Fermi National Accelerator Laboratory

TM-1627

Proposed Method of Assembly for the BCD Silicon Strip Vertex Detector Modules

Carl Lindenmeyer
Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

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Carl Lindenmeyer
Research Division
Mechanical Department

1.0 INTRODUCTION

The BCD Silicon Strip Vertex Detector is constructed of 10 identical central region modules (Fig. 1) and 18 similar forward region modules. This memo describes a method of assembling these modules from individual silicon wafers. Each wafer is fitted with associated front end electronics and cables and has been tested to insure that only good wafers reach the final assembly stage.

The technique of cementing the wafers together is to be covered in a separate memo and is not detailed here.

The proposed method of assembly employs a servo driven Coordinate Measuring Machine (C.M.M.) as both an inspection device and a manipulator to position each wafer in the assembly. Key problems the assembly system must address are:

1. Precision:

   The final determination of allowable errors has yet to be made, but even the most generous estimates require good design to be achievable. Every step must be accurate and repeatable with no accumulation of error from one step to the next. The proposed system will contribute very little to the error budget. The final determinant of accuracy will be the quality of the C.M.M. used.

2. Safety:

   Each wafer in the module could cost about $1,000 since the central region modules contain 42 wafers each. A moment of carelessness could be very expensive. The proposed assembly method depends as little as possible on the manual skill of the assembler.

3. Accessibility:

   During the assembly procedure, joint areas must be available for cementing. The fixturing used must not be so bulky that access to joints is difficult and therefore hazardous to the fragile silicon.

2.0 EQUIPMENT

2.1 Coordinate Measuring Machine (C.M.M.)

A servo driven C.M.M. is required both for inspection and also to pick up the inspected wafer and position it in the assembly. Two basic styles of machines are available, cantilever and bridge. The cantilever style offers an unobstructed work area and would be the most convenient to use; however, the accuracy of the machine suffers. The bridge style offers greater rigidity and accuracy, but access to the work area is restricted. The C.M.M. must be fitted with an optical system capable of measuring edges and fiducial locations on the wafer. Mounted near the optical system would be a vacuum pickup probe with a flat, accurately aligned pickup surface.

A few typical machines are shown in Figures 2A, 2B and 2C.

Cordax 1800 series, Fig. 2A:

This machine is similar to several already at Fermilab. It offers modest accuracy and price. The table access is superior.

Cost:

Basic System:	$87,500
Optical System:	6,500
	$94,000

Volumetric accuracy (400MM ball bar): .013MM

Ferranti Sciaky, Fig. 2B.

This machine is typical of the bridge style of construction. Access to the table is awkward, but the improved rigidity may be worth the inconvenience.

Cost:

Basic System: (High Accuracy)	$117,000
Optical System:	6,500
	$123,500

Volumetric accuracy (300MM ball bar): .005MM

Zeiss OMC 850, Fig. 2C

This is a high precision C.M.M. incorporating a standard optical system and a probe mount.

Cost: $250,000

Volumetric accuracy (400MM ball bar): .0032 MM

Many brands of C.M.M. are available. A careful evaluation will be needed at the time of purchase. Although the C.M.M. represents a large investment, it can be used for many years for many projects. It may be unwise to compromise performance to enable the entire cost to be amortized on one project.

2.2 Inspection Pedestal, Fig. 3

This device supports the wafer during inspection and presents it to the pickup vacuum probe for transfer to the assembly area. Interchangeable adapters with vacuum pads permit holding various wafer sizes. Fitted around the vacuum pad is a template to guide the operator in placing the wafer for inspection, the wafer need only be within about 1/16" and 3^{o} of the nominal location indicated by the template.

A tangent screw is provided to correct the angular orientation of the wafer using the fiducial marks as a reference.

Vertical travel of the spring loaded stem is used to provide a signal to transfer vacuum from the inspection pedestal to the vacuum carrier on the C.M.M.

If made carefully, the inspection pedestal should not contribute any measurable errors to the position of the wafer in the assembly.

Estimated Cost: $3000.00

2.3 Assembly Fixture - Figures 4 & 5 (Trunion mounted version shown)

The module is built up on this device which can present the correct face of the assembly at the proper orientation to the next wafer to be mounted. The wafer to be added to the assembly always approaches the module at right angles to the surface to which it is mounted. The wafer is held in place by the C.M.M. without touching the assembly, while the cementing takes place.

The assembly fixture consists of a precise indexing table mounted on trunions to permit changing the axis of rotation from vertical to horizontal. A central mandrel fitted with vacuum pads is mounted concentric with the axis of rotation (see Fig. 5). This mandrel carries the module as it is being built up and is the only part that contracts the silicon. Three posts are fitted to a concentric ring to position the module mounts on the completed silicon structure. These posts rotate (after releasing vacuum on the mandrel) to provide clearnace for ejecting the finished module, see Fig. 5. The posts lift in unison to remove the module from the fixture.

The index table is accurate to 1/8 arc sec., repeatable to 1/20 arc sec. (1/8 arc sec. = .00044 MM at O.D. of module). The pivot axis is preloaded and should repeat to less than 1 micron at the module. Perpendicularity and parallelism to the C.M.M. axes can be adjusted to within the accuracy of the C.M.M. The assembly fixture itself will not contribute any significant errors to the assembled module.

NOTE: The module once started cannot be removed from the fixture until fully completed. This will require some careful planning for the vacuum system.

Estimated Cost: $15,000.00

2.4 Miscellaneous

A few other special devices will be required such as C.M.M. modifications to accept the vacuum pick-up, two types of vacuum pick-ups, ancillary equipment such as vacuum, electrical interlocks, etc.

Estimated Cost: $15,000

2.5 Total Cost

Given the above estimates, the total assembly system package cost should be between $127,000 and $283,000 depending on the level of accuracy, the degree of automation and the sophistication of the software.

3.0 ASSEMBLY PROCEDURE (With Trunion Mounted Assembly Fixture)

3.1 Starting Conditions

3.1.1 Assembly Fixture

* Assembly fixture rotated to horizontal position.
* Mount positioning posts rotated to clockwise limit.
* Mount positioning posts retracted fully to spring loaded position.
* Index table rotated to bring #1 facet to top horizontal position.
* All vacuum valves on mandrel closed.

3.1.2 Inspection Pedestal

* Small vacuum pad with mylar template mounted.
* Tangent screw rotated to approximately center of adjustment.

3.1.3 C.M.M.

* Small spring loaded vacuum probe mounted.

3.2 Inner Barrel Assembly

* Place 1st wafer on inspection pedestal in approximate location as indicated by mylar template.
* Apply vacuum to clamp wafer in place.
* Using C.M.M. in manual mode, locate fiducial with optical system.
* Traverse C.M.M. in X direction to locate other fiducial, move in Y if required to locate, note Y displacement.
* Return C.M.M. in Y, half of previous amount.
* Rotate wafer with tangent screw to bring fiducial on screen.
* Traverse C.M.M. in X to 1st fiducial, note position.
* Repeat above steps until both fiducials are exactly aligned with X axis.
* Zero C.M.M. by returning to fixed C.M.M. fiducial.
* Measure location of fiducials on wafer.
* Enter servo controlled mode and traverse periphery of wafer to ensure compliance with tolerance range.
* Using sub-routine in C.M.M. control, move vacuum pickup probe to Z axis reference monument on table, zero vacuum probe pickup surface.
* Using sub-routine in C.M.M., place vacuum pickup probe on wafer, transfer vacuum from inspection pedestalto pickup.
* Using sub-routine in C.M.M., place wafer on assembly fixture mandrel.
* Open vacuum valve for appropriate mandrel vacuum pad.
* Remove vacuum from pickup probe and return to parking position.
* Index mandrel 60°.
* Repeat all above steps for remaining 5 inner barrel wafers, cementing wafers together when placed on mandrel.

3.3 Inner Discs

* Rotate assembly fixture to vertical position.
* Exchange small vacuum pad for large pad on inspection pedestal.
* Exchange small vacuum pickup on C.M.M. for large pick up.

* Place inner disc wafer template on inspection pedestal.
* Orient, inspect, and place on assembly all 6 inner disc wafers.

3.4 Remainder

Continue building module using same general procedures until all 42 pieces of silicon are mounted.

3.5 Module Mounts

Apply adhesive to module mounts and attach to mount positioning posts on assembly fixture. Allow sufficient time for bonding to be secure.

3.6 Removal

* Turn off vacuum to mandrel. Module is now supported by mount positioning posts.
* Rotate mount positioning posts 6 degrees counterclockwise.
* Raise posts 2-1/4", lifting module assembly clear of mandrel.
* Disconnect module mounts from posts. Perform any additional cementing required and place finished module in protective box.

4.0 ADDITIONAL COMMENTS

The system of assembly detailed herein will be capable of assembling B.C.D. silicon strip vertex detector modules with outstanding dimensional and geometric accuracy. Certain assumptions have been made which have a bearing on the use of this system:

1. All wafers have detector stripes on each side that are aligned with respect to each other to an acceptable tolerance. This system makes no provision for viewing the underside of a wafer being inspected.

2. The cable pigtails will be manageable and will not place substantial strain on the wafers.

3. The cementing system will not cause any motion as a result of surface tension or polymerization.

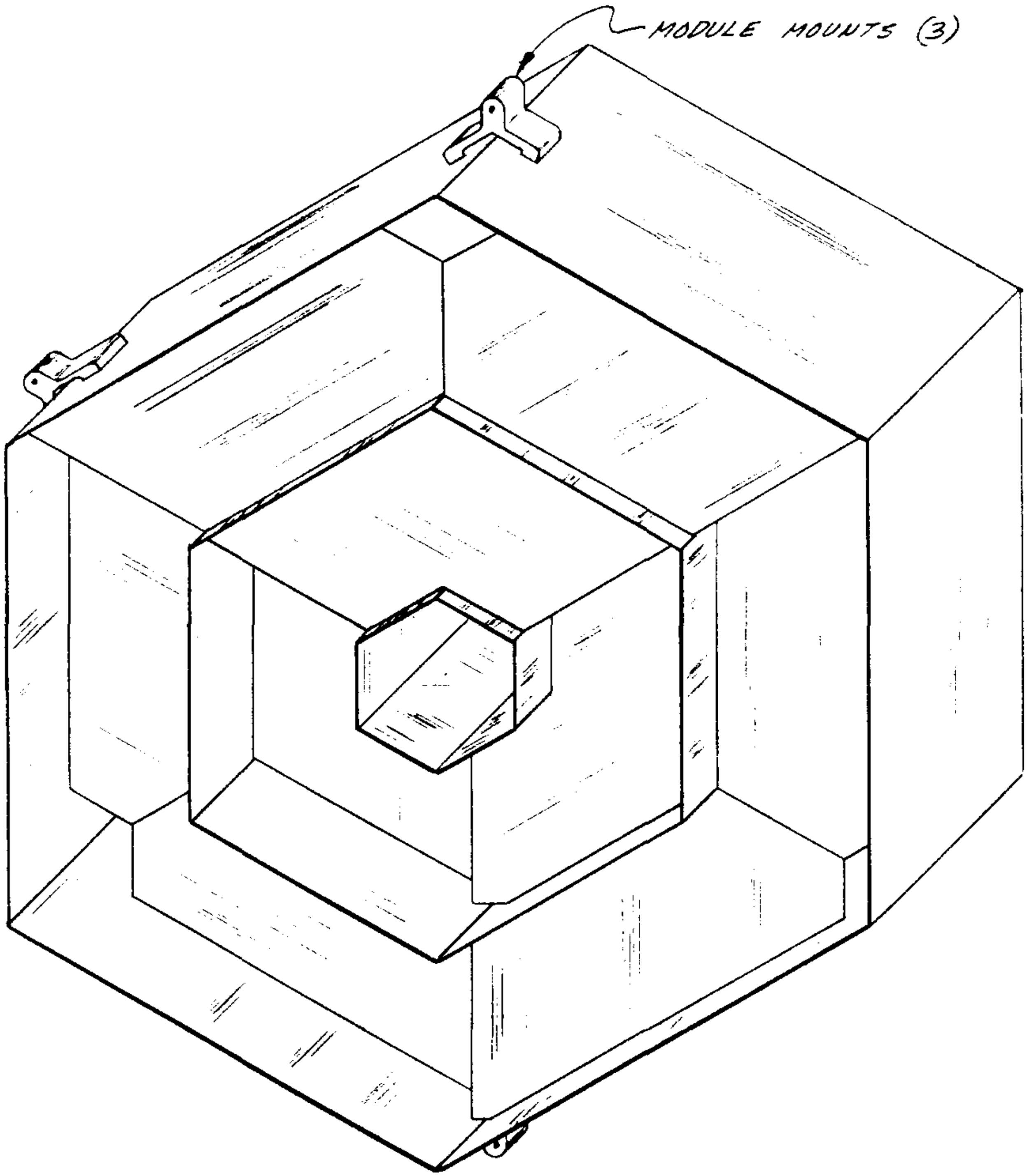
4. Contact (without sliding) of vacuum pads with the wafers will cause no damage. Vacuum pads must be sufficiently hard and rigid to permit precise machining (porous bronze?)

5. The assembly fixture does not permit access to several joints that could be cemented. The module must maintain its integrity after removal from the assembly fixture until these joints can be cemented from the rear side.

5.0 ALTERNATE VERSION

Another very similar approach is being considered in which the trunion mounted assembly fixture is replaced by a similar device with the index axis fixed in the vertical position. The vacuum pickup probe mounted on the C.M.M. Z axis would have a two position pivot mechanism to enable picking up wafers from the inspection pedestal in the horizontal position and rotating the wafer to a vertical position for addition to the assembly. The assembly sequence would be the same as detailed earlier, except instead of changing the assembly fixture orientation, the wafer orientation is changed.

This approach offers improved access to the assembly for cementing joints, but makes the pickup probe design very difficult.



CENTRAL REGION MODULE

Figure 1

Sheffield Measurement Division
Warner & Swasey/A Cross & Trecker Company

Cordax® 1800 Series
coordinate measuring machines

Cross & Trecker

Figure 2A

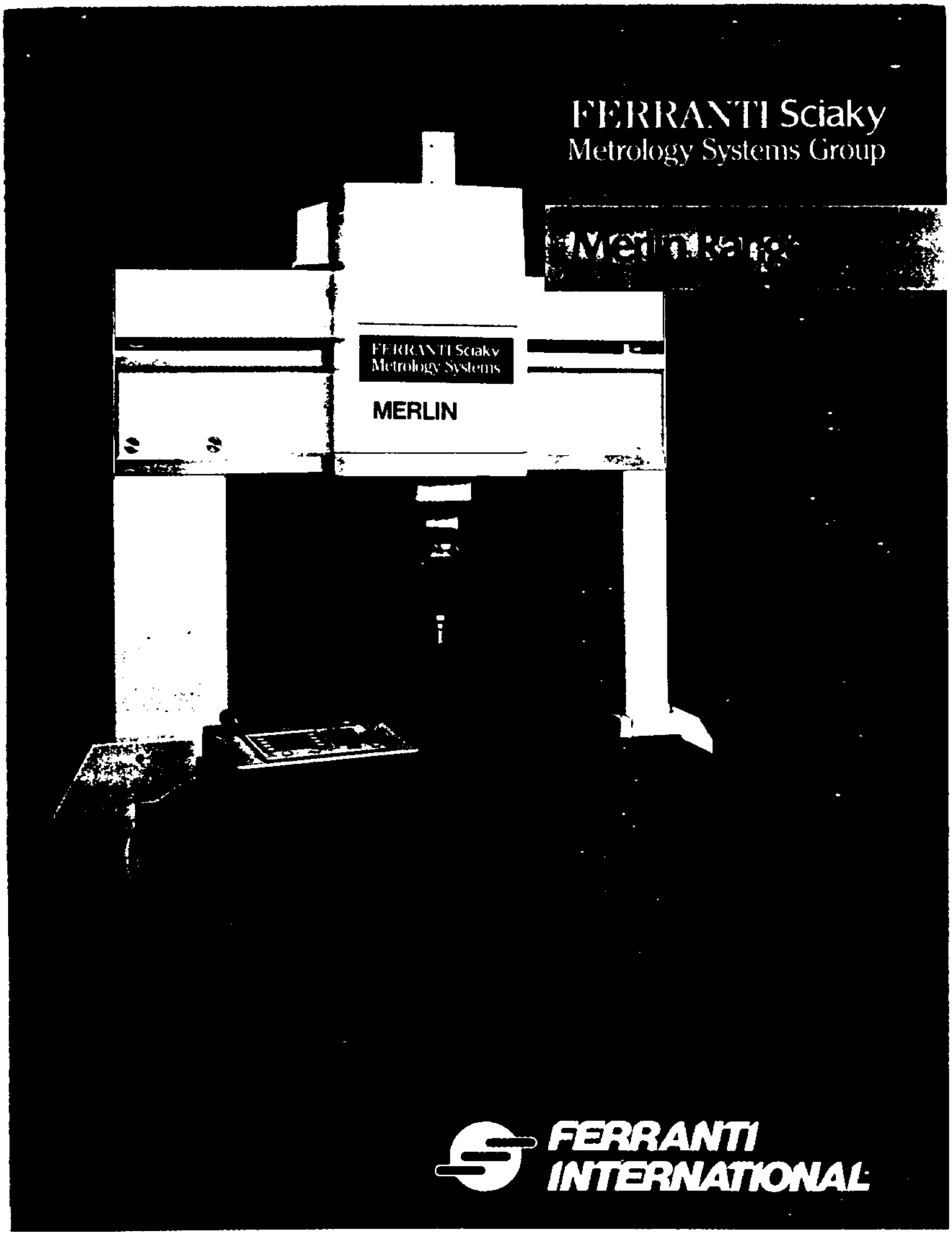

FERRANTI Sciaky
Metrology Systems Group
FERRANTI Sciaky
Metrology Systems
MERLIN
FERRANTI
INTERNATIONAL

Figure 2B

OMC 850

Opto-mechanical Measuring Center

ZEISS

West Germany

Product Information

Carl Zeiss
D-7082 Oberkochen

Geschaftsbereich
Industrielle Meßtechnik

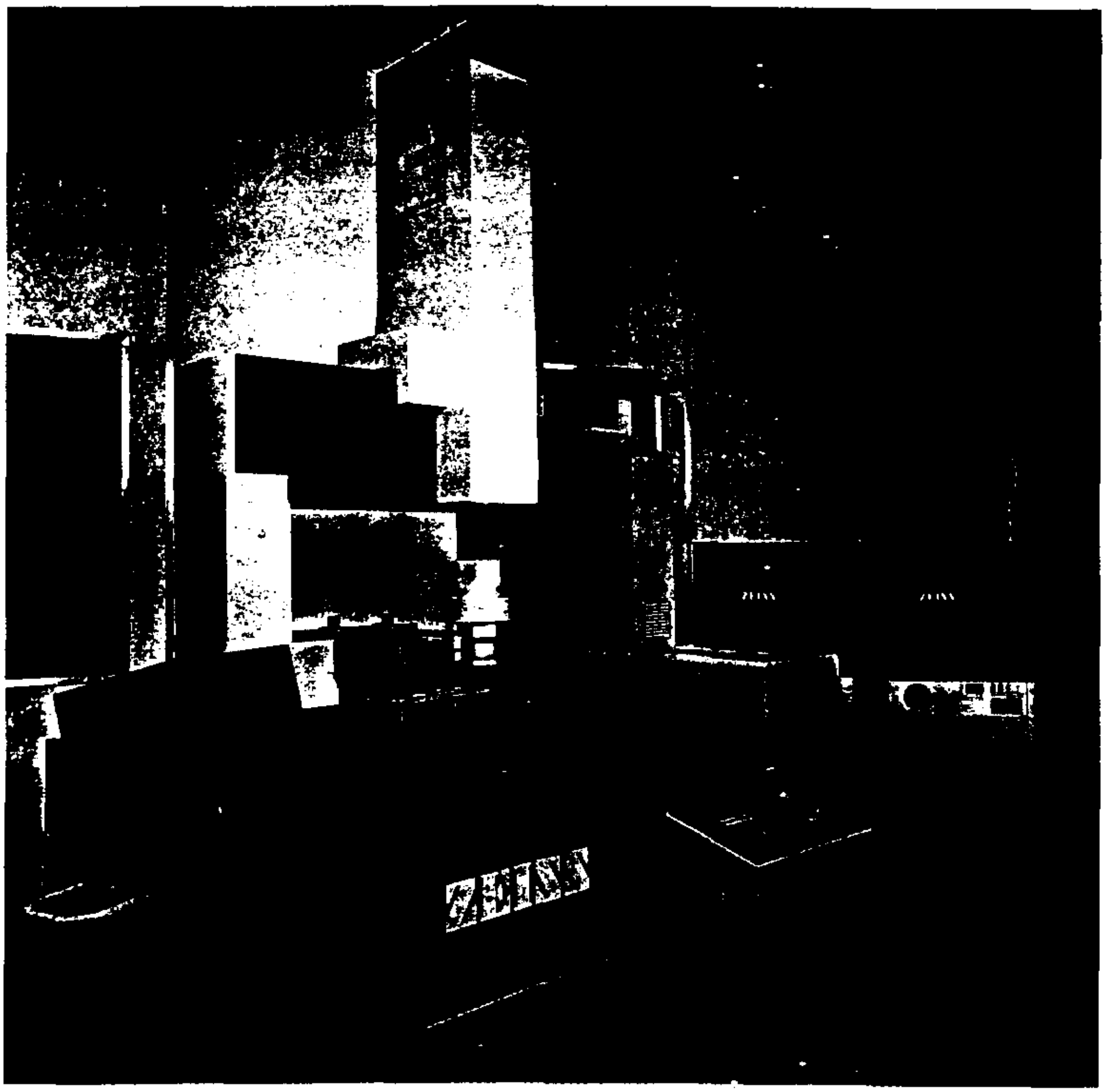
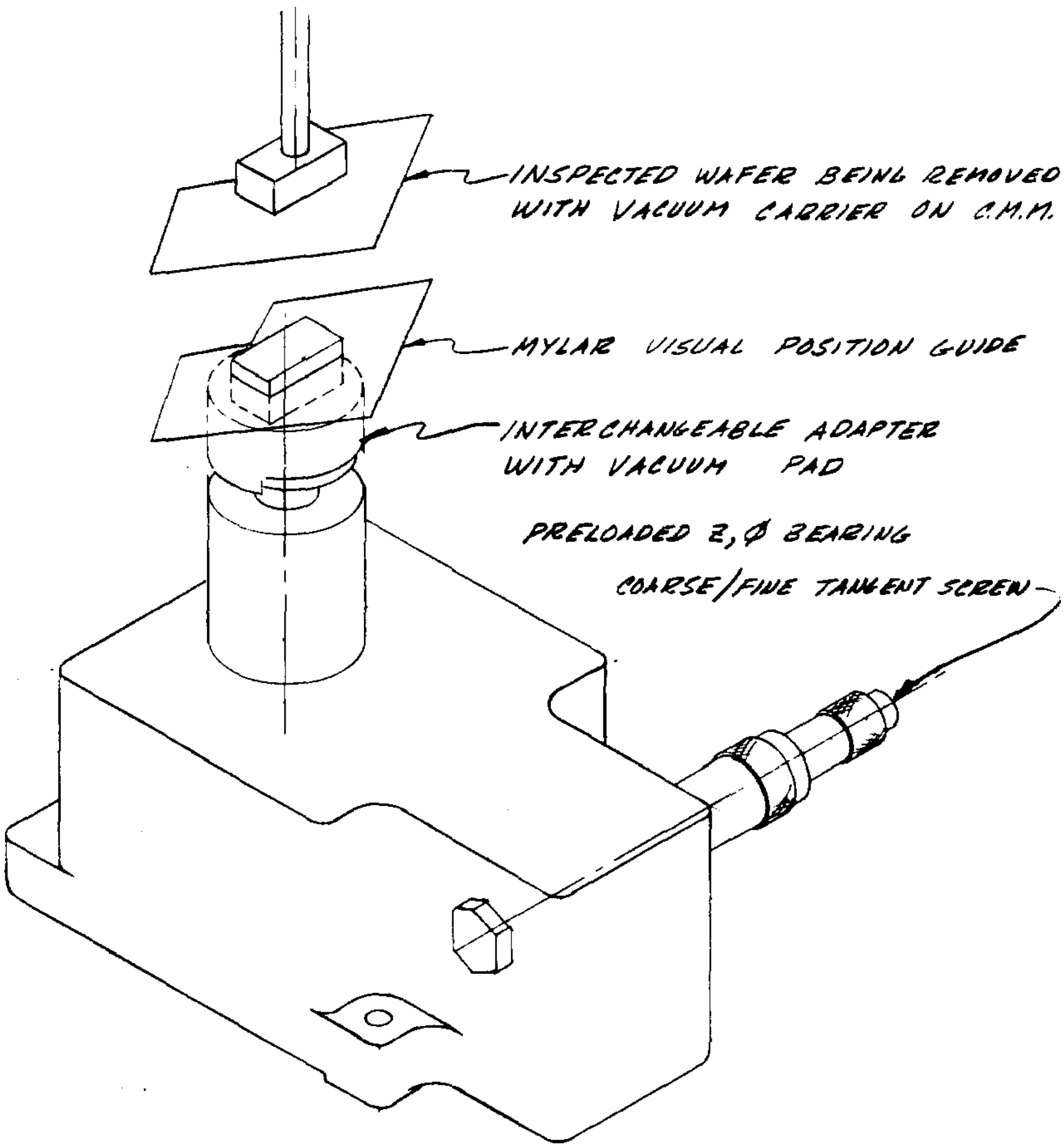
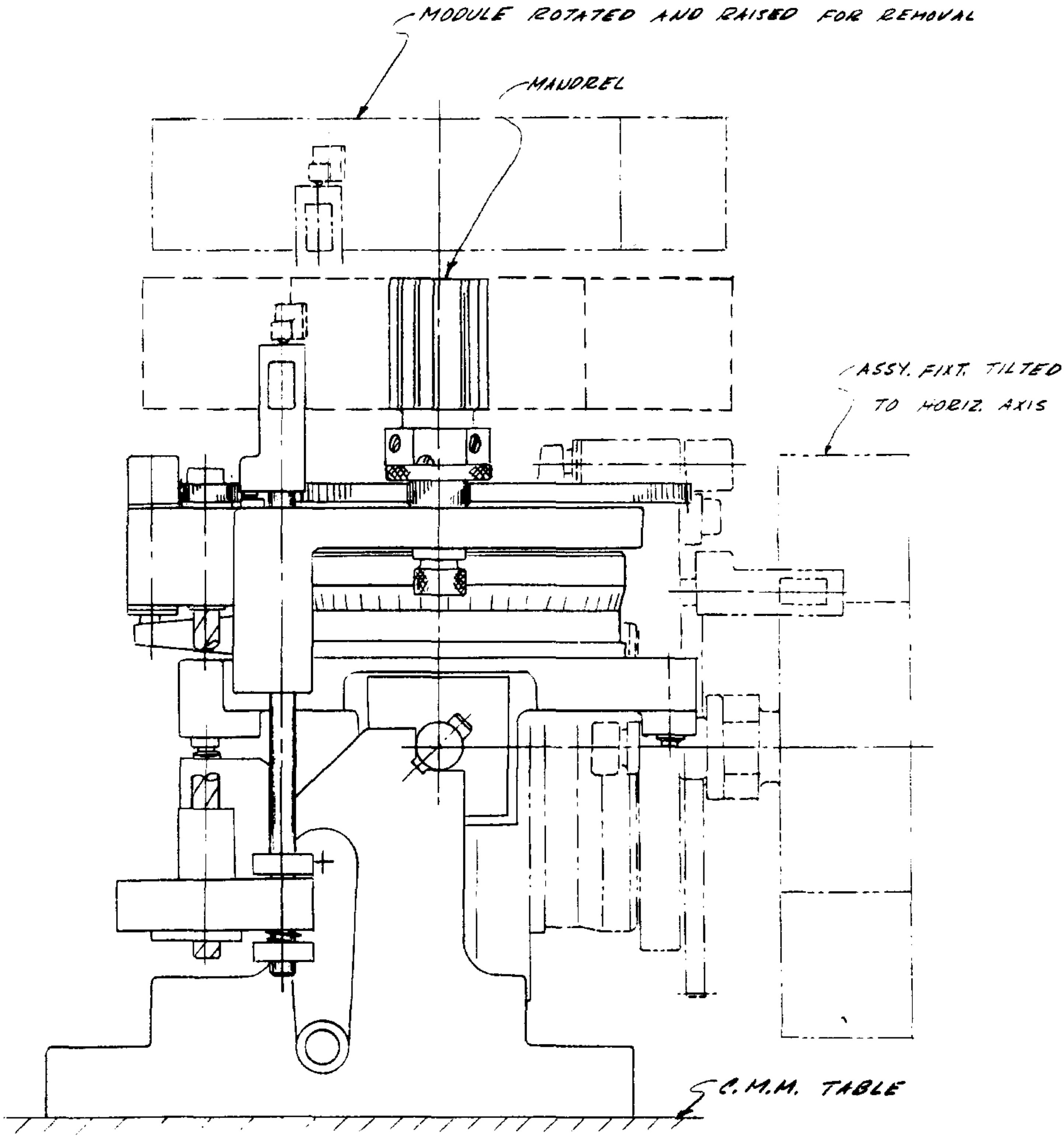


Figure 2C



INSPECTION PEDESTAL

Figure 3



ASSEMBLY FIXTURE (HALF SIZE)

Figure 4

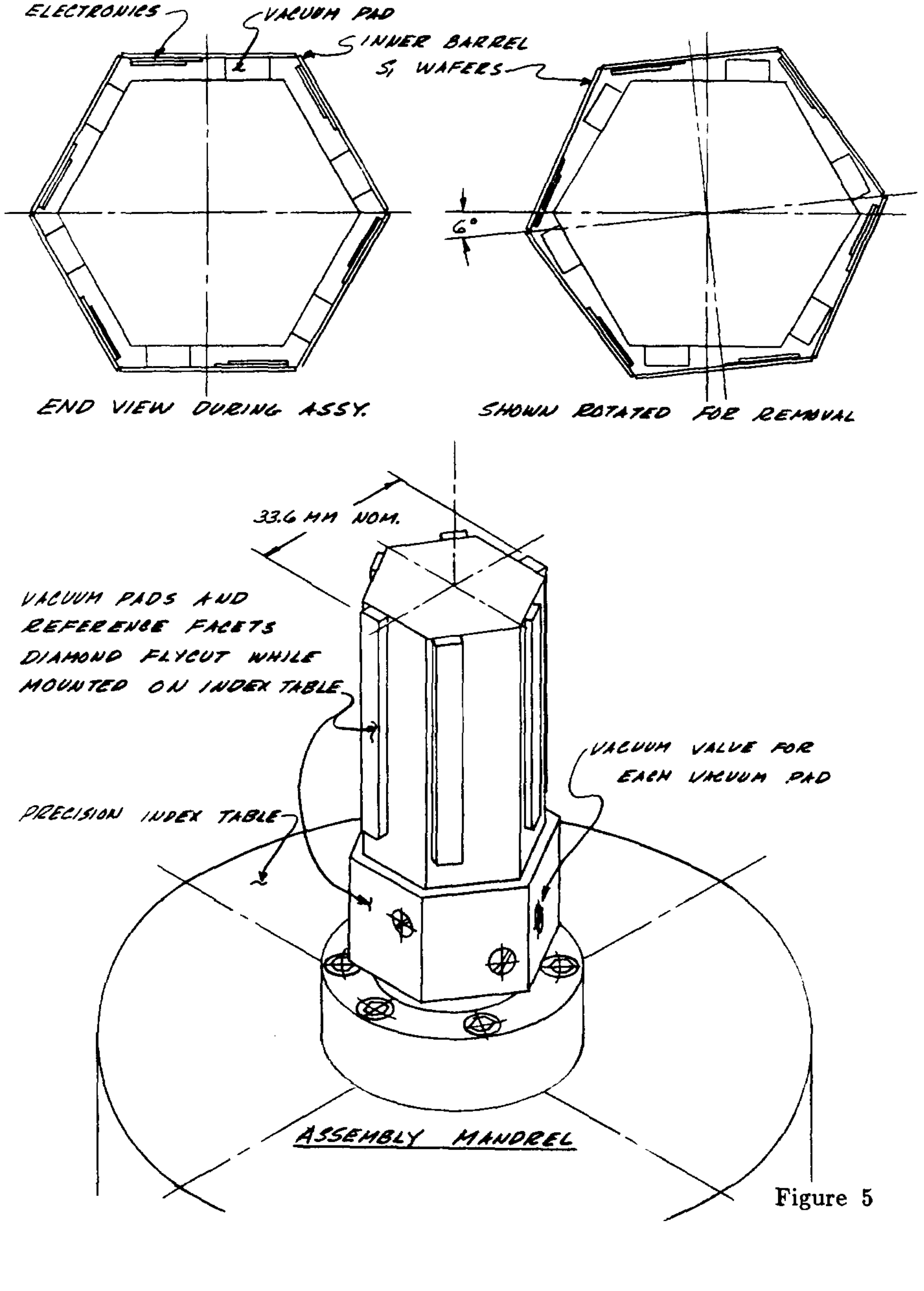

ELECTRONICS
VACUUM PAD
INNER BARREL
Si WAFERS
6°
END VIEW DURING ASSY.
SHOWN ROTATED FOR REMOVAL
33.6 MM NOM.
VACUUM PADS AND
REFERENCE FACETS
DIAMOND FLYCUT WHILE
MOUNTED ON INDEX TABLE
VACUUM VALVE FOR
EACH VACUUM PAD
PRECISION INDEX TABLE
ASSEMBLY MANDREL

Figure 5