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INTERIM TESTING ARTIFACT (ITA) a Performance Evaluation System for Coordinate Measuring Machines (CMMs)

USER MANUAL

**A.T. Singer
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S.D. Phillips
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U.S. DEPARTMENT OF COMMERCE
Technology Administration
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1 OVERVIEW

OVERVIEW OF THE CMM INTERIM TESTING ARTIFACT

The Interim Testing Artifact (**ITA**) is designed to quickly test CMMs for performance problems so that they can be repaired before significant numbers of good parts are erroneously rejected (or bad parts accepted) by the CMM. Frequent testing using the ITA is designed to supplement, **NOT REPLACE**, complete CMM calibrations by identifying problems with the CMM between regular calibrations. Such testing is often referred to as **interim testing**.

The ITA system is available in three different versions. (1) The **manual pneumatic** system is recommended for most direct computer controlled CMMs which do not have a rotary table. (2) The **automatic pneumatic** system is also available for direct computer controlled CMMs which do not have a rotary table and is useful for situations requiring a high degree of automation or for conducting extensive periods of unattended testing. (3) The **manual/rotary** system is recommended for manual CMMs and for direct computer controlled CMMs which have a computer controlled rotary table.

This manual contains 3 sub-manuals which describe the 3 systems. Each sub-manual is a self-contained reference which provides all the necessary information to set up that system. For your specific system, refer to the appropriate section.

FEATURES OF THE ITA

- The ITA is designed for rapid assembly and disassembly, and for easy, rapid interim testing of a CMM.
- The ITA is designed for fast relocation in the work zone. Once the initial location for the ITA is established, users can easily relocate the ITA for future interim tests. Consequently, once a computer program is written and the initial set up is complete, no manual datum points are necessary to perform the interim test. This can be accomplished by recalling the ITA reference frame (coordinate system) previously established.
- The ITA checks all available sub-systems of the CMM. Indexing probe heads, probe rack changers, and temperature compensation systems are all tested by the ITA.

1 OVERVIEW

The purpose of the user manual is to:

- 1) assure the ITA is set up correctly;
- 2) provide instructions on how to use the ITA;
- 3) provide information on proper maintenance of the ITA.

DO

1. **READ** the instructions before assembling the ITA.
2. **HANDLE** the ball bars carefully. The ball bars are precision instruments which can be easily damaged.
3. **HANDLE** the ball bars with gloves for high-accuracy application to reduce heat transfer to the ball bars.
4. **STORE** the ball bars in the storage case to avoid damage.
5. **PROTECT** the ball bars by leaving them in their case, until the ITA is installed and adjusted to operate smoothly.
6. **CLEAN** the balls of the ball bar with methyl or ethyl alcohol and a lint-free cloth before each interim test.
7. **INSPECT** the kinematic ball bar mounts to assure no debris is present (refer to Figure 1 on page 3). The magnets may attract chips and filings. Clean if necessary as directed above.
8. **INSPECT** the 16 cylinders comprising the indexing seats to assure no debris is present (refer to Figure 2 on page 3). Remove visible debris.
9. **NOTE** the support arms are not symmetric. Attach the support arms to the columns with the appropriate color coded labels.
10. **ATTACH** support structure columns to mounting plate so that color codes correctly match. (See **Appendix D** on page 62.)
11. **NOTE: For high accuracy measurements use a low probing force (less than 10 grams).**

FOR ADDITIONAL TROUBLESHOOTING, REFER TO THE TROUBLESHOOTING SECTION BEGINNING ON PAGE 52.

1 OVERVIEW

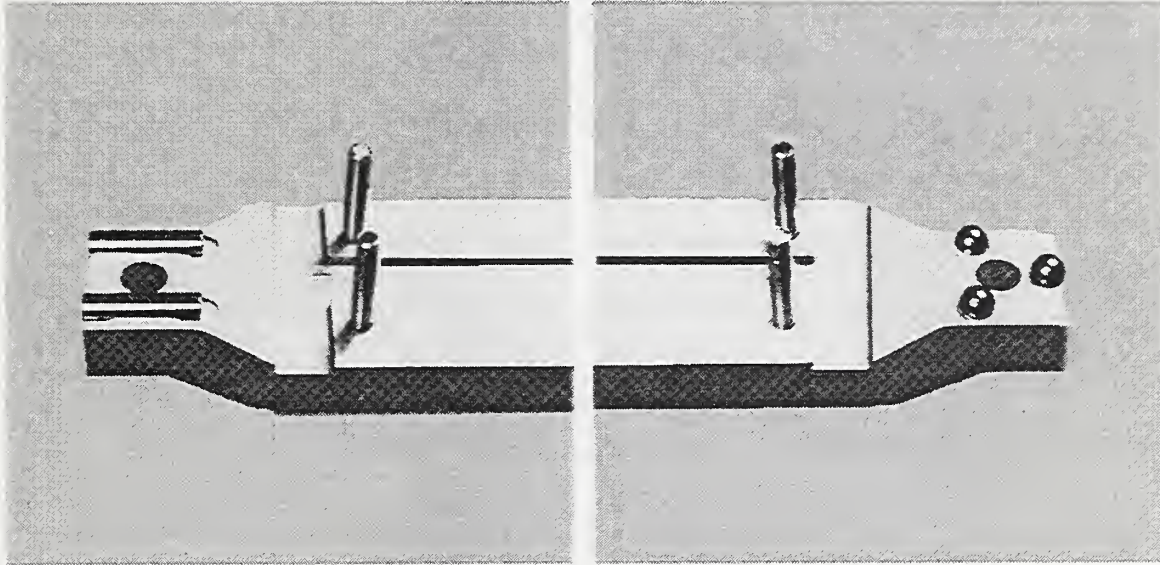


Figure 1. Kinematic ball bar mounts on support arm

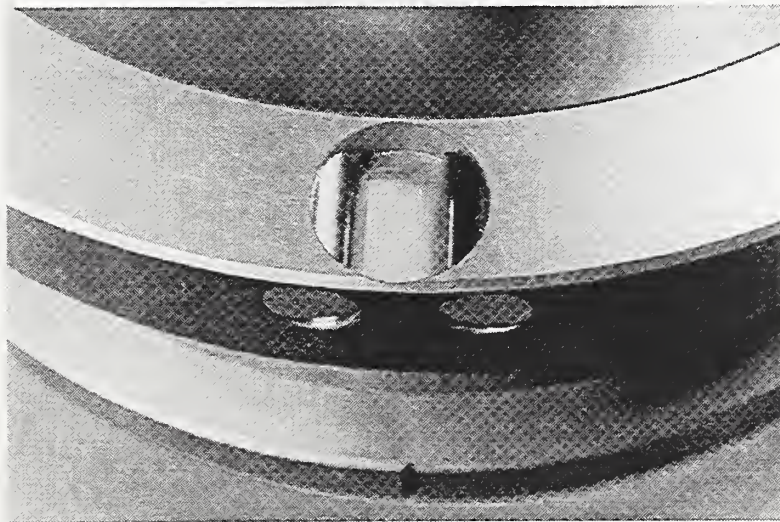


Figure 2. Indexing seats in base unit (pneumatic indexing units only)

1 OVERVIEW

DO NOT

1. **DO NOT DROP** or otherwise shock the ball bars.
(This may negate the calibration.)
2. **DO NOT LET** the ball bars become dirty or contaminated.
3. **DO NOT STEP** on the air hose.
4. **DO NOT USE** air pressure over 1050 kpa (150 lbf/in²).
5. **DO NOT USE** a probing force greater than .98 N (100 grams).
6. **DO NOT LAY** ball bars without anti-roll collars on any flat surface. (They will roll off!)

1 OVERVIEW

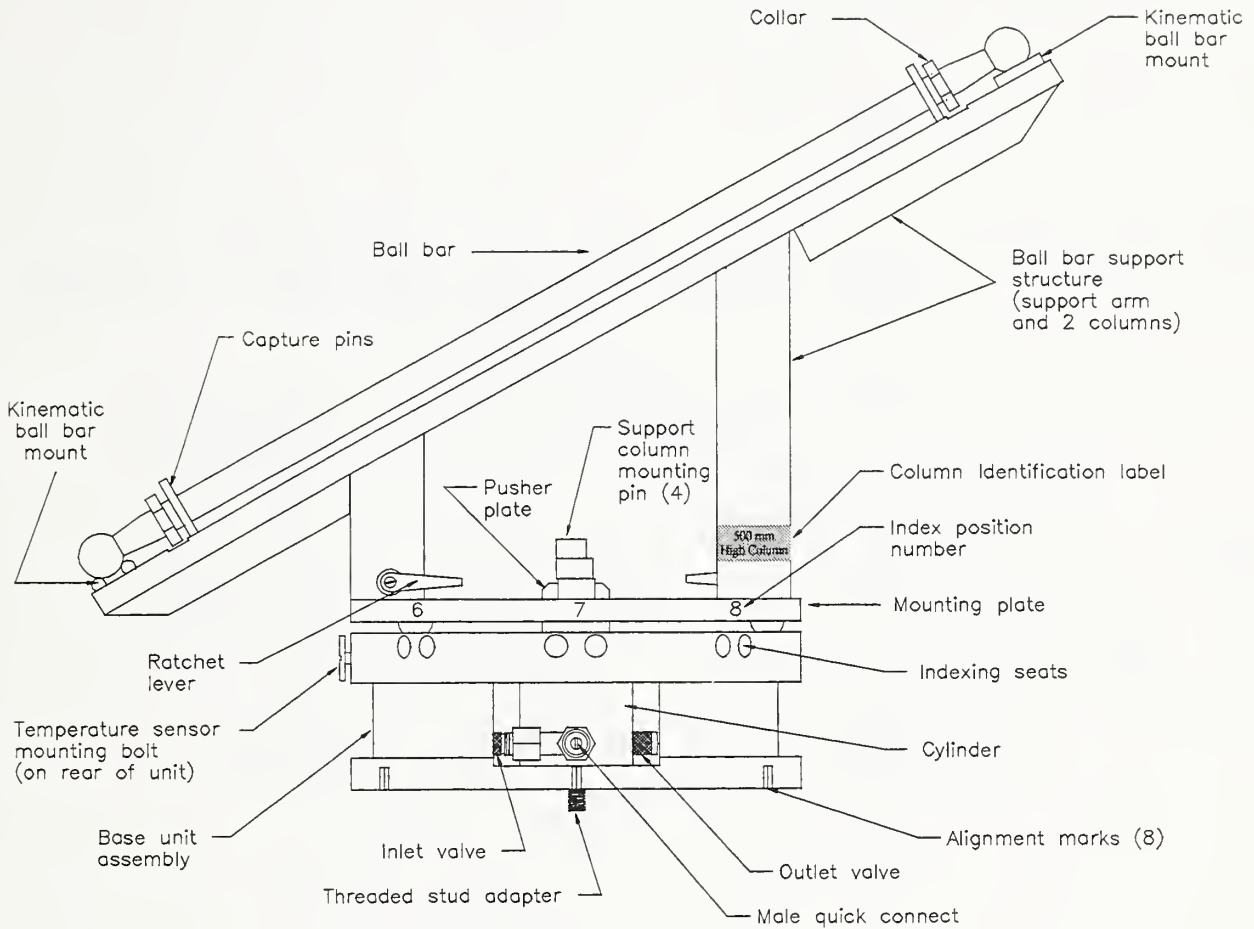


Figure 3. The Manual Pneumatic Interim testing artifact, shown with one inclined arm.

1 OVERVIEW

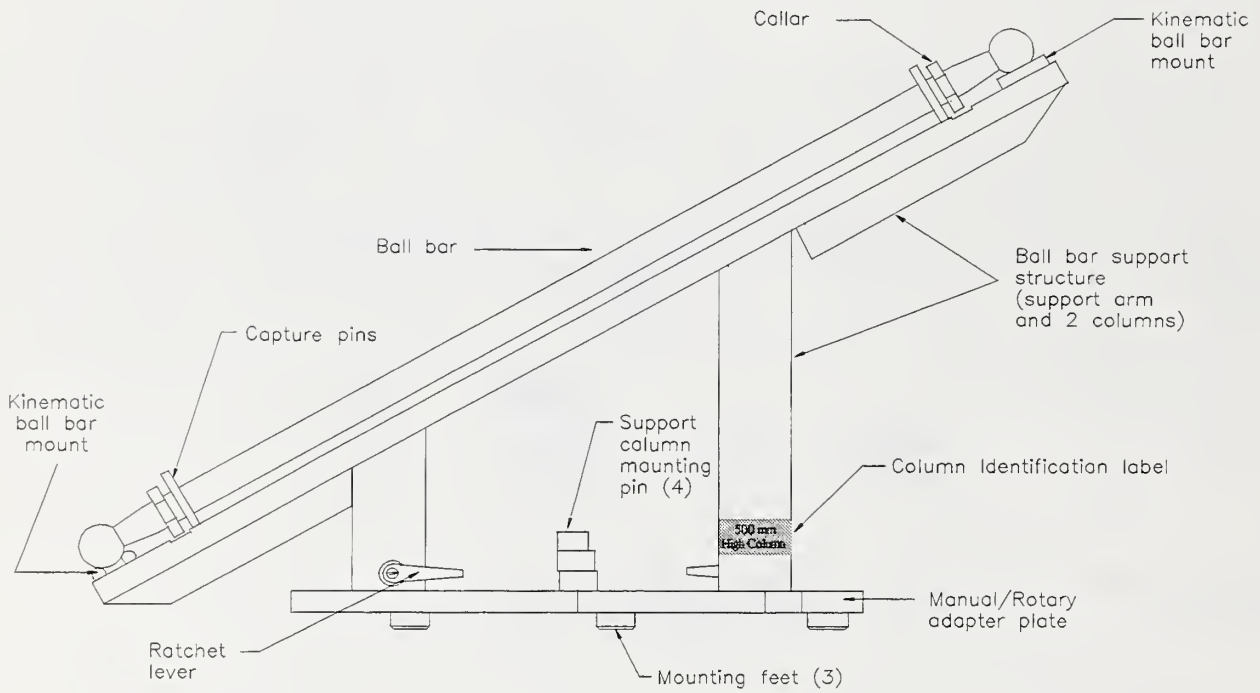


Figure 4. Manual/Rotary version of the ITA, shown with one inclined arm.

2 MANUAL PNEUMATIC INDEXING SYSTEM

THIS SECTION IS A SELF CONTAINED REFERENCE FOR THE CARE, USE AND ASSEMBLY OF THE MANUAL PNEUMATIC INDEXING SYSTEM.

2 MANUAL PNEUMATIC INDEXING SYSTEM

The manual pneumatic indexing system provides a convenient mechanism for indexing the ball bar assembly. Using this version of the ITA, the pneumatic system lifts the ball bar assembly allowing the operator to rotate the structure from one indexing position to the next. The ITA allows for a full system test under computer control, without any manual datuming of probing points. This "no-datum" capability allows this version of the ITA to provide very fast testing times for computer controlled CMMs.

The list below contains the various components that arrive with the manual pneumatic indexing ITA.

2.1 COMPONENTS OF SYSTEM

Quantity

- 1 manual pneumatic base unit assembly with mounting plate and case
 - 1 * ball bar support structure consisting of columns, support arm and case. (Arm length should match ball bar length.) **NOTE:** The arm is bolted to one set of columns for an inclined position or bolted to a different set of columns for a horizontal position.
 - 1 * ball bar (calibrated or uncalibrated)
(available sizes 300 mm, 500 mm, 700 mm, 900 mm, 1200 mm and 1500 mm)
 - 1 ** threaded stud adapter (to attach the ITA to the table) (Figure 5)
 - 1 M10 pan head screw (to seal off the air cylinder when the ITA is attached to the CMM table by some alternative method)
 - 1 quick-connect air hose assembly
- * Optional second ball bar support structure and ball bars are available.
- ** Six threaded stud adapters are available in the following sizes: 3 metric (M8, M10, M12); 3 inch (5/16, 3/8, 1/2). One adapter is included in your system.

2 MANUAL PNEUMATIC INDEXING SYSTEM

- 2 hex keys (sizes: M4, M8)
- 1 temperature sensor mounting bolt

Miscellaneous air system components:

- quick-connect to $\frac{1}{4}$ inch pipe thread adapter
- $\frac{1}{4}$ inch pipe thread tee
- spare front and back ferrules for swagelok connection

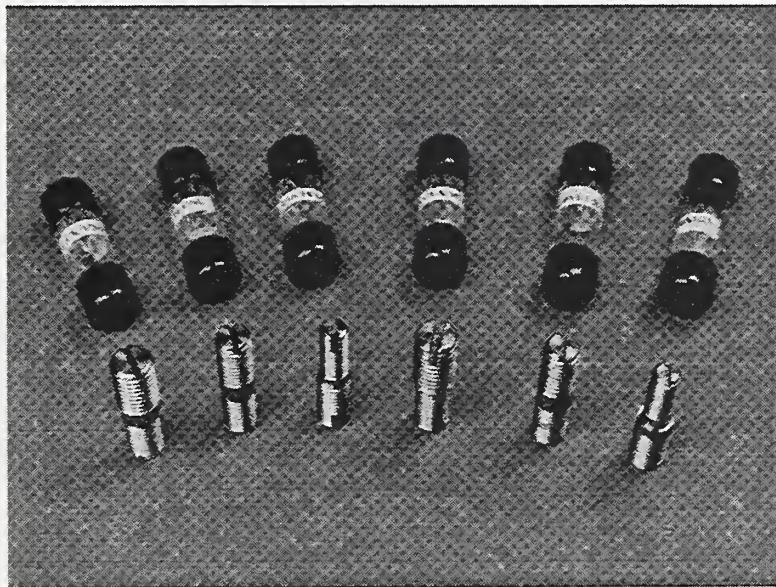


Figure 5. Threaded stud adapters (six available sizes)

2 MANUAL PNEUMATIC INDEXING SYSTEM

For assembly of this version of the ITA, follow the instructions below. Refer to Figure 3 on page 5 as needed.

2.2 ASSEMBLY

UNPACKING THE BASE UNIT

- Step 1. Remove the base unit assembly with mounting plate from the base unit case.
- Step 2. Remove any packing material from inside the base unit.
NOTE: Inspect the indexing seats for debris (refer to Figure 2 on page 3). Remove or clean any contamination.

SETTING UP THE SYSTEM

The ITA is attached to the CMM using the threaded inserts located on the CMM table. If your CMM table **does not** have threaded inserts, the base unit may be clamped down or rested under its own weight on the CMM table. In this case, seal the cylinder by using the pan head screw provided (Figure 6). See **Appendix A** on page 56 for additional information on clamping methods.

NOTE: To prevent the base from rocking, be sure the area under the ITA is free of debris.

- Step 3. Select the appropriate threaded stud adapter that matches your threaded table insert and screw the M10 end of the threaded stud adapter into the center hole in the base unit. (Figure 7).

2 MANUAL PNEUMATIC INDEXING SYSTEM

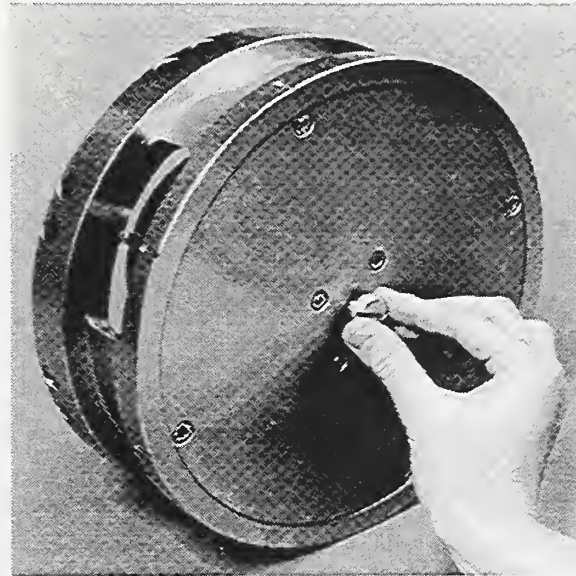


Figure 6. Inserting pan head bolt into the center hole of base unit

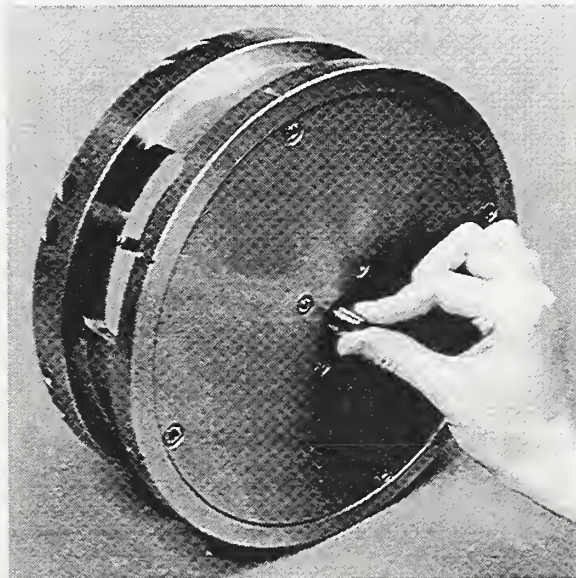


Figure 7. Inserting threaded stud adapter into the center hole of base unit

2 MANUAL PNEUMATIC INDEXING SYSTEM

Position the base unit over the threaded insert where the CMM measurements will be taken. Normally, this is near the center of the table over a threaded insert.

NOTE: Position the base unit over the selected threaded insert so that the following occurs:

- (1) A pair of indexing seats and corresponding alignment marks are parallel to the X and Y axes of the CMM (see figure 8). This alignment may be done by eye, and need only be accurate to a few degrees.

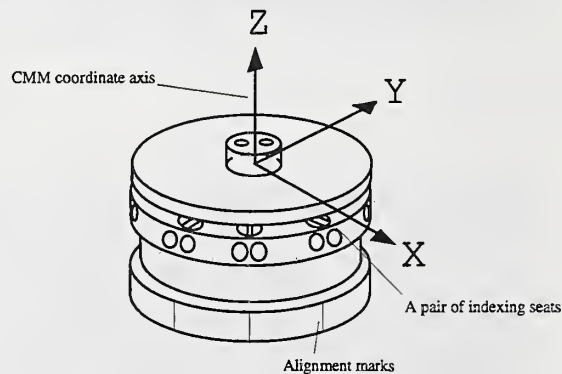


Figure 8. Aligning the ITA with the CMM coordinate axis

- (2) the air hose can be easily connected to the ITA

2 MANUAL PNEUMATIC INDEXING SYSTEM

Bolt the base unit to the CMM table by turning the pusher plate clockwise while maintaining light downward pressure, until the base unit is securely fastened. Refer to Figure 9.

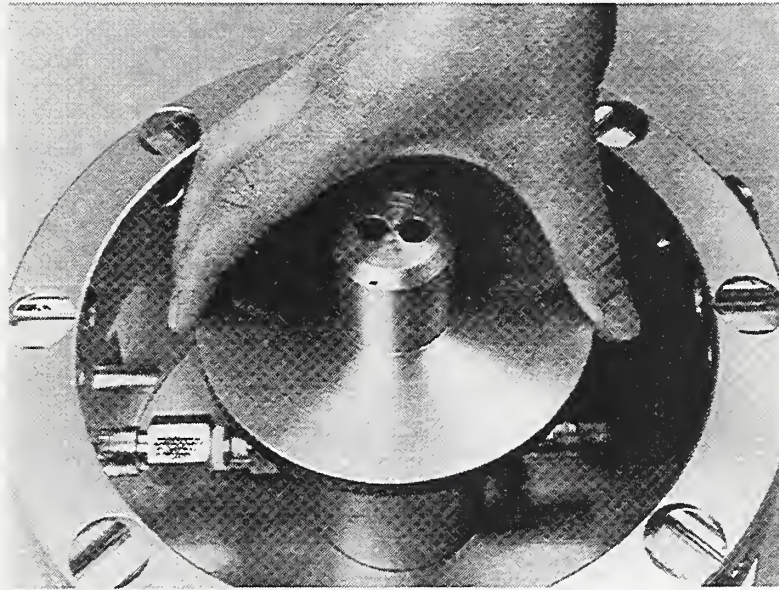


Figure 9. Turning the pusher plate to bolt the ITA to the CMM table

2 MANUAL PNEUMATIC INDEXING SYSTEM

NOTE: For consistency and time-saving for future ITA tests, always attach the ITA into the **same threaded insert** in the CMM table. This saves time by avoiding the necessity for manual intervention to re-establish the datums when setting up future ITA tests. If you are running the interim test for the first time, you need to establish an ITA reference frame (coordinate system). **Appendix G** on page 65 contains the necessary information to initially establish or re-establish the ITA reference frame.

CONNECTING AND DISCONNECTING THE QUICK AIR ATTACHMENT

Step 4. TO CONNECT the quick-connect air attachment to the ITA:

- a. Remove the air hose assembly and air system components from the arm/ball bar case.
- b. Connect the air gun to the shop air supply.
- c. Align the cone-shaped female quick-connect (on the hose) with the male connection (located inside the ITA).
- d. Push the body of the female quick-connect toward the center of the base unit until it clicks. Refer to Figure 10. To shorten the air hose assembly to suit your application, see **Appendix C** on page 60.

NOTE: Air pressure should be between 124 kpa (20 psi) and 1050 kpa (150 psi).

2 MANUAL PNEUMATIC INDEXING SYSTEM

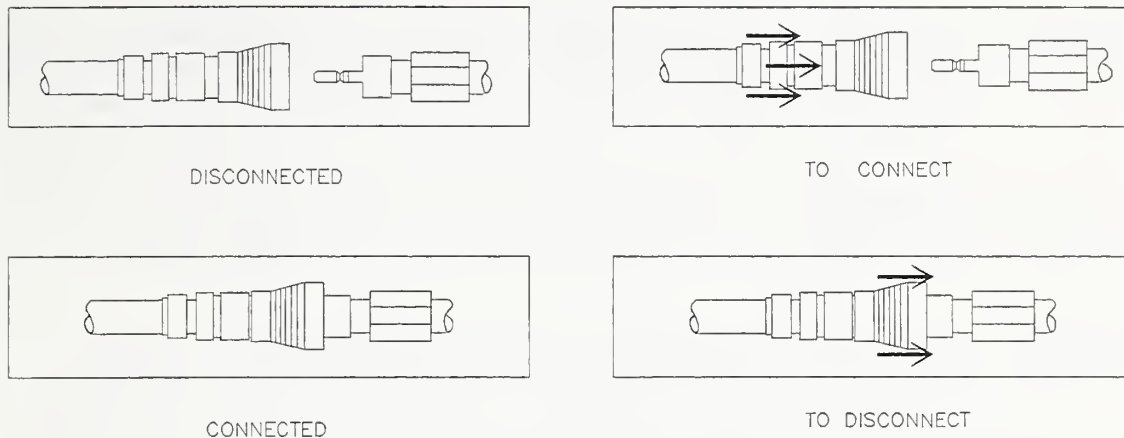


Figure 10. Female and male quick-connect operation

TO DISCONNECT the quick-connect air attachment from the ITA:

- a. Push the collar on the female quick-connect toward the center of the base unit. (The air hose will spring back.)
- b. After the air hose springs back, gently pull the disconnect away from the base unit.

ATTACHING THE MOUNTING PLATE AND BALL BARS

Step 5. Attaching the mounting plate

If the columns are not bolted to the support arm, see **Appendix D** on page 62 for bolting procedure.

NOTE: You can either put the mounting plate on the ITA base unit and then attach the ball bar support structure to the mounting plate, **OR** you can attach the ball bar support structure to the mounting plate, and then place the entire assembly onto the base unit. The first procedure will often be easier for systems using large ball bars.

2 MANUAL PNEUMATIC INDEXING SYSTEM

- a. Check the three balls on the bottom of the mounting plate and the 8 pairs of cylinders in the base unit for debris. Clean or remove any contamination. Place the mounting plate on either the CMM table or the base unit as described above.
- b. Remove the appropriate ball bar support structure (columns and arm) from its case. Check the kinematic ball bar mounts for debris.
- c. If a horizontal ball bar support structure is employed, slide the support structure over the column mounting pins which have black and white labels. It is possible to attach the horizontal support structure backwards. Therefore, be sure to match the corresponding color of the column label to the label adjacent to the column mounting pin. (See **Appendix D** on page 62 for assembling column to support arm if necessary). Engage the ratchet levers and secure the structure as described in Step 5d.

If the inclined ball bar is used, slide the support structure column over the column mounting pins which have red and blue labels. It is possible to attach the inclined support structure backwards. Therefore, be sure to match the corresponding color of the column label to the label adjacent to the column mounting pin. Engage the ratchet levers and secure the structure.

If both ball bars are used, first attach the horizontal support structure and then the inclined support structure.

- d. Procedure for securing the support structure to the mounting plate: Secure each column by tightening the ratchet one-half turn clockwise until it is tight against the column mounting pin. To adjust the position of the ratchet lever, see **Appendix E** on page 63.

The ball bar support structure should now be secured to the mounting plate and the assembly positioned on top of the base unit.

2 MANUAL PNEUMATIC INDEXING SYSTEM

NOTE: If the columns do not easily slide over the column mounting pins, the ratchet levers may need to be adjusted (see **Appendix E** on page 63) or the columns may need to be readjusted on the support arms (see **Appendix D** on page 62)

Step 6. ITA Testing and Adjustment

Prior to performing interim testing, be sure to test and adjust the ITA for smooth indexing motion.

- a. SQUEEZE and HOLD the air gun trigger. This action causes the mounting plate and support assembly to be lifted off the base for easy rotation.
- b. Gently rotate the ball bar support structure to a new position. Refer to Figure 11 below.

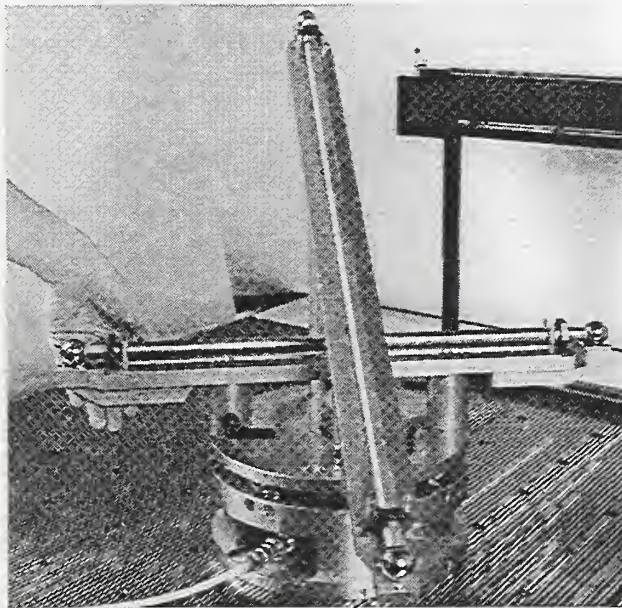


Figure 11. Rotating the ball bar support structure to a new position

2 MANUAL PNEUMATIC INDEXING SYSTEM

- c. Release the trigger. The ball bar support structure is lowered onto the base unit.
- d. If the mounting plate and support arm ascend and descend incorrectly, see "**ADJUSTING THE PNEUMATIC SYSTEM**" below.
- e. Rotate the mounting plate structure one complete revolution to be sure the CMM table is free of obstacles.

ADJUSTING THE PNEUMATIC SYSTEM

1. To increase the ascending rate of the mounting plate, slightly **open** the inlet valve inside the base unit.
NOTE: The ascending rate is too high if the mounting plate overshoots the desired indexing position, and should be decreased.
2. To decrease the ascending rate of the mounting plate, slightly **close** the inlet valve inside the base unit.
NOTE: The ascending rate should be slow enough (6 seconds) to avoid a hard impact of the mounting plate at the top of the ascending stroke.
3. To increase the descending rate, slightly **open** the outlet valve inside the base unit.
NOTE: The descending rate is too fast if the unit settles into the indexing seats within 6 seconds.
4. To decrease the descending rate, slightly **close** the outlet valve inside the base unit.
NOTE: The descending rate should be slow enough to avoid a hard impact of the mounting plate when returning to the indexing seats.

If system fails to ascend or descend, see the **Troubleshooting** section beginning on page 52.

2 MANUAL PNEUMATIC INDEXING SYSTEM

THE TEMPERATURE SENSOR MOUNTING BOLT (Optional)

Step 7. If your CMM has part temperature compensation, attach the temperature sensor to the temperature sensor mounting bolt. Refer to Figure 12.

The purpose of the temperature sensor mounting bolt is to provide a large, flat, metal surface for magnetically mounted temperature sensors. The bolt is also designed to mount the temperature sensor in a thermal environment similar to that of the ball bars.

Located on the side of the ITA base opposite the air hose, is an M8 threaded hole for attaching the temperature sensor mounting bolt. The spacer sleeve provided with the bolt is designed to keep the bolt from being screwed tightly to the base unit, maintaining a thermal break between the ITA base and CMM table.

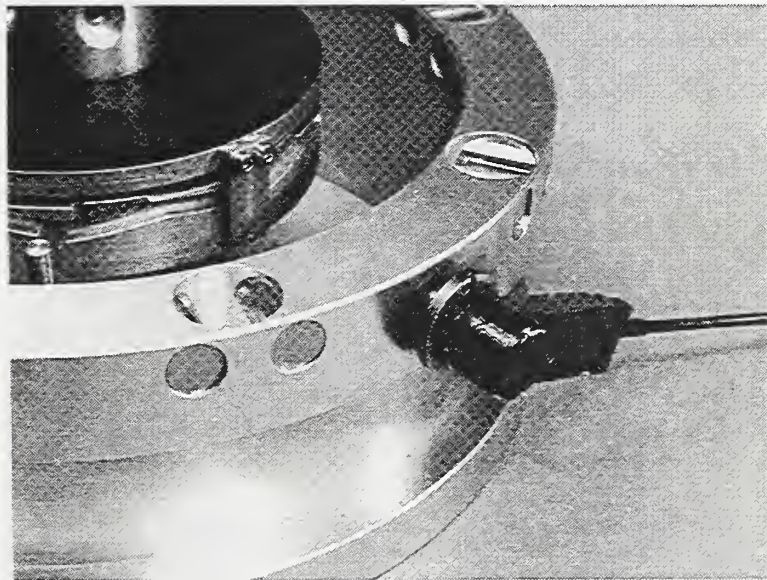


Figure 12. Temperature sensor mounting bolt with part temperature sensor magnetically attached to it

2 MANUAL PNEUMATIC INDEXING SYSTEM

INDEX POSITION NUMBERS

There are eight numbered labels around the edge of the mounting plate to clearly identify the specific position of the ITA. The ITA is defined to be in a specific index position when the number corresponding to that position faces the front of the CMM. Many users' programs will start in index position 4, meaning the high inclined arm is pointing toward the far left-hand corner of the CMM, and the number '4' is located in the front position of the mounting plate. It may be useful to refer to these index position numbers when using or writing a computer program.

- Step 8. Once the ITA is properly attached to the CMM table and adjusted, the ball bars may be installed.
- a. Remove the ball bars from their case. Inspect for any debris and clean as necessary. The ball bars are carefully calibrated for roundness; even a small amount of debris can degrade a test.
 - b. **GENTLY** place each ball bar into the kinematic ball bar mount, first by placing one ball into the three ball mount, and then lowering the other ball into the parallel mount.

HINT: By rotating the ball bar slightly about its axis (once mounted) you will ensure that it is fully secure.

NOTE: For ball bars with calibrated ball diameters, ball #1 should be placed in the parallel cylinder kinematic ball bar mount; ball #2 should be placed in the three ball kinematic ball bar mount. **For ball bars with anti-roll collars, make sure the collars do not contact the support structure.** There are grooves along each end of the support arm which provide clearance for the anti-roll collars. (See **appendix H** on page 68 for additional information.) For uncalibrated ball bars, either end can be interchangeably placed on the mount.

2 MANUAL PNEUMATIC INDEXING SYSTEM

2.3 CHECKLIST FOR MANUAL PNEUMATIC INDEXING ITA

1. Position and attach the ITA base unit to the CMM table.
2. Check for debris in the indexing seats and on the three balls on the bottom of the mounting plate.
3. Connect the air hose to the base unit.
4. Check and clean the kinematic ball bar mounts on the support arm.
5. Attach and secure the support arm structure.
6. Check the ball bars, and place them onto the kinematic ball bar mounts.
7. Run the CMM interim testing program.
8. Examine results. If the machine fails the test, check to make sure that the ITA is in good working order (see **Troubleshooting** section which begins on page 52). If the machine fails a second time, the CMM may need repair or recalibration.
9. When finished, return the ITA to the storage cases.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

THIS SECTION IS A SELF CONTAINED REFERENCE FOR THE CARE, USE AND ASSEMBLY OF THE AUTOMATIC PNEUMATIC INDEXING SYSTEM.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

The automatic pneumatic indexing system is capable of being computer driven for a fully automated CMM test. This version of the ITA is useful for users who seek a high degree of automation or need to conduct continuous testing over a long period of time. For programming and testing purposes, it works exactly the same as the manual indexing system. A manual pneumatic version of the ITA can be converted into a automatic version by replacement of the pusher plate assembly with a cam follower assembly.

The list below contains the various components that arrive with the automatic pneumatic indexing ITA.

3.1 COMPONENTS OF SYSTEM

Quantity

- 1 automatic pneumatic indexing base unit assembly with mounting plate, friction pad and case
- 1 * ball bar support structure consisting of columns, support arm and case. (Arm length should match ball bar length.) **NOTE:** The arm is bolted to one set of columns for an inclined position, or bolted to a different set for a horizontal position.
- 1 * ball bar (calibrated or uncalibrated)
(available sizes 300 mm, 500 mm, 700 mm, 900 mm, 1200 mm, and 1500 mm)
- 1 electronic interface box with manual indexing button and 3.6 m (12 foot) length BNC extension cable
- 1 75 mm long tightening rod for use with the base unit
- 1** threaded stud adapter to attach the ITA to the table (Figure 13).

* Optional second ball bar support structure and ball bar are available.

** Six threaded stud adapters are available in the following sizes: 3 metric (M8, M10, M12); 3 inch (5/16, 3/8, 1/2). One adapter is included with your system.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

- 1 computer cable 6.1 m (20 ft.)
- 1 M10 pan head screw (to seal off the air cylinder when the ITA is attached to the CMM table by some alternative method)
- 1 quick-connect air hose assembly
- 3 hex keys (sizes: M2, M4, M8)
- 1 temperature sensor mounting bolt

Miscellaneous air system components:

- quick-connect to ¼ inch pipe thread adapter
- ¼ inch pipe thread tee
- spare front and back ferrules for swagelok connection

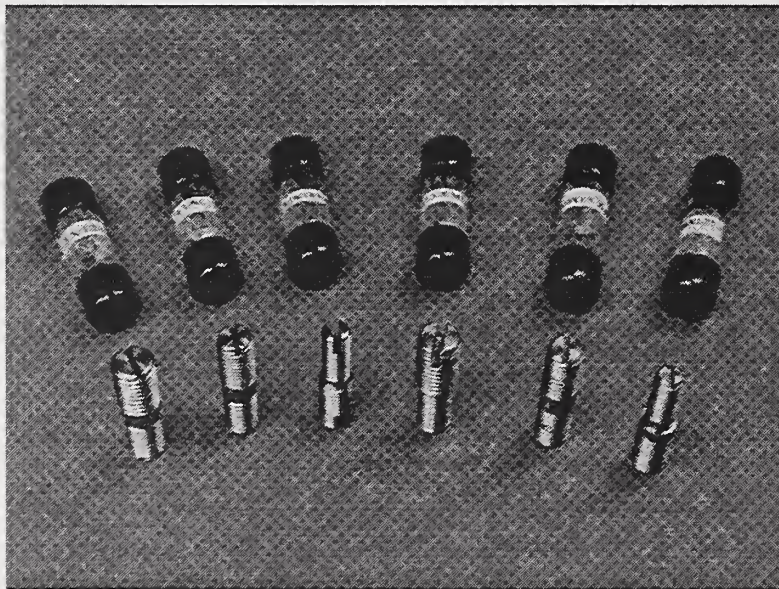


Figure 13. Threaded stud adapters (six available sizes)

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

For assembly of this version of the ITA, follow the instructions below. Refer to Figure 3 on page 5 as needed.

3.2 ASSEMBLY

UNPACKING THE BASE UNIT

- Step 1. Remove the base unit assembly with mounting plate from the base unit case.
- Step 2. Remove any packing material from inside the base unit.
NOTE: Inspect the indexing seats for debris (refer to Figure 2 on page 3). Remove or clean any contamination.

SETTING UP THE SYSTEM

To attach the ITA to the CMM table, use a threaded insert provided on your CMM table. If your CMM table **does not** have threaded inserts, the base unit may be clamped down or rested under its own weight on the CMM table. In this case, seal the cylinder by using the pan head screw provided. Refer to Figure 14. See **Appendix A** on page 53 for additional information on clamping methods.

NOTE: To prevent the ITA from rocking, be sure the area under the ITA is free of debris.

- Step 3. Select the appropriate threaded stud adapter that matches your threaded table insert and screw the M10 end of the threaded stud adapter into the center hole in the base unit. Refer to Figure 15.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

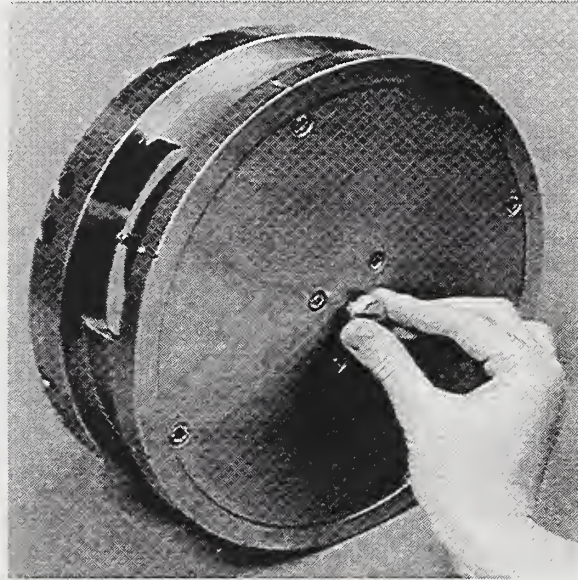


Figure 14. Inserting Pan head bolt into the center hole of the base unit

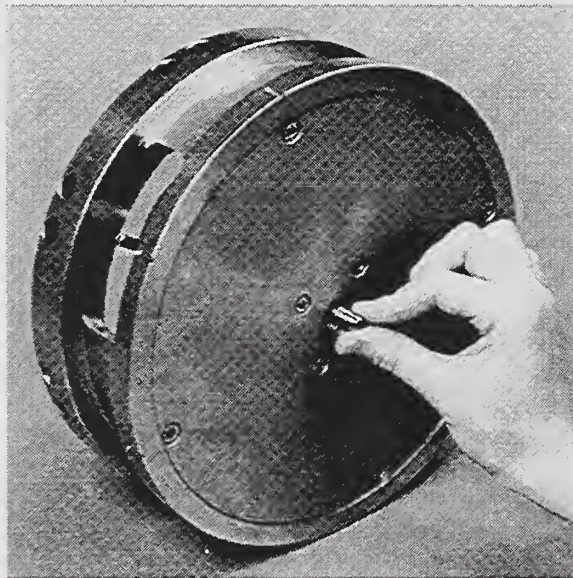


Figure 15. Inserting threaded stud adapter into the center hole of the base unit

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

Position the base unit over the threaded insert where the CMM measurements will be taken. Normally, this is near the center of the table over a threaded insert.

NOTE: Align the base unit with respect to the CMM axis so that the following occurs:

- (1) A pair of indexing seats and corresponding alignment marks are parallel to the X and Y axes of the CMM (see figure 16). This alignment may be done by eye, and need only be accurate to a few degrees.

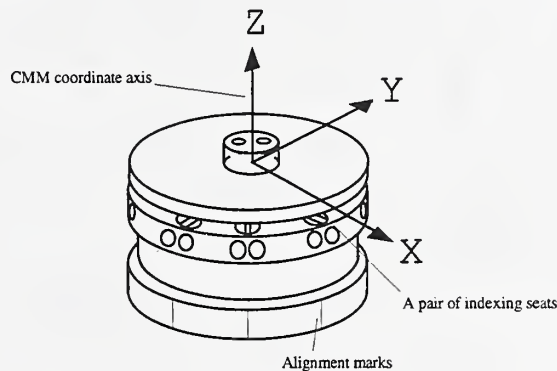


Figure 16. Aligning the ITA with the CMM coordinate axis

- (2) the air hose can be easily connected to the ITA.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

Bolt the base unit assembly to the threaded insert on the CMM table by turning the center knob clockwise while maintaining light pressure on the center knob, until the base unit assembly is securely fastened. During the final stages of tightening, insert the 75 mm tightening rod through the cross holes to generate sufficient clamping force for secure fixturing, as shown in Figure 17. The tightening rod is found clipped inside the base unit.



Figure 17. Fastening the automatic pneumatic ITA to the CMM

NOTE: For consistency and time-saving for future ITA tests, always attach the ITA into the **same threaded insert** in the CMM table. This saves time by avoiding the necessity for manual intervention to re-establish the datums when setting up the ITA. If you are running the interim test for the first time, you need to establish an ITA reference frame (coordinate system).

Appendix G on page 65 contains the necessary information to initially establish or re-establish the ITA reference frame.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

CONNECTING THE ELECTRONIC INTERFACE BOX

- Step 4. TO CONNECT the electronic interface box to the ITA:
- a. Remove the air hose assembly and air system components from the case.
 - b. Remove the electronic interface box from its case and place on or near the CMM, located so the cables and hoses are out of the path of the CMM.
 - c. Connect compressed air at the TO SHOP AIR fitting located on the electronic interface box.
 - d. Align the cone-shaped female quick-connect (on the hose) with the male connection (located inside the ITA).

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

- e. Push the body of the female quick-connect toward the center of the base unit until it clicks. Refer to Figure 18. To shorten the air hose to suit your application, see **Appendix C** on page 60.
- f. Connect the larger female quick-connect to the TO ITA connection on the electronic interface box.
- g. Locate the MANUAL INDEXING connector on the side of the box. Plug in the manual indexing button connector to the MANUAL INDEXING connector on the side of the box. If it is not convenient to place the interface box near the CMM, a 3.6 meter (12 foot) BNC extension cable is provided.
- h. Locate the COMPUTER INDEXING connectors on the side of the box. Align either the DB9 or the BNC connector so the pins on the plug correspond with the pins on the box, and push the plug into the socket. See **Appendix B** on page 57 for additional computer interface requirements.
- I. Plug the ITA into a 110V supply. Turn the switch on the back of the box to the "1" position.

NOTE: Air supply should be between 124 kpa (20 psi) and 1050 kpa (150 psi).

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

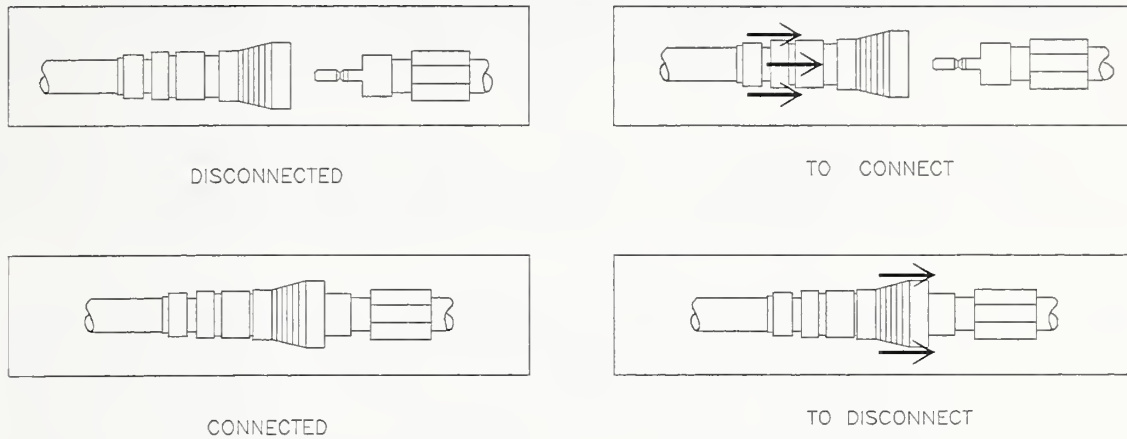


Figure 18. Female and male quick-connect operation

TO DISCONNECT the quick-connect air attachment from the ITA:

- a. Push the collar on the female quick-connect toward the center of the base unit. (The air hose will spring back.) See Figure 18.
- b. After the air hose springs back, gently pull the disconnect away from the center of the base unit.

ATTACHING THE MOUNTING PLATE AND BALL BARS

Step 5. Attaching the mounting plate

If the columns are not bolted to the support arm, see **Appendix D** on page 62 for bolting procedure.

NOTE: You can either put the mounting plate on the ITA base unit and then attach the ball bar support structure to the mounting plate **OR** you can attach the ball bar support structure to the mounting plate, and then place the entire assembly onto the base unit. The first procedure will often be easier for systems using large ball bars.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

- a. Check the three balls on the bottom of the mounting plate and the 8 pairs of cylinders in the base unit for debris. Clean or remove any contamination. Place the mounting plate on either the CMM table or the base unit as described above.
- b. Remove the appropriate ball bar support structure (columns and arm) from its case. Check and clean, if necessary, kinematic ball bar mounts.
- c. If a horizontal ball bar support structure is employed, slide the support structure over the column mounting pins which have black and white labels. It is possible to attach the horizontal support structure backwards. Therefore, be sure to match the corresponding color of the column label to the label adjacent to the column mounting pin. (See **Appendix D** on page 62 for assembling column to support arm if necessary). Engage the ratchet levers and secure the structure as described in Step 5d.

If the inclined ball bar support structure is used, slide the support structure column over the column mounting pins which have red and blue labels. It is possible to attach the inclined support structure backwards. Therefore, be sure to match the corresponding color of the column label to the label adjacent to the column mounting pin. Engage the ratchet levers and secure the structure.

If both ball bars are used, first attach the horizontal support structure and then the inclined support structure.

- d. Procedure for securing the support structure to the mounting plate: Secure each column by tightening the ratchet lever one-half turn clockwise, until it is tight against the column mounting pin. To adjust the position of the ratchet lever, see **Appendix E** on page 63.

The ball bar support structure should now be secured to the mounting plate and the assembly positioned on top of the base unit.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

NOTE: If the columns do not easily slide over the column mounting pins, the ratchet levers may need to be adjusted (see **Appendix E** on page 63) or the columns may need to be readjusted on the support arms (see **Appendix D** on page 62).

Step 6. ITA Testing and Adjustment

Prior to performing interim testing, be sure to test and adjust the ITA for smooth indexing motion.

- a. Make sure the CMM is free of obstacles, so that when the ITA rotates it will not collide with anything on the table.
- b. Press and briefly hold (three seconds) the manual indexing button. This action causes the mounting plate, with the ball bar support structure attached, to be lifted off the base and rotated.
- c. The system should have rotated 45° and the mounting plate should be resting securely on the indexing seats of the base unit. There should be no rocking or instability of the mounting plate on the base unit. If any instability is observed, check the indexing seats to be sure that they are clean. Repeat indexing as necessary to carry out one full revolution of the ITA, to be sure the system is operating correctly.
- d. Return the mounting plate and the ball bar support structure to the correct initial position needed to start the ITA test. (This can be done by simply picking up the assembly and placing it on the correct seats, if the assembly is not too heavy.)
- e. The rising time and descending time of the mounting plate should each be about 6 seconds. If the mounting plate and support arm ascend and descend incorrectly, see the box **"ADJUSTING THE PNEUMATIC SYSTEM"** on the following page.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

ADJUSTING THE PNEUMATIC SYSTEM

1. To increase the ascending rate, slightly **open** the inlet valve inside the base unit.
NOTE: The ascending rate is too high if the mounting plate overshoots the desired indexing position, and should be decreased
2. To decrease the ascending rate, slightly **close** the inlet valve inside the base unit.
NOTE: The ascending rate should be slow enough (6 seconds) to avoid a hard impact of the mounting plate at the top of the ascending stroke.
3. To increase the descending rate, slightly **open** the outlet valve inside the base unit.
NOTE: The descending rate is too fast if the unit settles into the indexing seats within 6 seconds.
4. To decrease the descending rate, slightly **close** the outlet valve inside the base unit.
NOTE: The descending rate should be slow enough to avoid a hard impact of the mounting plate when returning to the indexing seats.

If the system fails to ascend or descend, see **Troubleshooting** on page 52.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

THE TEMPERATURE SENSOR MOUNTING BOLT (Optional)

Step 7. If your CMM has part temperature compensation, attach the temperature sensor to the temperature sensor mounting bolt. Refer to Figure 19.

The purpose of the temperature sensor mounting bolt is to provide a large, flat, metal surface for magnetically mounted temperature sensors. The bolt is also designed to mount the temperature sensor in a thermal environment similar to that of the ball bars.

Located on the side of the ITA base opposite the air hose, is an M8 threaded hole for attaching the temperature sensor mounting bolt. The spacer sleeve provided with the bolt is designed to keep the bolt from being screwed tightly to the base unit, maintaining a thermal break between the ITA base and CMM table.

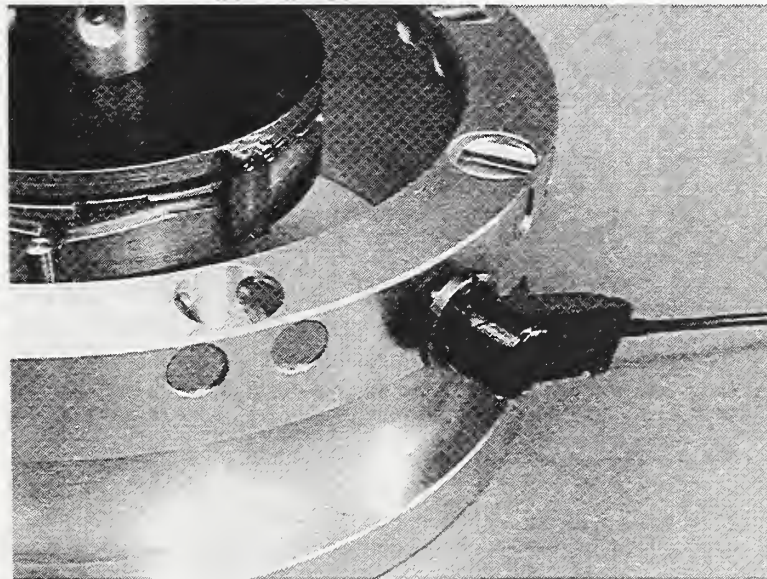


Figure 19. Temperature sensor mounting bolt with part temperature sensor magnetically attached to it

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

INDEX POSITION NUMBERS

There are eight numbered labels around the edge of the mounting plate to clearly identify the specific position of the ball bars. These numbers are provided for reference only. The ball bar assembly is defined to be in a specific index position when the number corresponding to that position faces the front of the CMM. Many users' programs will start in index position 4, meaning the high inclined arm is pointing toward the far left-hand corner of the CMM, and the number '4' is located in the front position of the mounting plate. It may be useful to refer to these index position numbers when using or writing a computer program.

- Step 8. Once the ITA is properly attached to the CMM table and adjusted, the ball bars may be installed.
- a. Remove the ball bars from the case. Inspect for any debris and clean as necessary. The ball bars are carefully calibrated for roundness; even a small amount of debris can invalidate a test.
 - b. **GENTLY** place each ball bar into the kinematic ball bar mount, first by placing one ball into the three ball mount, and then lowering the other ball into the parallel mount.

HINT: By rotating the ball bar slightly about its axis (once mounted) you will ensure that it is fully secure.

NOTE: For ball bars with calibrated ball diameters, ball #1 should be placed in the parallel cylinder kinematic ball bar mount; ball #2 should be placed in the three ball kinematic ball bar mount. **For ball bars with anti-roll collars, make sure the collars do not contact the support structure.** There are grooves along each end of the support arm which provide clearance for the anti-roll collars. (See **appendix H** on page 68 for additional information.) For uncalibrated ball bars, either end can be interchangeably placed on the mount.

3 AUTOMATIC PNEUMATIC INDEXING SYSTEM

3.3 CHECKLIST FOR AUTOMATIC PNEUMATIC INDEXING ITA

1. Position and attach the ITA base unit to the CMM table.
2. Check for debris in the indexing seats and on the three balls on the bottom of the mounting plate.
3. Connect the air hose to the base unit.
4. Check and clean the kinematic ball bar mounts on the support arm.
5. Attach and secure the support arm structure.
6. Check the ball bars, and place them onto the kinematic ball bar mounts.
7. Run the CMM interim testing program.
8. Examine results. If the machine fails the test, check to make sure that the ITA is in good working order (see **Troubleshooting** on page 52). If the machine fails a second time, the CMM may need repair or re-calibration.
9. When finished, return the ITA to the storage cases.

4 MANUAL/ROTARY SYSTEM

THIS SECTION IS A SELF CONTAINED REFERENCE FOR THE CARE, USE AND ASSEMBLY OF THE MANUAL/ROTARY INDEXING SYSTEM

4 MANUAL/ROTARY SYSTEM

The manual/rotary system is the simplest and least expensive version of the ITA, but it does not provide for incremental indexing. It is designed for manual CMMs, which cannot take advantage of the "no-datum" indexing feature which is provided in the pneumatic versions of the ITA. Similarly, this version can be used on rotary table CMMs where the CMM can rotate the ITA, which will include the rotary table in the system test, giving a system check.

The manual/rotary adapter plate has a series of bolt hole patterns to allow the plate to be bolted to a variety of rotary tables. Figure 20 illustrates the bolt hole patterns appropriate for some common CMMs. Provisions for attaching the chuck adapter disk is also included in this system. A hole is located in the center of the adapter plate which can be used as a pivot point for manually rotating the ITA.

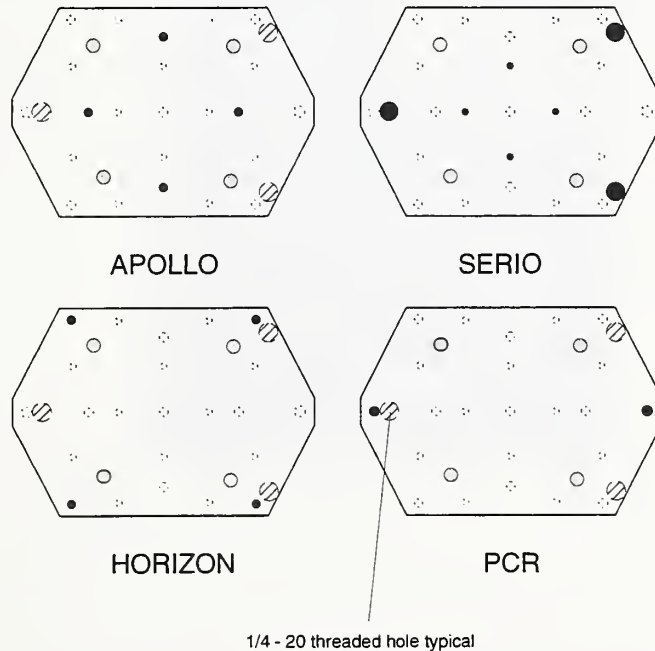


Figure 20. Bolt hole patterns of manual/rotary adapter plate

4 MANUAL/ROTARY SYSTEM

The list below contains the various components that arrive with the manual/rotary ITA.

4.1 COMPONENTS OF SYSTEM

Quantity

- 1 manual/rotary adapter plate and case
- 1 * ball bar support structure consisting of columns, support arm and case. (Arm length should match ball bar length.) **NOTE:** The arm is bolted to one set of columns for an inclined position, or bolted to a different set for a horizontal position.
- 1 * ball bar (calibrated or uncalibrated)
(available sizes 300 mm, 500 mm, 700 mm, 900 mm, 1200 mm, and 1500 mm)
- 1 chuck adapter disk
- 1 temperature sensor mounting bolt

* Optional second ball bar support structure and ball bar are available.

4 MANUAL/ROTARY SYSTEM

4.2 ASSEMBLY OF THE ITA OF FOR MANUAL CMMS

For assembly of this version of the ITA, follow the instructions below. Refer to Figure 4 on page 6 as needed.

NOTE: Before assembly, inspect the kinematic ball bar mounts for contamination. Remove any debris.

Step 1. Remove the manual/rotary adapter plate from its case.

Step 2. Attach the ball bar support structure (refer to Figure 21):

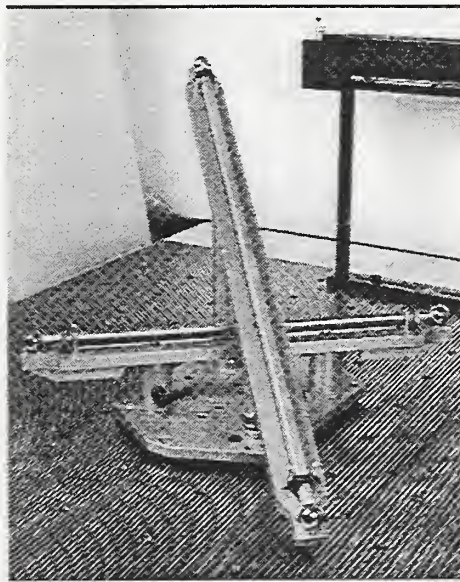


Figure 21. Manual ITA with ball bar support structure attached

4 MANUAL/ROTARY SYSTEM

- a. Remove the appropriate ball bar support structure (columns and arm) from its case. Check the kinematic ball bar mounts for debris.
- b. If a horizontal ball bar support structure is employed, slide the support structure over the column mounting pins which have black and white labels. It is possible to attach the horizontal support structure backwards. Therefore, be sure to match the corresponding color of the column label to the label adjacent to the column mounting pin. (See **Appendix D** on page 62 for assembling column to support arm if necessary). Engage the ratchet levers and secure the structure as described in Step 2c.

If the inclined ball bar is used, slide the support structure column over the column mounting pins which have red and blue labels. It is possible to attach the inclined support structure backwards. Therefore, be sure to match the corresponding color of the column label to the label adjacent to the column mounting pin. Engage the ratchet levers and secure the structure.

If both ball bars are used, first attach the horizontal support structure and then the inclined support structure.

- c. Procedure for securing the support structure to the adapter plate: Secure each column by tightening the ratchet one-half turn clockwise until it is tight against the column mounting pin. To adjust the position of the ratchet lever, see **Appendix E** on page 63.

The ball bar support structure should now be secured to the adapter plate and the assembly positioned on top of the table.

NOTE: If the columns do not easily slide over the column mounting pins, the ratchet levers may need to be adjusted (see **Appendix E** on page 63) or the columns may need to be readjusted on the support arms (see **Appendix D** on page 62).

4 MANUAL/ROTARY SYSTEM

THE TEMPERATURE SENSOR MOUNTING BOLT (Optional)

Step 3. If your CMM has part temperature compensation, attach the temperature sensor to the temperature sensor mounting bolt.

The purpose of the temperature sensor mounting bolt is to provide a large, flat, metal surface for magnetically mounted temperature sensors. The bolt is also designed to mount the temperature sensor in a thermal environment similar to that of the ball bars.

Located on top of the adapter plate is a ¼-20 threaded hole for mounting the temperature sensor mounting bolt (see Figure 20 on page 39).

4 MANUAL/ROTARY SYSTEM

INDEX POSITION NUMBERS

There are eight numbered labels around the edge of the adapter plate to clearly identify the specific position of the ITA. The ITA is defined to be in a specific index position when the number corresponding to that position is located on the front of the machine. Many users' programs will start in position 4, meaning the high inclined arm is facing the far left hand corner of the CMM, and the number '4' is located in the center position of the adapter plate. It may be useful to refer to these index position numbers when using or writing a computer program.

4 MANUAL/ROTARY SYSTEM

USING THE ITA ON A MANUAL CMM

If the CMM has a threaded insert near the center of the table, a hole is provided in the middle of the manual/rotary adapter plate to allow a bolt to be inserted through it. Insert a bolt and engage it into the threaded insert, to serve as a pivot point during the manual rotations.

Before using the manual system check for debris under the three feet of the manual/rotary adapter plate. This will assure the unit is stable on the CMM table. Manually rotate the ITA to positions on the table, as shown in Figure 22.

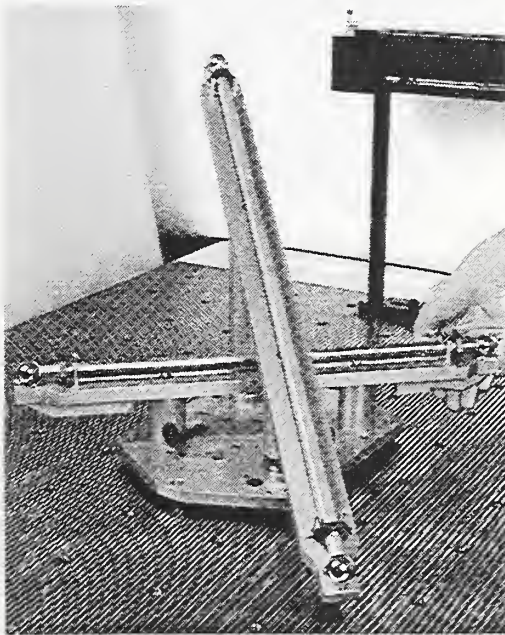


Figure 22. Rotating the manual/rotary system

4 MANUAL/ROTARY SYSTEM

4.3 ASSEMBLY OF THE ITA FOR ROTARY TABLE CMMS

Step 1. Remove the manual/rotary adapter plate from its case.

Step 2. Attach the plate to the rotary table:

Bolt the plate to the threaded inserts or T-slots on the rotary table using at least two clamping points. See Figure 20 on page 39.

Alternative for CMMs with rotary tables having a chuck adapter disk: Bolt the chuck adapter disk to the bottom of the adapter plate using two M6 bolts and clamp it in the chuck of the rotary table (Figure 23).

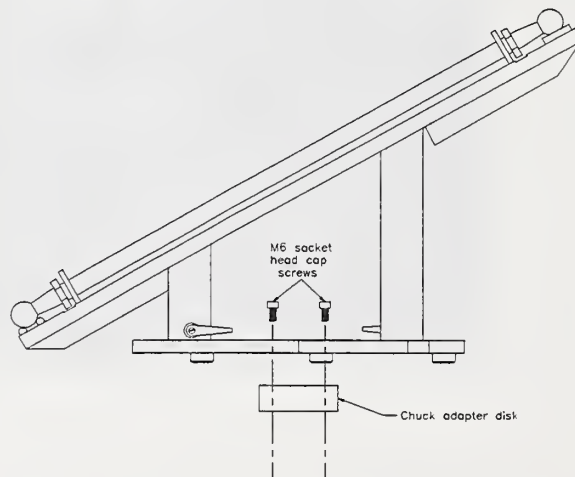


Figure 23 Attaching the chuck adapter disk to the rotary table adapter

4 MANUAL/ROTARY SYSTEM

- Step 3. Attach the ball bar support structure and ball bar (see Figure 24):

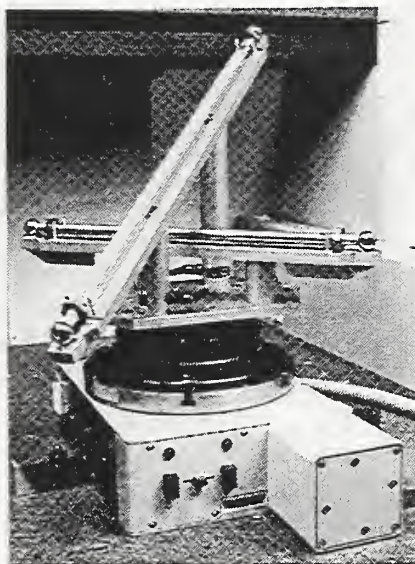


Figure 24. Manual/Rotary system and rotary table

- a. Remove the appropriate ball bar support structure (columns and arm) from its case. Check the kinematic ball bar mounts for debris.
- b. If a horizontal ball bar support structure is employed, slide the support structure over the column mounting pins which **DO NOT** have labels. Engage the ratchet levers and secure the structure as described in Step 2c.

If the inclined ball bar is used, slide the support structure column over the column mounting pins which have red and blue labels. It is possible to attach the inclined support structure backwards. Therefore, be sure to match the corresponding color of the column label to the label adjacent to the column mounting pin. Engage the ratchet levers and secure the structure.

If both ball bars are used, first attach the horizontal support structure and then the inclined support structure.

4 MANUAL/ROTARY SYSTEM

- c. Procedure for securing the support structure to the adapter plate: Secure each column by tightening the ratchet one-half turn clockwise until it is tight against the column mounting pin.

To adjust the position of the ratchet lever, see **Appendix E** on page 63. The ball bar support structure should now be secured to the adapter plate and the assembly positioned on top of the table.

NOTE: If the columns do not easily slide over the column mounting pins, the ratchet levers may need to be adjusted (see **Appendix E** on page 63) or the columns may need to be readjusted on the support arms (see **Appendix D** on page 62).

4 MANUAL/ROTARY SYSTEM

THE TEMPERATURE SENSOR MOUNTING BOLT (Optional)

Step 4. If your CMM has part temperature compensation, attach the temperature sensor to the temperature sensor mounting bolt.

The purpose of the temperature sensor mounting bolt is to provide a large, flat, metal surface for magnetically mounted temperature sensors. The bolt is also designed to mount the temperature sensor in a thermal environment similar to that of the ball bars.

Located on top of the adapter plate is a ¼-20 threaded hole for attaching the temperature sensor bolt (see Figure 20 on page 39).

4 MANUAL/ROTARY SYSTEM

USING THE ITA ON ROTARY TABLE CMMS

Before using the rotary table system, check to make sure the adapter plate is securely attached to the rotary table. Check the CMM table to make sure that it is free of obstacles which could interfere with the ITA rotation.

4 MANUAL/ROTARY SYSTEM

4.4 CHECKLIST FOR MANUAL/ROTARY SYSTEM

1. Position (and attach if necessary) the manual/rotary adapter plate on the CMM table.
2. Check and clean the kinematic ball bar mounts on the support arm.
3. Attach and secure the support arm structure.
4. Check the ball bars, and place them onto the kinematic ball bar mounts.
5. Run the CMM interim testing program.
6. Examine results. If the machine fails the test, check to make sure that the ITA is in good working order. (See **Troubleshooting** beginning on page 52). If the machine fails a second time, the CMM may need repair or re-calibration.
7. Return the ITA to the storage case.

5 TROUBLESHOOTING

Several problems that users may encounter are listed in the table below:

TROUBLESHOOTING TABLE		
PROBLEM	REASON	CORRECTION
<p>The base unit does not screw down securely to the CMM table.</p>	<p>a. The pusher plate is not engaging the threaded stud adapters properly. Hence, the stud adapter will not screw into the table insert. See Appendix F on page 64.</p> <p>b. The stud adapter is the wrong thread.</p> <p>c. Debris is under the ITA.</p> <p>d. The CMM table threaded insert is damaged or dirty.</p>	<p>a. Apply light, downward pressure on the pusher plate. Turn it until the pins on the bottom of the piston engage into the holes on the screw-down plate. This allows the threaded stud adapter to be turned. See Appendix F on page 64.</p> <p>b. Use the correct stud adapter for each individual CMM table. Check to determine the actual threads of the insert on the CMM table and select the correct one.</p> <p>c. Remove debris, and check to be sure the base is fully positioned on the CMM.</p> <p>d. Repair or clean the threaded insert, or select a different one.</p>
<p>The mounting plate ascending or descending rates do not change when valves are adjusted.</p>	<p>a. The set screw on the valve adjustment knob is not fully engaged.</p>	<p>a. Using an M2 hex key wrench, tighten the set screw on the valve adjustment knob.</p>

5 TROUBLESHOOTING

TROUBLESHOOTING TABLE

PROBLEM	REASON	CORRECTION
<p>The mounting plate will not rise.</p>	<ul style="list-style-type: none"> a. The system is not screwed down to the table. b. The inlet valve is not open far enough or the outlet valve is open too far. c. The air pressure is too low. d. When using the pan head screw instead of the threaded stud adapter, the pan head screw is not tight. e. The ball bar support structure is improperly mounted. f. The cylinder O-ring or piston O-ring may be broken. 	<ul style="list-style-type: none"> a. Be sure the base is tightly screwed to the table with the threaded insert. b. Adjust valve settings, see the box "Adjusting the Pneumatic System" on page 34. c. Check to make sure the air pressure exceeds 124 kpa (20 psi). d. Tighten the pan head screw, refer to Figure 6 on page 11. e. Make sure the inclined ball bar is properly mounted. Check to be sure the labels are correctly matched. f. Replace the damaged part. (Under normal circumstances, these O-rings do not need maintenance and do not need to be replaced.) See Appendix F on page 64.
<p>The mounting plate descends too quickly.</p>	<ul style="list-style-type: none"> a. The outlet valve is open too far. b. The system is not screwed down to the table. c. When using the pan head screw instead of the threaded stud adapter, the pan head screw is not tight. d. The cylinder O-ring or piston O-ring may be broken. 	<ul style="list-style-type: none"> a. Close the outlet valve more. b. Be sure the base is tightly screwed to the table with the threaded insert. c. Tighten the Pin head screw, refer to Figure 6 on page 11. d. Replace the damaged part. (Under normal circumstances, these O-rings do not need maintenance and do not need to be replaced.)

5 TROUBLESHOOTING

TROUBLESHOOTING TABLE		
PROBLEM	REASON	CORRECTION
<p>The columns do not easily slide on to the column mounting pins.</p>	<ul style="list-style-type: none"> a. The assembly is improperly held during mounting. b. The ratchet levers are screwed too far in, preventing the column from seating. c. The ball bar support structure is not adjusted for this mounting plate. d. Debris or burrs are present in the columns or on the column mounting pins. 	<ul style="list-style-type: none"> a. The assembly must be held straight while it is lowered onto the column mounting pins. b. Unscrew the ratchet levers, seat the columns, and re-tighten the ratchet levers. See Appendix E on page 63. c. Re-adjust the ball bar support structure by using the procedure in Appendix D on page 62 d. Check, clean and deburr as needed.
<p>The CMM fails the interim test, and the results are not repeatable. (If the results are repeatable, the CMM itself is out of tolerance.)</p>	<ul style="list-style-type: none"> a. The ball bar is rocking and is unstable in the kinematic ball bar mounts because the magnet area is collecting debris. b. The mounting plate is not seating properly in the indexing seats. c. The ITA base is not firmly secured to the CMM table. d. The support structure is not securely attached to the column mounting pins. 	<ul style="list-style-type: none"> a. Clean the kinematic ball bar mounts with methyl or ethyl alcohol. Check to be sure that the balls do not touch the magnets. b. Check to make sure the balls on the bottom of the mounting plate and the indexing seats are clean. Make sure the pusher plate is disengaged from the mounting plate when the mounting plate is in the indexing seats. c. Securely attach the base to the table. d. Make sure the ball bar support structure is firmly fastened to the mounting plate.

5 TROUBLESHOOTING

TROUBLESHOOTING TABLE		
PROBLEM	REASON	CORRECTION
<p>Measured ball roundness and diameters are outside of specifications for inclined ball bar.</p>	<p>a. Probing forces are too large causing bending of the inclined ball-bar support structure.</p> <p>b. Ratchet arms are not fully engage allowing the support structure to rock.</p> <p>c. The ball bar is rocking and is unstable in the kinematic ball bar mounts because the magnet area is collecting debris.</p>	<p>a. Reduce the CMM probing force to less than 100 grams. For high accuracy CMMs, probing forces should not exceed 10 grams.</p> <p>b. Remove the inclined ball bar and fully engage the ratchet arms (see Appendix E on page 63).</p> <p>c. Clean the kinematic ball bar mounts with methyl or ethyl alcohol. Check to be sure that the balls do not touch the magnets.</p>

6 APPENDIX

APPENDIX A

CLAMPING METHODS

If your CMM table does not have threaded inserts or T-slots, you will need to find an alternative way to clamp the ITA to the table. If you do not bolt the ITA base to the CMM table using the threaded insert, insert the pan head screw to seal the cylinder, as shown in Figure 6 on page 11. The ledge near the bottom of the ITA base can serve as a clamping point. Treat the ITA as you would treat a part and attach similarly.

In order to take full advantage of the "no-datum" feature, find a way to repeatedly secure the ITA to the same place on the CMM table. one suggestion would be to place unobtrusive markings on the CMM table that can be aligned with the alignment marks on the ITA base.

6 APPENDIX

APPENDIX B

ELECTRONIC INTERFACE BOX

The electronics interface box is designed to allow computer operation of the automatic pneumatic indexing system. This appendix provides the complete instructions for connecting this interface box to a personal computer or an alternative voltage source.

Provided are two computer interface connectors, 9 pin D-sub and BNC. These connectors are located on the side of the box labeled COMPUTER INDEXING. To use the automatic indexing feature, connect one end of a standard serial interface cable, either 9 or 25 pin, to an available RS-232 communications port at the rear of your personal computer (refer to Figure 25 for proper pin connections). Attach the opposite end of the interface cable to the 9 pin D-sub connector on the side of the electronic interface box.

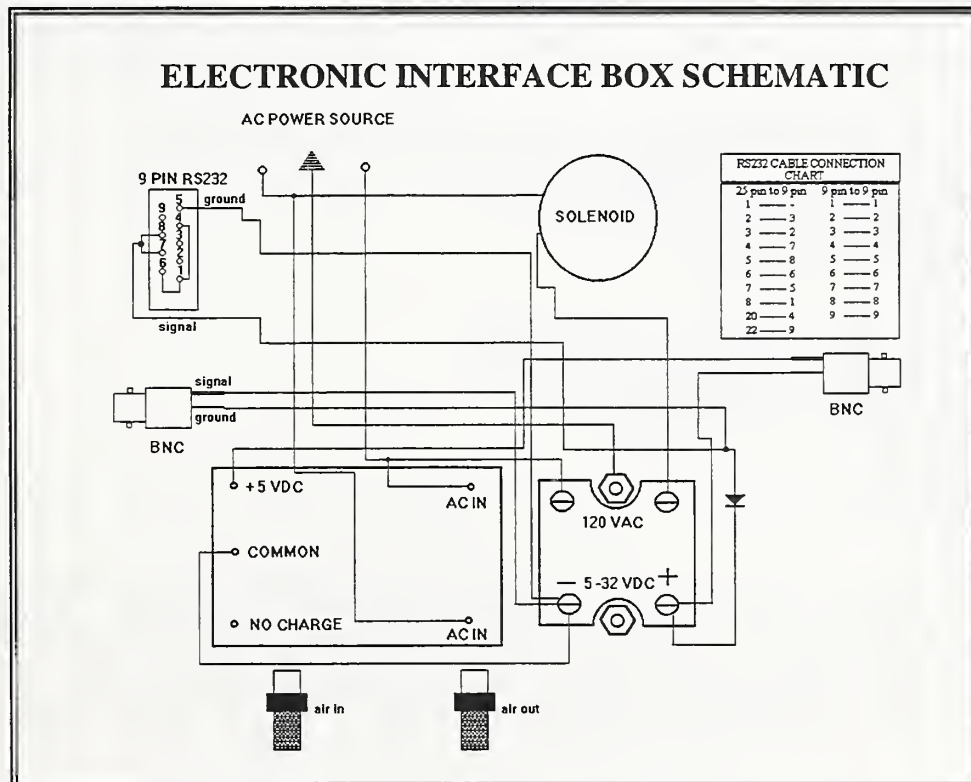


Figure 25. Electronic interface box schematic and RS-232 interface cable standard

6 APPENDIX

NOTE: Before proceeding further, make sure all connections described in step 4 of the automatic pneumatic indexing section on page 27 of this manual have been completed.

Once the electronic interface box is physically connected to both the PC and the ITA, computer operation can begin. The air flow is activated when the solenoid receives a pulse through the RS232 interface cable. To index the ITA, a subroutine should be written to open the communications port for 4-5 seconds. This should be sufficient time to allow the mounting plate to completely rise above the base assembly. To ensure proper seating of the mounting plate, the communications port should be closed for a minimum of 12 seconds before returning to the ball bar inspection routine. Additionally, this **valve must remain closed during all measurements subsequent to indexing.**

The logic from the following routine can be employed to create subroutines within your part inspection program. Further, this program can be used to ensure the electronic interface box is functioning properly. (This program is written in Basic and can be run directly with any Qbasic interpreter supplied with MS-DOS version 5.0 or greater). If an audible click is heard each time this routine is executed, the box is performing correctly.

```
Rem QBASIC ROUTINE TO TEST COMMUNICATION LINK
Rem open communications port #2 to activate air flow
OPEN "COM2" FOR OUTPUT AS #1
Rem recording start time
TIMEZERO = TIMER
DO
DELTATIME = TIMER - TIMEZERO
Rem keep air on for 5 seconds
LOOP WHILE DELTATIME < 5
Rem Turn off air flow
CLOSE #1
Rem recommended mounting plate seating time (12 seconds)
SLEEP 12
```

Alternatively, the ITA can be indexed using the BNC connector and a D to A board. To index the ITA using this method, attach a standard BNC cable to the BNC connector located on the side of the electronic interface box. Attach the opposite end of the cable to the D to A port located at the rear of your computer.

The solenoid is activated by supplying between 5 and 32 volts DC to the BNC connector. (Refer to figure 25 on page 57 for the

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appropriate polarity). If this method is used, your ball bar inspection program should include a subroutine which opens and closes the solenoid valve. The valve should be opened for 5 seconds to allow the mounting plate to completely rise above the base unit. To allow sufficient time for the mounting plate to properly seat in the kinematics, the solenoid valve should be closed for a minimum of 12 seconds before returning to the ball-bar inspection routine. Additionally, this **valve must remain closed during all measurements subsequent to indexing.**

It is important to note, any 5-32 volt DC source applied across either the RS232 or BNC connectors may be used to index the ITA. However, DC sources which operate independently of the measurement routine require careful coordination of ball-bar inspection and indexing routines to avoid unexpected ITA and CMM collisions. Subsequently, **voltage sources such as function generators are not recommended** unless the inspection routine is actively monitored to avoid unexpected collisions.

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APPENDIX C

SHORTENING THE AIR HOSE ASSEMBLY

To shorten the swagelok end of the air hose (that will be attached to the ITA base unit):

Refer to Figure 26 on page 61, for clarification of parts and procedure.

1. Check to be sure there is no air pressure in the line.
2. Unscrew the tightening nut from the quick-connect adapter. Pull the hose off the quick-connect adapter.
3. Cut the hose to the desired length close to the tightening nut. (The tightening nut stays on the hose.)
4. Slide the tightening nut, then the new back ferrule, and finally the new front ferrule onto the end of the hose (refer to Figure 26 on page 61 for the correct alignment). Insert the hose end into the open end of the quick-connect adapter. Push in on the hose end until it stops.
5. Slide all three pieces (tightening nut, front ferrule and back ferrule) down the hose until the tightening nut can be screwed onto the quick-connect adapter.
6. With a wrench, tighten the nut one and one-quarter turns farther. You are now connected with a shortened air hose.

NOTE: By tightening the connection one and one-quarter turns, you are assured that all the pieces are firmly sealed.

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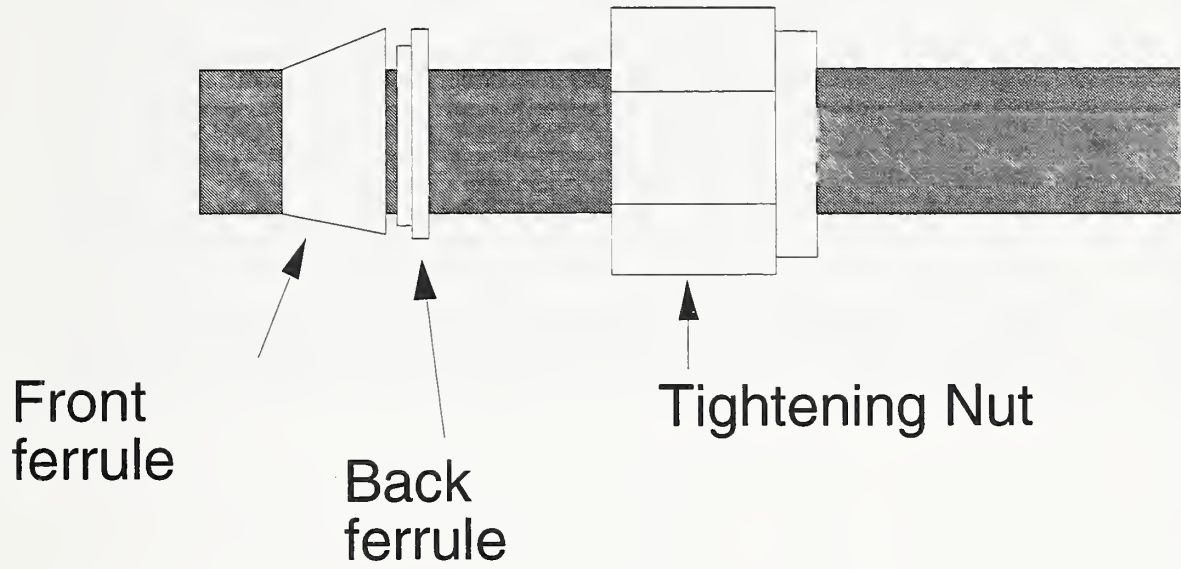


Figure 26. Air hose assembly parts

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APPENDIX D

BOLTING THE SUPPORT ARMS TO THE COLUMNS

To initially attach the support arm to the columns, tighten the four bolts (two M10's and two M5's), but leave them partially loose. Make sure the blue and red labels situated toward the top of each column corresponds with the same color label near the kinematic mounts of each support arm. Slide the columns over the mounting pins so that the labels located near the bottom of each column match the labels adjacent to each of the mounting pins. Attach the ratchet levers and secure. Further tighten the four bolts in the support arm in a rotating sequence, securing the support arm structure of the column mounting pins. Check to make sure the ball bar support structure easily slides off the column mounting pins. Once the columns are correctly attached to the arm, the assembly can be stored in the storage case for future use.

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APPENDIX E

ADJUSTING THE RATCHET LEVERS

The ITA is designed for the columns to be fully engaged to the column mounting pins by rotating the ratchet levers one-half turn clockwise. The levers should be parallel to the mounting plate when fully engaged or disengaged, as shown in Figures 27 and 28. When the levers are rotated one-half turn counterclockwise, the column will be completely disengaged, as shown in Figure 28.

To adjust the position of the ratchet lever without turning the position of the screw, pull out on the spring-loaded ratchet lever head, as shown in Figure 29.

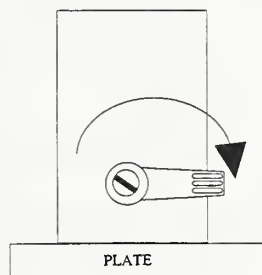


Figure 27. Engaged ratchet lever

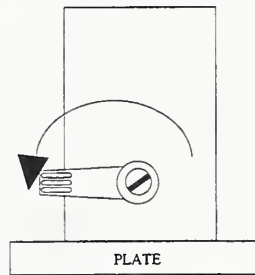


Figure 28. Disengaged ratchet lever

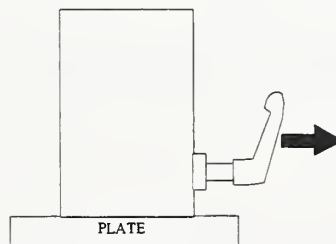


Figure 29. Ratchet lever with head pulled out

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APPENDIX F

MANUAL PNEUMATIC INDEXING SYSTEM SCHEMATIC

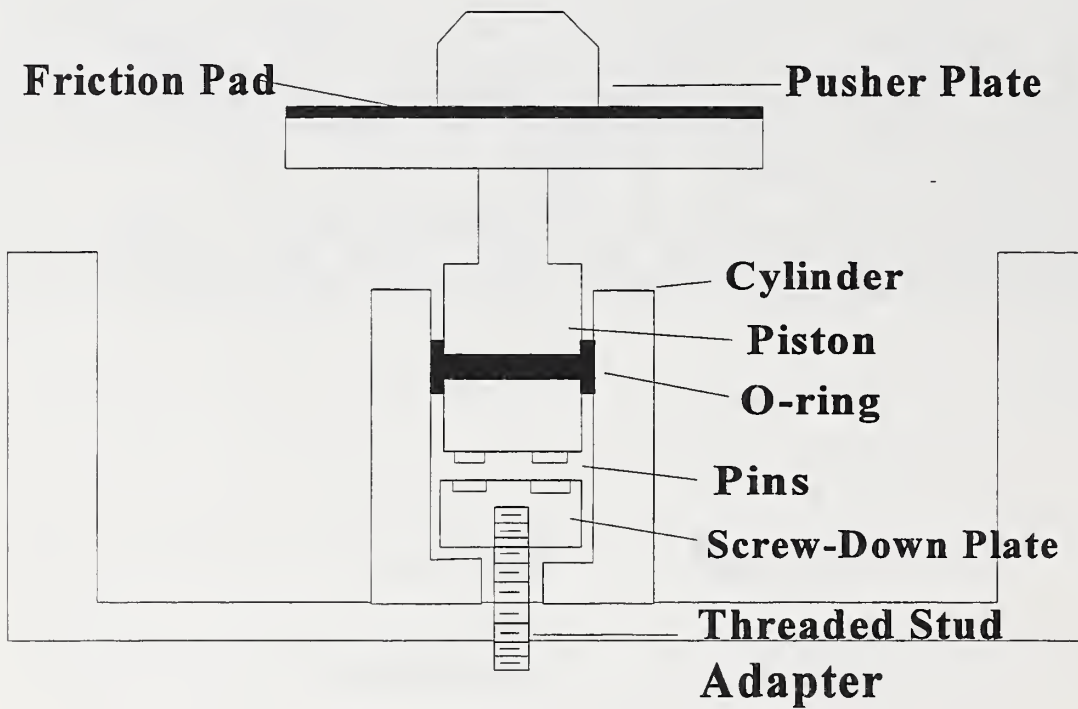


Figure 30. Manual pneumatic indexing system schematic

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APPENDIX G

PROGRAMMING CONSIDERATIONS

Setting up the ITA Coordinate System:

One of the advantages of the ITA is the ability to run an interim test without any manual referencing (manually taking points to establish a part coordinate system). This is possible if the CMM is capable of storing an absolute reference frame (defined coordinate system) which can be established once and retrieved whenever the ITA test is run. In this case, there is a one-time procedure to establish the reference frame which will be valid until a power outage, memory failure, or clearing of reference frames eliminates the stored frame. Note that it does not matter exactly what frame, i.e. coordinate system, is established, as long as the ITA parameters stored in the program are taken in that frame.

The recommended reference frame is parallel to the top surface of the ITA mounting plate. It has X and Y zero at the center of the mounting plate and Z zero on the top of the mounting plate. The Z axis is taken perpendicular to the plane of the mounting plate. (see figure 31) The frame can be established by three touches around the edge of the mounting plate to find the center, and three touches on the top of the mounting plate to establish the plane. It is not necessary to take any more than three or four touches, as the accuracy required is only about 1 mm (0.040 inches). This origin and Z axis direction can be stored for all future ITA testing procedures, and need not be remeasured unless the ITA is located at a different location in the CMM work zone.

The final information to establish a complete reference frame is establishing the X and Y axis orientation for the ITA coordinate system. Since the mounting procedure of the ITA recommends that the inclined arm be oriented in its initial position by eye, it is necessary to take touches to establish the X axis. Often this is done with two touches on the side of the inclined support arm. After projecting this line into the XY plane, it can be defined as the ITA X axis. (see figure 32) **Note that this final alignment, unlike setting the origin of the reference frame, should be done whenever the ITA is remounted.** Once this procedure is completed, the ITA coordinate system is fully established. If the ITA is removed and reset for future runs, only the final two touches are needed to establish the X axis of the ITA system. Commonly these final touches are part of the ITA

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program, which eliminates all manual operation. This procedure only needs to be done each time the ITA is remounted.

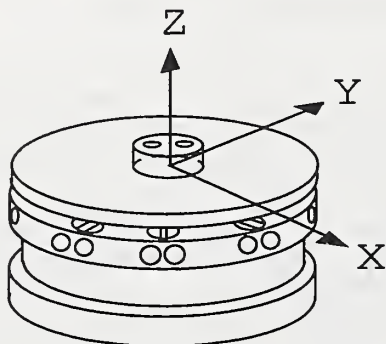


Figure 31. ITA coordinate system established using the mounting plate

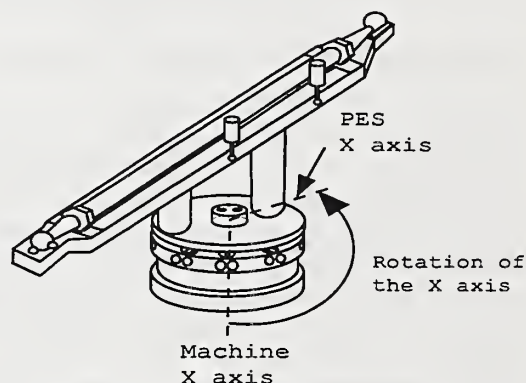


Figure 32. Setting the ITA coordinate system X axis

Predicting the Locations of the Balls on the Ball Bar:

The computer program must be able to calculate the positions of the balls well enough for the CMM to locate them. How close this needs to be is governed by the probe approach distance and by the pattern of touches on the ball which is used in the program. The ball locations usually need to be predicted only within 2 or 3 mm of their actual locations in order to find them for the measurement. The limitations of the calculation for predicting ball location depend on how nearly the ITA acts as a perfect 45° indexing table. The ITA is designed and manufactured to tolerances which will keep variability due to this to about 1 mm (0.040 inches).

To do the calculations to predict the location of the balls, it is necessary to know the relative locations of each ball in the ITA coordinate system. Each ball position should be measured and the location stored in a file. Measure the X, Y and Z coordinates of all of the balls, and save the values. To predict the ball locations for the next index position of the ITA, mathematically rotate the ITA coordinate system around the Z axis by 45 or 90 degrees, depending on the next desired index position. Since the coordinate system is aligned with the ITA in the first index position, all the balls will be at the same coordinates in the rotated coordinate system that they were in the original (unrotated) system. Most CMM software can do this coordinate system rotation with one command. For each subsequent position, re-rotate the ITA part coordinate system until all

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desired positions have been measured. Hence the ball coordinates appear constant in all of the rotated coordinate systems.

Rotating the ITA coordinate system is the simplest method to predict the ball locations, since the balls remain mathematically fixed in the coordinate system. Alternatively, the coordinate system may remain fixed and the balls are rotated in this coordinate system. This method requires some trigonometry to predict the ball coordinates after rotation. This is a matter of programming preference; the choice does not affect the results.

Running the ITA on a regular basis :

As long as the support arm is not unbolted from the columns, the ball locations in the ITA coordinate system will be constant (to about 1 mm) for each support structure. There is 1.5 mm (0.060 inches) of clearance around the bolts holding the arm to the columns; disassembly and reassembly can change the ball coordinates by 3 or 4 mm, or even more for the longer arms. This can affect the ball position calculation enough to make the CMM unable to find the ball. The solution is to remeasure the ball coordinates whenever the arms are unbolted from the columns and rebolted together. Because this remeasurement will usually require manual point taking to find the new ball coordinates, causing a slow procedure; the arms should remain bolted to the columns whenever possible..

After the first time the ITA is used and a ITA program written, future interim testing is much simpler. Place the ITA in the same threaded insert of the CMM table to physically locate the ITA unit at the same CMM location (within 1 mm). Take manually or, more commonly, automatically two touches on the arm of the inclined support structure to establish the ITA X axis. The ball positions as calculated should be within about a millimeter of the actual locations. This is sufficiently close to enable the CMM to find all of the balls. Note that the ITA coordinate system need only be accurate enough to locate the balls, which are then precisely measured using the CMM. As long as the CMM can find the balls, the ball bar measurement results are determined by the CMM's accuracy, and are not affected by small variations in the ITA position. The sphere center to center length should always be measured as a true three-dimensional point-to-point distance, since the ITA coordinate system is approximate and is only used for locating the balls.

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APPENDIX H

BALL BAR CONSIDERATIONS

The support arms are available in lengths of 300, 500, 700, 900, 1200 and 1500 mm. Any ball bar within about 1 millimeter of these values can be used. Magnets are used to hold the ball bars in place; a ball bar with non magnetic balls may not be securely held in the inclined position. Some calibrated ball bars are equipped with hexagonal collars to prevent them from rolling off of a flat surface. These collars are designed to work with the capture pins of the support arms as a safety feature to keep the ball bar from falling off of the ITA in the event of a collision.

If a calibrated ball bar is used, it is necessary to keep track of the locations of the balls so that their calibrated diameters can be compared with the CMM measured values. A ITA computer program is expecting specific values for each ball diameter at each ITA position. If the ball bar is reversed, ball 2 will be in the expected ball 1 location. (Since the diameters of the two balls of the ball bar are within $0.25 \mu\text{m}$, this is only a serious problem for high accuracy CMMs.) To unambiguously determine the ball bar location, there are "Ball 1" and "Ball 2" labels on the calibrated ball bars. There are corresponding labels on the support arms to show which way to mount the ball bar.

Similarly, the ball bar support structure (arms and columns) must be mounted in the correct orientation on the mounting plate. The black and white labels are necessary to assure that the horizontal ball bar is mounted consistently. The two ends of the support arm are not symmetric, and mounting it the wrong way will put the balls 3 mm (0.120 inches) away from the position saved in the ITA program. Consequently, the CMM may be unable to find the balls. Always mount the columns to the corresponding color coded labels on the mounting plate.

Uncalibrated ball bars, for example a screw-together system, will work with the ITA. However, in this case there is less information available to evaluate the CMM's accuracy. There are classes of errors which cannot be detected with an uncalibrated ball bar, including probe calibration errors, temperature sensor miscalibration, and CMM scale errors (if consistent between axes). Some screwed-together ball bars may change length by more than $50 \mu\text{m}$ (0.002 inches), even under normal handling. Hence, the long term stability of this type of ball bar is questionable.

