off | on  | on  | off | off | off/on                     |
| +/- 106.81              | on  | on  | on  | off | off | off/on                     |
| +/- 122.07              | off | off | off | on  | off | off/on                     |
| +/- 137.33              | on  | off | off | on  | off | off/on                     |
| +/- 152.59              | off | on  | off | on  | off | off/on                     |
| +/- 167.85              | on  | on  | off | on  | off | off/on                     |
| +/- 183.11              | off | off | on  | on  | off | off/on                     |
| +/- 198.36              | on  | off | on  | on  | off | off/on                     |
| +/- 213.62              | off | on  | on  | on  | off | off/on                     |
| +/- 228.88              | on  | on  | on  | on  | off | off/on                     |

For error correction between  $\pm 244.14$  and  $\pm 457$ , add 244.14 to the setting closest to the required correction and set switches 1-4 as indicated, and switch 9 "on".

|                  |    |    |    |    |    |         |
|------------------|----|----|----|----|----|---------|
| Diameter Readout | on | on | on | on | on | off (+) |
|------------------|----|----|----|----|----|---------|

## SECTION 5 MAINTENANCE

### 5.1. GENERAL

This section is primarily devoted to troubleshooting the system. Table 5-1 will assist you in isolating the problem and making the proper repair. In addition, this section includes procedures for troubleshooting A-R/1 and A-R/5 scale assemblies, plus procedures for reading head removal and replacement. Figures 5-1 and 5-2 identify electronic parts and test points on both the typical axis/display printed-circuit board and the power supply board. Refer to Figures 5-3 and 5-4 for identification of scale assembly parts.

#### NOTE

All of the procedures that follow in this section are based on a 2-axis system.

The ACU-RITE II digital measuring system can be conveniently serviced because of its modular design. Therefore, any malfunction can usually be traced to an easy-to-replace, modular part. Some malfunctions that may occur in the ACU-RITE system can be corrected in the field with a minimum of down time, if you have some electrical or electronic background. Replacement of circuit boards and reading head assemblies are relatively simple.

### 5.2. PRELIMINARY TROUBLESHOOTING

All malfunctions will exhibit symptomatic readings on the digital display. However, different causes can sometimes produce similar symptoms. A simple diagnostic procedure combined with the correct interpretation of the symptoms will aid in isolating the faulty component. The first step is to determine the location of the malfunction by one of the two preliminary procedures below:

- Switch the reading head cables from one axis to the other. If the symptoms change from one display to the other, the malfunction is in the reading head or scale assembly. If the symptoms do not change axes when the cables are switched, the malfunction is in the console.
- Using the same reasoning, individual circuit boards can be switched from one axis to the other to help in locating the faulty circuit board.

#### NOTE

Problems in the console that cannot be remedied by simple parts replacement should be handled by a qualified electronic technician and must be referred to your ACU-RITE dealer service representative.

### 5.3. SYSTEM TROUBLESHOOTING

Table 5-1 contains a list of possible problems that may occur in the system. Each is followed by the probable cause and procedures used to remedy the problem. If "a" is not the remedy, proceed to "b", "c", and so on. Be sure to read Preliminary Troubleshooting, paragraph 5.2., before using this table.

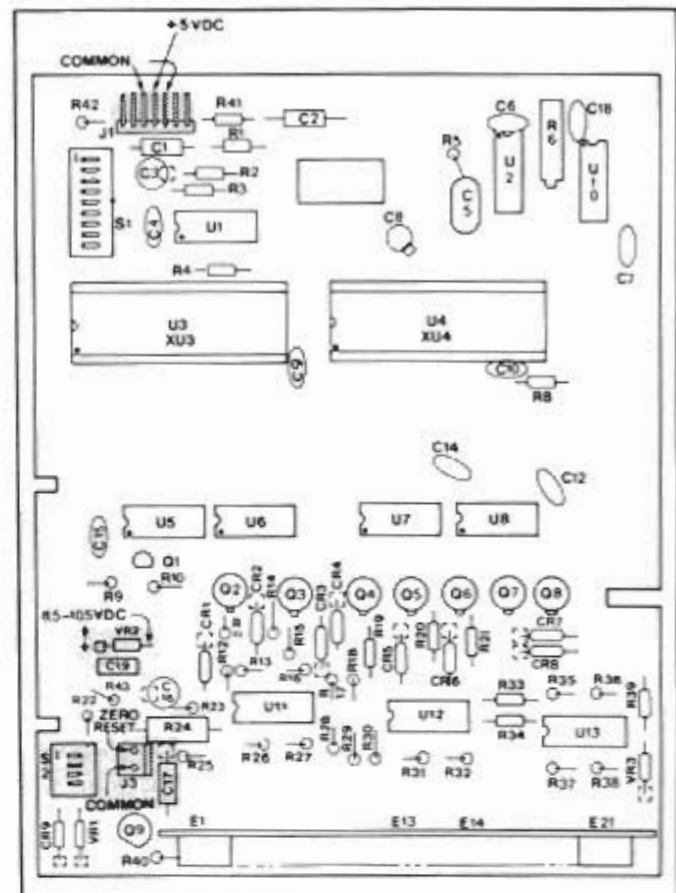


Figure 5-1. Test Points on Axis/Display Board

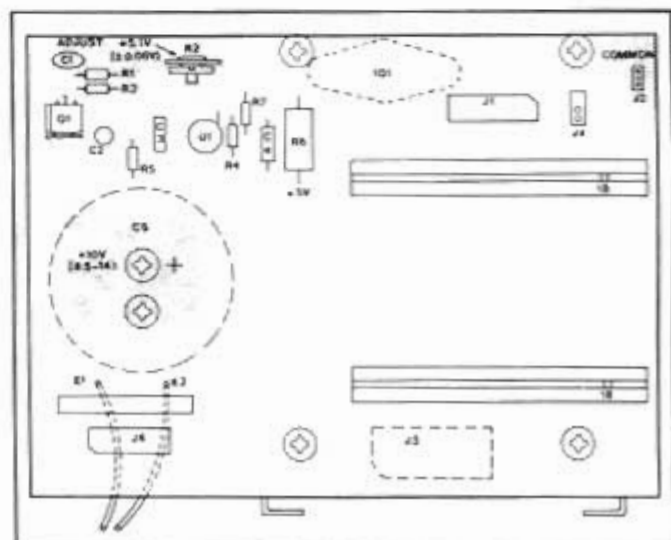


Figure 5-2. Test Points on Power Supply Board

**Table 5-1. System Troubleshooting**

| Problem                                                                              | Probable Cause                                                           | Remedy                                                                                                                                                                                                                                                                                                       |
|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| a. Console is turned on, but fault indicators do not light up.                       | 1. Improper or no line voltage at the power outlet.                      | Check the line voltage at the power outlet. It should match the rating on the serial number plate (rear of console).                                                                                                                                                                                         |
|                                                                                      | 2. Power cord not plugged, or improperly plugged, into the power outlet. | Check to make sure that the 3-prong power cord is properly plugged into the power outlet.                                                                                                                                                                                                                    |
|                                                                                      | 3. A blown fuse                                                          | Check the fuse on the console back panel. (Spring inside fuse will be compressed if blown.) Replace if necessary.                                                                                                                                                                                            |
|                                                                                      | 4. A short in the cable connecting the reading head to the console.      | Disconnect the reading head cable from the console; replace reading head/cable assembly (See Reading Head Replacement, paragraph 5.5.).                                                                                                                                                                      |
| b. Console is turned on, but one fault indicator does not light up.                  | 1. Internal connection is not making proper contact.                     | Disconnect the line power cord, remove the console cover, inspect all inside connections for proper contacts. Check the axis boards to be sure they are seated in their connectors properly. Unplug and reinsert the connectors.                                                                             |
|                                                                                      | 2. Voltage supply(ies) on the axis board inadequate                      | For qualified electronic technician only: Check the +10V D.C. (may range from +8.5V to 14.0V) and +5 V D.C. (must be $+5.1V \pm 0.5V$ ) supplies at points shown in Figure 5-1.                                                                                                                              |
|                                                                                      | 3. Component-level repair or replacement is required.                    | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty components or repair of the console.                                                                                                                                                                             |
| c. Fault indicator lights up, but no digits appear when ZERO RESET button is pushed. | 1. Internal connection is not making proper contact.                     | Disconnect the line cord, remove the console cover, inspect all inside connections for proper contact, and check the axis board on which the indicator is located to be sure it is seated in its connector properly. Unplug and properly reinsert all connectors, particularly J3, the zero reset connector. |
|                                                                                      | 2. Axis printed-circuit board is faulty.                                 | Interchange the faulty board with a good board to verify that the board is faulty.                                                                                                                                                                                                                           |
|                                                                                      | 3. Voltage supply(ies) on the axis board inadequate.                     | For qualified electronic technician only: Check the +10V D.C. and +5V D.C. supply voltages (see "b." 2.).                                                                                                                                                                                                    |

**Table 5-1. System Troubleshooting (continued)**

| Problem                                               | Probable Cause                                                        | Remedy                                                                                                                                                                              |
|-------------------------------------------------------|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                       | 4. ZERO RESET button contacts are faulty.                             | Check the voltage across the zero reset contact (should be zero when ZERO RESET button is fully depressed). If a voltage reading exists, the button is faulty and must be replaced. |
|                                                       | 5. Component-level repair or replacement is required.                 | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty components or repair of the console.                                                    |
| d. Only one digit or sign lights up.                  | 1. Faulty display oscillator and/or LSI chip.                         | Turn off the console power immediately. Replace the axis board.                                                                                                                     |
|                                                       | 2. Component-level repair or replacement is required.                 | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty component or repair of the console.                                                     |
| e. One or several digits or segments do not light up. | 1. Faulty axis board.                                                 | Disconnect line cord and replace the axis board.                                                                                                                                    |
|                                                       | 2. Component-level repair or replacement is required.                 | Contact your ACU-RITE dealer service representative for repair or replacement of faulty component or repair of the console.                                                         |
| f. Only one axis will not preset properly.            | 1. The procedure for presetting has not been done properly.           | Check the procedure for presetting in the Operation section, paragraph 3.4.5. Repeat, if necessary.                                                                                 |
|                                                       | 2. Axis board is not connected properly.                              | Disconnect the line cord, remove the console cover, and remove and reinsert the axis board.                                                                                         |
|                                                       | 3. Faulty connection between the keyboard and the power supply board. | Disconnect the line cord and remove console cover. Unplug and check the cable connection between the keyboard and the supply board. Check for bent or broken pins.                  |
|                                                       | 4. Axis board is faulty.                                              | Interchange axis boards to see if problem can be isolated. Replace axis board, if necessary.                                                                                        |
|                                                       | 5. Power supply board is faulty.                                      | Replace the power supply board, if necessary.                                                                                                                                       |
|                                                       | 6. Component-level repair or replacement is required.                 | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty components or repair of the console.                                                    |

**Table 5-1. System Troubleshooting** (continued)

| Problem                                              | Probable Cause                                                        | Remedy                                                                                                                                                                                 |
|------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| g. Console will not preset properly.                 | 1. The procedure for presetting has not been done properly.           | Check the procedure for presetting in the Operation section, paragraph 3.4.5. Repeat, if necessary.                                                                                    |
|                                                      | 2. Faulty connection between the keyboard and the power supply board. | Disconnect the line cord and remove console cover. Unplug and check the cable connection between the keyboard and the supply board. Check for bent or broken pins.                     |
|                                                      | 3. Faulty keyboard assembly.                                          | Replace the keyboard assembly by 1) removing the cable plug from power supply board, 2) removing holding bracket and screws, and 3) removing assembly.                                 |
|                                                      | 4. Component-level repair or replacement is required.                 | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty component or repair of the console.                                                        |
| h. Counting occurs only on least significant digits. | 1. Faulty reading head assembly.                                      | Interchange reading head cables between axes to isolate the problem to the reading head assembly or console. Replace reading head, if necessary. See procedures later in this section. |
|                                                      | 2. Faulty connection from axis board to input connector.              | Disconnect line cord and check connection at rear of axis board and input connector for loose wires or plugs. Correct if necessary.                                                    |
|                                                      | 3. Component-level repair or replacement in the console is required.  | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty component or repair of the console.                                                        |
| i. Counting occurs in one direction only.            | 1. Faulty reading head assembly.                                      | Interchange reading head cables between axes to isolate the problem to the reading head assembly or console.                                                                           |
|                                                      | 2. Reading head is not aligned correctly.                             | Check the reading head alignment. Refer to appropriate scale installation manual (A-R/1, A-R/5 or Mini-Scale) for details of installing and aligning the reading head.                 |
|                                                      | 3. Axis board is faulty.                                              | Disconnect line cord and replace the axis board.                                                                                                                                       |
|                                                      | 4. Component-level repair or replacement is required.                 | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty component or repair of the console.                                                        |

**Table 5-1. System Troubleshooting** (continued)

| Problem                                                            | Probable Cause                                                                    | Remedy                                                                                                                                                                                                                            |
|--------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| j. Counting occurs in one measurement mode but not the other.      | 1. Axis board is faulty.                                                          | Disconnect line cord, then replace the axis board.                                                                                                                                                                                |
|                                                                    | 2. Component-level repair or replacement is required.                             | Contact your ACU-RITE dealer service representative for repair or replacement of the faulty component or repair of the console.                                                                                                   |
| k. Absolute/incremental mode selection does not function properly. | 1. Specific operating procedure has been done incorrectly.                        | Check Operating Procedure, paragraph 3.5., and repeat, if necessary, to be certain that all steps have been done correctly.                                                                                                       |
|                                                                    | 2. Component-level repair or replacement is required.                             | Contact your ACU-RITE dealer service representative for repair or replacement of faulty component or repair of console.                                                                                                           |
| l. System will not repeat to within a least count.                 | 1. Scale assembly is not aligned correctly.                                       | Check the spar brackets for alignment and stability. Refer to appropriate scale installation manual (A-R/1, A-R/5 or Mini-Scale) for details of installing and aligning the reading head.                                         |
|                                                                    | 2. Low supply voltage.                                                            | For qualified electronic technician only: Check for low +5V D.C. supply voltage. See Figure 5-1 (also see "b". 2.).                                                                                                               |
|                                                                    | 3. Glass scale is dirty.                                                          | Gently clean the scale with a cotton swab and isopropyl (rubbing) alcohol to remove foreign matter. Keep swab saturated while cleaning.                                                                                           |
|                                                                    | 4. Reading head is defective.                                                     | Replace the reading head. Refer to appropriate scale installation manual (A-R/1, A-R/5 or Mini-Scale) for Mounting of Reading Head or to Reading Head Replacement, paragraph 5.5. Be sure to install temporary alignment bracket. |
| m. Error accumulation on display.                                  | 1. Reading head and/or scale out of alignment.                                    | Check head/scale alignment. Refer to appropriate scale installation manual (A-R/1, A-R/5 or Mini-Scale) for Scale mounting.                                                                                                       |
|                                                                    | 2. Low voltage supply.                                                            | For qualified electronic technicians: Check for low +5V D.C. supply voltage (see "b". 2.).                                                                                                                                        |
|                                                                    | 3. Improper ground from console machine tool base; or improper cable connections. | Check the ground wire and connectors of the console and machine tool. Correct, if necessary.                                                                                                                                      |
|                                                                    | 4. Machine tool geometry error has accumulated.                                   | Refer to Machine Error Compensation (Error Correction Procedure, paragraph 4.3.) for corrective action.                                                                                                                           |

**Table 5-1. System Troubleshooting** (continued)

| Problem                                                                                                                | Probable Cause                                                                      | Remedy                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| n. Fault indicator lights up frequently during operation.                                                              | 1. Machine tool table is either operating at an excessive speed or it is vibrating. | Check the machine tool operation for excessive speed or vibration, and correct as required.                                                                         |
|                                                                                                                        | 2. Reading head is not aligned properly.                                            | Check the head for proper alignment. Refer to appropriate scale installation manual (A-R/1, A-R/5 or Mini-Scale) for Scale Installation procedure.                  |
|                                                                                                                        | 3. Loose or improper ground connections.                                            | Check all ground connections. Make sure the scale housing reading head and console are properly grounded.                                                           |
|                                                                                                                        | 4. Loose wire, component or board connection.                                       | Disconnect the power cord, remove the console cover, and tighten any loose connections, including the power supply capacitor (C5). Unplug and reconnect all boards. |
|                                                                                                                        | 5. Glass scale is dirty.                                                            | Clean scale (refer to "I", 3.).                                                                                                                                     |
| o. Fault indicator appears or spurious (false) counts occur when machine tool (or shop equipment) is turned on or off. | 1. Power outlet is on a circuit that should not be used for the system.             | Transfer the power cord to another power outlet on a circuit with no potentially high or disruptive noise or surges.                                                |
|                                                                                                                        | 2. Loose or improper ground connections.                                            | Check all ground connections.                                                                                                                                       |
|                                                                                                                        | 3. Machine tool is not protected against line power surges or noise.                | For qualified electronic technician only: Suppress machine tool circuit breakers with R-C networks or transient voltage suppressors.                                |
|                                                                                                                        | 4. System is not protected against line power surges or noise.                      | For a qualified electronic technician only: Interface a line noise filter or isolation transformer between power cord and power source.                             |

#### 5.4. SCALE ASSEMBLY TROUBLESHOOTING (A-R/1 AND A-R/5)

When there is a malfunction in the reading head and scale assemblies, check first for correct mounting of the scale and its associated hardware on the machine tool. Sometimes a purely mechanical failure will occur and cause problems in reading head carriage tracking or possibly a calibration error. Refer to the appropriate scale installation manual (A-R/1 or A-R/5) for Scale Installation procedure.

##### NOTE

For Mini-Scale troubleshooting, refer to the Mini-Scale installation manual, 380306-10001.

The following are some possible conditions to check in these cases for both the A-R/1 and A-R/5 scale assemblies (see Figures 5-3 and 5-4 for parts identification):

- a. Wires on LED board (11) rubbing against the inside of the scale housing (2). Physically check for this condition by removing one end cap and, with a flashlight, looking inside the scale housing. If wires are rubbing, move the head to the end of the housing and use a convenient tool to reposition the wires. If this is not convenient, remove the head and reposition the wires. Refer to Reading Head Removal and Replacement, paragraph 5.5.
- b. Alignment bracket (5) was bent in shipment or mounting brackets are loose or bent out of place.
- c. Reading head was bumped in shipment and, even though alignment bracket (5) was not bent, the flat head screws have shifted slightly off center. This causes the head carriage (9) to be out of parallel with the bottom of the scale (1).
- d. Reading head misalignment can be caused by a few other conditions including the following:
  1. If the reading head is not mounted in its correct position, the ball spring (10) will not be parallel to scale edge (1). Any additional lateral movement between the head and scale will cause a cosine error.
  2. If the carriage (9) rides up and down on a damaged scale edge, the index grating will not track on a true course. Physically check for this condition by separating the lip seals and, with a flashlight, looking at the scale to see if it is chipped or cracked.
  3. If the set screws (15a) that secure the scale housing (2) to the spar (15) are not tightened uniformly, or some are overtightened or are not tightened at all, the scale housing may distort,

causing misalignment between the reading head (4, 9) and the glass scale (1).

- e. A calibration error can be caused by non-linear tracking of the machine tool carriage on which the scale is mounted. Refer to Error Compensation, paragraph 1.2.4.
- f. Ball on cantilever spring (10) has come out of its socket on the printed-circuit board (14).
- g. Wires on the inside of the reading head casting (4) have been pinched between the casting and the cover plate (8). If wires are severely damaged, head will have to be replaced or repaired. Contact your ACU-RITE dealer service representative.

#### 5.5. READING HEAD REMOVAL AND REPLACEMENT

To remove the reading head from the A-R/5 scale assembly, remove the end cap from the scale housing by applying a slight pressure to the bottom. (A rubber hammer can be used to tap it loose.) To remount the end cap, use silicone rubber cement and tape in place until cement sets.

A-R/1 end caps are removed by removing the plastic screws in the end caps; replacement is in reverse order.

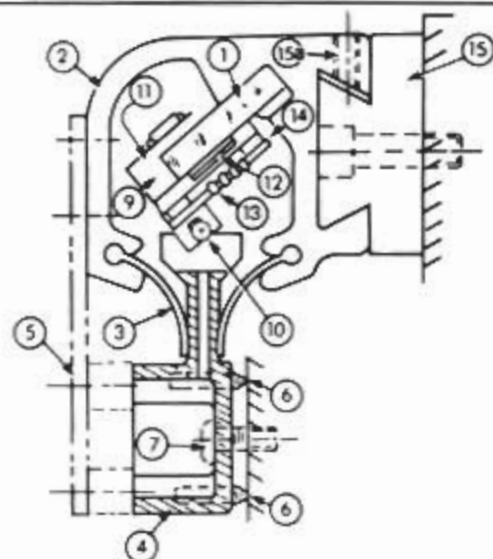
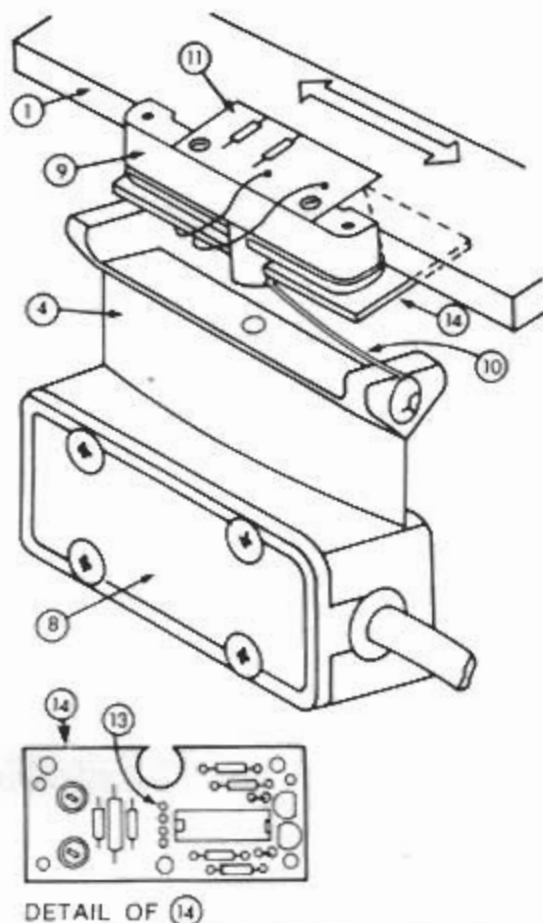
When the end caps are removed slide the defective head out of the housing, carefully, and replace as follows (refer to Figures 5-3 and 5-4 for parts identification):

- a. Unpack and assemble the new reading head according to enclosed instructions.

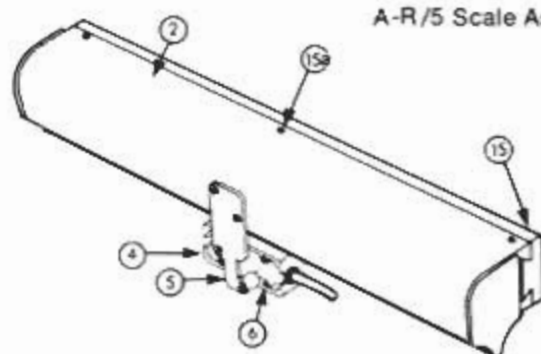
##### NOTE

Before installing new head, clean glass scale with isopropyl alcohol and a lint-free cloth or swab.

- b. Slide the reading head into the scale housing (2) making sure the circuit boards (11,14) and carriage (9) are properly placed and aligned on the glass scale (1).
- c. Install the temporary alignment bracket (5) on the scale housing (2) and reading head casting (4).
- d. Align the reading head casting (4) with the original mounting surface and secure with associated hardware.
- e. Reroute the reading head cable to the console and plug the connector to the appropriate axis on the back of the console.
- f. Run the repeatability test as detailed in the appropriate scale installation manual (A-R/1, A-R/5 and Mini-Scale).

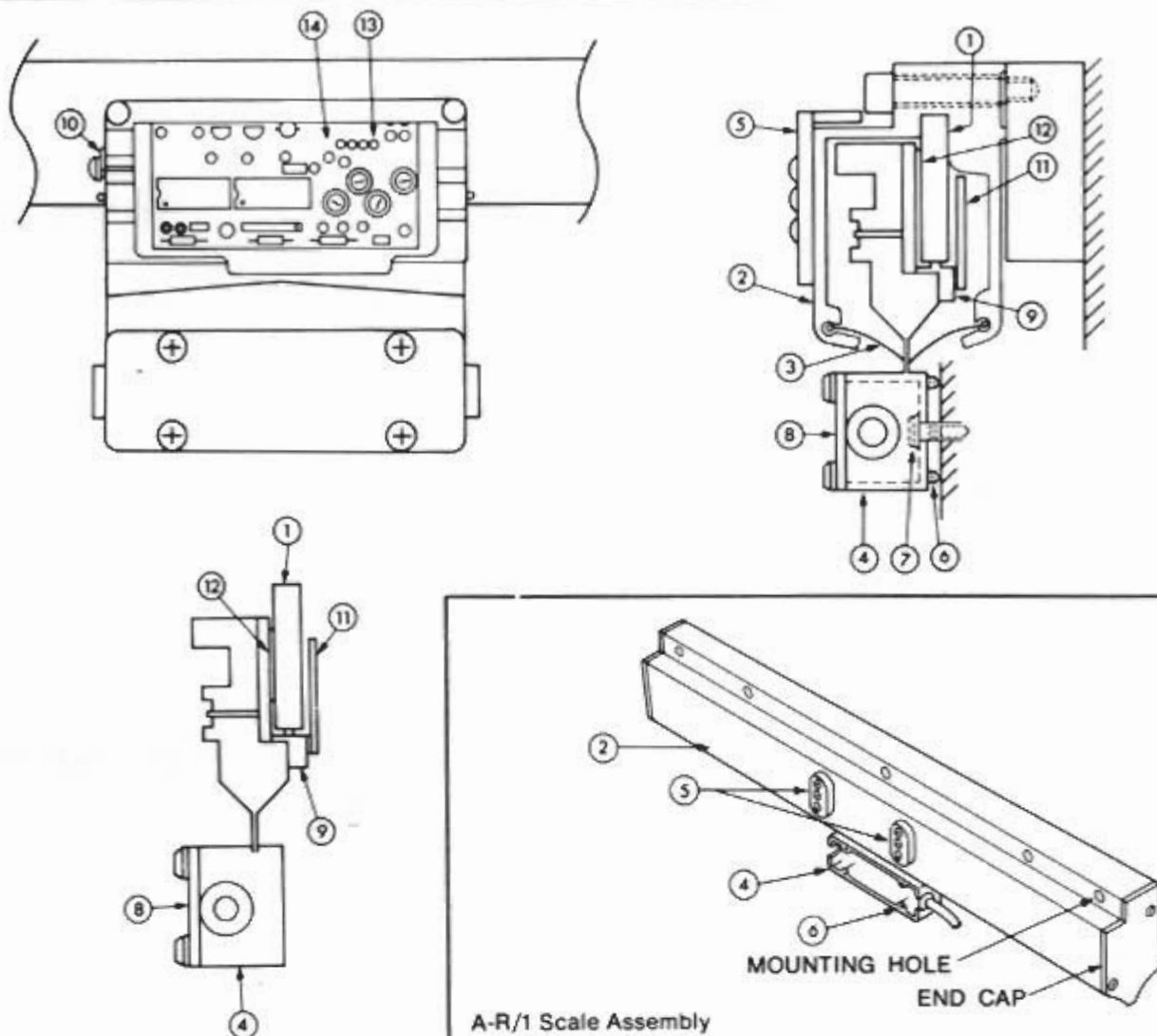


A-R/5 Scale Assembly



1. Glass scale — 1/4" with vacuum deposited chrome Ronchi rulings.
2. Scale case or housing — 3/16" thick anodized aluminum.
3. Elastomer lip seals — provide protection from shop environment, coolant sprays, etc.
4. Reading head casting.
5. Temporary alignment brackets — hold reading head in correct position for mounting — to be removed after mounting is completed.
6. Jack screws (4 pcs.) — allow for quick and easy mounting of reading head to different surfaces.
7. Reading head mounting bolts (2 pcs.)
8. Reading head cover plate.
9. Carriage body — low friction, high wear-resistant material slides directly on ground and polished edge of glass scale.
10. Cantilever spring with ball and socket joint — holds carriage body against scale and allows for slight misalignments between scale and reading head.
11. LED board.
12. Index grating — with Ronchi rulings similar to scale, produces moire fringes as the carriage traverses the scale.
13. Photocells (4 pcs.) — convert light and dark patterns of moire fringes into two-channel sine/cosine output.
14. Printed circuit board with integrated circuit — converts sine/cosine waves from photocells into a quadrature square wave (7400 TTL compatible) for console.
15. Male dovetail spar — bolted to machine at approximately 8" intervals. Scale is slid over it and set screws (15a) are tightened.

Figure 5-3. A-R/5 Scale Assembly Parts Identification



A-R/1 Scale Assembly

1. Glass scale — 1/4" with vacuum deposited chrome Ronchi rulings.
2. Scale housing — anodized aluminum.
3. Elastomer lip seals — provide protection from dirt, chips, coolant sprays, etc.
4. Reading head casting.
5. Temporary alignment brackets — hold reading head in correct position for mounting — to be removed after mounting is completed.
6. Jack screws (4 pcs.) — allow for quick and easy mounting of reading head to different surfaces.
7. Reading head mounting bolts (2 pcs.)
8. Reading head cover plate.
9. Carriage body — low-friction, high wear-resistant material slides directly on ground and polished edge of glass scale.
10. Cantilever spring with ball and socket joint — holds carriage body against scale and allows for slight misalignments between scale and reading head. This is very important.
11. LED board.
12. Index grating — with Ronchi rulings similar to scale, produces moire (vernier or zoned) fringes as the carriage traverses the scale.
13. Photocells (4 pcs.) — convert light and dark patterns of moire (vernier or zoned) fringes into two-channel sine/cosine output.
14. Printed circuit board with integrated circuit — converts sine/cosine waves from photocells into a quadrature square wave (7400 TTL compatible) for console.

Figure 5-4. A-R/1 Scale Assembly Parts Identification

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