INSTALLATION AND ALIGNMENT OF LAMPF 201 MHz AND 805 MHz LINAC TANKS*

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ABSTRACT

Design considerations and alignment techniques used in the mounting and installation of the LAMPF Accelerator tanks are described. Extensive use of laser alignment equipment along with optical tooling and linear tooling tapes were used to position tanks in the beam channel. Assembly procedures used to reliably make 368 "one-shot" knife edge vacuum-rf joints on the side-coupled linac are also discussed.

I. INITIAL DESIGN CONSIDERATIONS

Several methods of providing the supporting foundation for the LAMPF linac tanks were studied in the early stages of LAMPF design. These were eventually reduced to the following two proposals:

1. Concrete piers constructed to be independent of the beam channel floor and anchored to bedrock below the floor.

2. An integral and continuous support base consisting of a box beam type of beam channel building in which the floor would provide the supporting foundation.

The latter method of box beam construction was chosen when the following criteria were compared:

1. Overall cost

2. Excellent foundation base provided by the tuff of Mesita de Los Alamos.

3. The favorable experience of SLAC with a similar type of construction.

4. The integral construction feature of a box beam would provide maximum strength, with the capability of mitigating any step function deflection that might be impressed upon the building structure due to settling, etc.

This beam channel under construction is shown in Fig. 1.

The beam channel floor was constructed in a straight line, as a proton would travel, and not on a level line referenced to the Earth's gravity and curvature. This resulted in an elevation correction of $\sim$ 0.75 in. at the midpoint of the 2,600 ft beam channel.

Initially, it was proposed to design the accelerator alignment system around standard optical tooling techniques using alignment scopes and jig transits. The emergence of commercial tooling laser alignment systems during this time of preliminary design was fortunate for LAMPF. We had considered a laser alignment system, similar to the one used at SLAC, as not being justified for LAMPF requirements. Our early experience with tooling lasers on prototype linac models, such as the EPA, proved that the commercial laser units were much superior to optical tooling in long linear alignment situations. The use of tooling lasers was started in mid 1967 at LAMPF. The details of establishing the accelerator beam line and other alignment details are covered in E. W. Colston's paper.[1]

II. 201 MHz TANK INSTALLATION

The 201 MHz tanks are supported on structural steel stands which are bolted to steel plates in the beam channel floor. Each four-section tank is supported by five alignment mounts with the center mount fixed and the others floating in a constrained manner to allow for thermal expansion and to maintain alignment. A typical tank support consisting of an alignment mount and the structural stand is shown in Fig. 2.

The 201 MHz portion of LAMPF consists of a single section tank No. 1 and tanks Nos. 2, 3, and 4, which are made up of four sections each. Tanks No. 1 and No. 2 are physically tied together by a rigid intertank spacer. Tank No. 1 is mounted on a special track-type alignment mount that allows it to be moved upstream for disassembly if required. The

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intertank spacer and tank end head vacuum joints were made using aluminum O-rings. Mechanical joints used to join tank sections were a combination bolted-welded type joint as shown in Fig. 3.

A typical installation and assembly sequence for 201 MHz sections was as follows:

1. Each tank section was prepared for assembly by bead blasting the interior copper surface and cleaning the complete unit.

2. Tank Section "A" was set on its alignment mounts and positioned on beam line by using a laser reference line. An alignment fixture, which held the laser targets, was bolted to each end of the tank as shown in Fig. 4. After alignment was complete and the tank fixed on its mounts, the downstream end of Tank Section "A" served as a pilot for the upstream end of Tank Section "B". Tank alignment was on the order of ±0.010 in. to ±0.015 in., with closer tolerance work (±0.005 in.) being reserved for drift tube installation.

3. Tank Section "B" was attached to Section "A" by studs, with dowel pins being used to line up the joint. Shims were used in the joint to take up manufacturing tolerances and to assure proper linear spacing of the drift tube mounting holes. An across-the-joint drift tube spacing measurement is being taken in Fig. 5. The position of the downstream end of Tank Section "B" was monitored by a laser target, Fig. 4, during the joint makeup, with corrections made as necessary to bring it on line. After the "A" to "B" joint was bolted together, the downstream end of "B" section was on line and ready to pilot the "C" section into position.

4. In a similar fashion, Tank Sections "C" and "D" were joined together to form a four-section 201 MHz tank.

5. The joints were now ready for the final assembly welding. A vacuum-tight steel weld was made around the outside of the joint and an intermittent steel weld was made on the inside as shown in Fig. 6. A copper skirt was now welded vacuum tight to the copper clad steel on the interior of the tank joint. Details of this welding technique are covered in a report by James R. Ruhe.[2] Mechanical details of the 201 MHz tanks are detailed in a report by H. G. Worstell.[3]

6. After all joints were welded and vacuum checked, the tank was ready for frequency checks and adjustments, "Q" measurements, and drift tube installation. Drift tube installation and alignment details are covered in Colston's paper.[1] The completed and operational 201 MHz Alvarez portion of LAMPF is shown in Fig. 7.

III. 805 MHz TANK INSTALLATION

The 805 MHz portion of LAMPF consists of 44 modules, the first 8 modules being made up of 4 two-section tanks and 3 bridge couplers. The balance of 36 modules is comprised of 2 four-section tanks and 1 bridge coupler. This gives a grand total of 104 tanks, 352 tank sections, and 60 bridge couplers. The 44 modules of 805 MHz tanks cover a total linear distance of $\sim$ 2,400 ft.

The support system for all 805 MHz tanks is a double I-beam rail assembly fastened to structural steel piers that are bolted to steel floor plates. A view of this structure prior to tank installation is shown in Fig. 8. The pipes located between the rails in Fig. 8 are laser target stations which were used to establish and maintain the proton beam centerline for alignment purposes. Each double I-beam assembly of $\sim$ 25 ft length is fastened to a pier top plate by 8 clips. These clips are designed to allow linear expansion along the beam axis and to restrain any transverse motion. An alignment mount, shown in Fig. 9, was used to support the tanks on the I-beam rails and provide precision alignment adjustments. These mounts are also designed to allow linear expansion in one axis and to restrict motion in the other directions. Ball bushings made it easy to move a completed module without strain during the Z axis spacing adjustments. All I-beam lengths, pier locations, intermodule spacings, and later the mounting hole locations on the rails were established by a computer printout.

A typical module installation and alignment sequence was as follows:

1. Completed tank sections - after the assembly braze, leak check, cleaning, etc. - were transported from the ETL Building to the 805 MHz beam channel and stored under the support rails. A module assembly was usually not started until all tank sections and bridge couplers for a complete module were on hand in the beam channel. This was done to make the installation process as smooth and efficient as possible.

2. The first section of a tank was placed on its alignment mounts and aligned to the beam line using laser targets shown in Fig. 10. The laser targets, mounted in a self-centering fixture as shown, were inserted in the bore of a tank section. The O-ring portion of the fixture was designed to span two drift tube bores and to be a snug slip fit in the bore diameters which provided a reliable and automatic centering action. This section was locked in position after the alignment was complete.

3. A second tank section was now hoisted into position and made ready for the "knife-edge" vacuum and rf joint that joins tank sections into an integral unit. The details of a knife-edge joint are shown in Fig. 11. The O-ring shown in the figure will allow a leaking joint to be differentially pumped during an emergency condition and until the joint can be repaired. Since this type of joint can be reliably assembled only one time, all knife edges and mating flats were carefully inspected and hand worked to remove small nicks and scratches on the sealing surfaces. Inspection of each joint was checked off and recorded on a form shown in Fig. 12. A typical tank section is being hoisted onto the rails in Fig. 13. Note the laser alignment target in the bore of the tank that is mounted on the rails. A joint is prepared and inspected in Fig. 14 and brought into position for assembly in Fig. 15. A steel band was used on the flange o.d. to pilot the mating flanges and maintain alignment during assembly. The bolts were tightened uniformly in small increments with $\sim$ 6 rounds being made on the joint before final torque was reached.

4. The balance of tank sections required to complete a module was assembled as previously described. Bridge couplers, as shown in Fig. 16, were assembled to the tank sections with a knife-edge joint identical to those used on the tank sections.

After five or six modules were installed, a linear spacing setup was made to position each module at its exact location in the beam channel. This setup consisted of a laser reference beam that was parallel to the proton beam line and offset $\sim$ 48 in., a jig transit equipped with a horizontal axis mirror, and a 300 ft optical tooling tape with Vernier. The jig transit line of sight was made perpendicular to the proton beam line by auto-reflecting off the laser beam. The transit was then bucked in on a preset point on the tooling tape and used to transfer this point to a tooling hole on the center bridge coupler of each module. A complete module was then moved on its alignment mounts (linear ball bushings) until the two points were coincident. The center alignment mount was now clamped to restrict linear motion and fix the module in its correct location. Linear placement tolerance of each module was $\sim \pm 0.010$ in. Overall accumulative errors in the 2,400 ft were minimized by using a full 300 ft setup each time, making temperature corrections on tape readings, and the precision transfer of each 300 ft increment. The 300 ft tooling tape and its Vernier are shown in Fig. 17.

In general the tank alignment was held to ± 0.005 in. or better over 100 ft increments. The base alignment line was monitored before and after each tank section assembly. This was done to minimize and correct the effect of laser beam drift, even though a typical base line was usually less than 100 ft long. The most significant causes of laser drift were temperature differences in air pockets along the beam channel and cold air currents. Winter conditions that would produce inside to outside temperature differences of 70° to 90°F were the most difficult to cope with. Temporary fixes were made using plywood closures over outside openings and spacing electric heaters in the beam channel. Temperature stabilization was still a big problem but this arrangement made it possible to install several modules prior to having the cluster building heating system operational.

By using rigid quality control, careful handling, considerable hand work and patience, all 368 knife edge joints except 3 were vacuum tight at the first assembly. One leaking joint was caused by the backup O-ring falling out of its groove and being pinched in the joint. The second bad joint was hand reworked and reassembled vacuum tight. It was determined that the other joint would require a higher knife edge so that it would make a deeper "bite" into the soft copper and make a good vacuum joint. To remove this section from the module for remachining the knife edge was quite risky since several other joints would have to be broken and reworked at the same time, due to the male-female nature of the joints. A pneumatic grinding tool was therefore designed to do the work on the flange with the tank section in place on the support rails. The grinding tool shown in Fig. 18 was inserted in the tank section bore and rotated about that center to remove metal from the stainless steel flange. This grinding plus hand work on both flanges resulted in a vacuum-tight joint when the section was reassembled.

Installation of the quadrupole doublet magnets under each bridge coupler and between each module was scheduled at intervals when four or five 805 MHz modules were complete. Each magnet was supported on a three-point alignment mount, which was bolted directly to a main support pier. This mounting minimized mechanical coupling between the 805 MHz tanks and the magnets. Alignment of the magnets was done with the tooling laser and is described in Colston's[1] paper. These magnets were the last major components to be put on beam line during the 805 MHz linac assembly activity. Other activities which followed the tank installation included final rf tuning, cooling water plumbing, vacuum manifold and pump installation, and beam line monitoring devices.

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1. E. W. Colston and V. E. Hart, "Alignment Philosophy, Design and Techniques Used at LAMPF", to be published in the Proceedings of this Conference.

2. J. R. Ruhe, "Copper-Clad Steel Welding Technique Developments", internal report MP-3/JRR-2, July 8, 1966.

3. H. G. Worstell, "Mechanical Design of L.A.S.L. Linac Structures - (LAMPF)", Proceedings of the 1968 Proton Linear Accelerator Conference, Brookhaven National Laboratory, pp. 1-16.

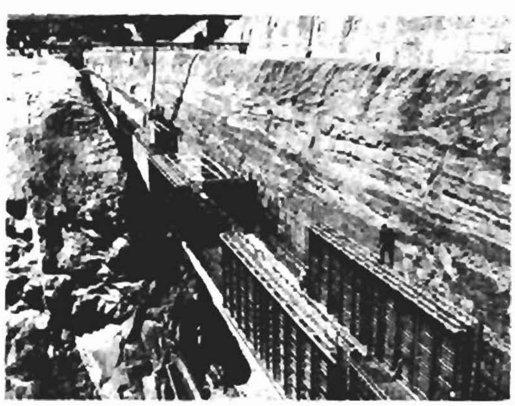

Fig. 1. 805 MHz beam channel building during construction

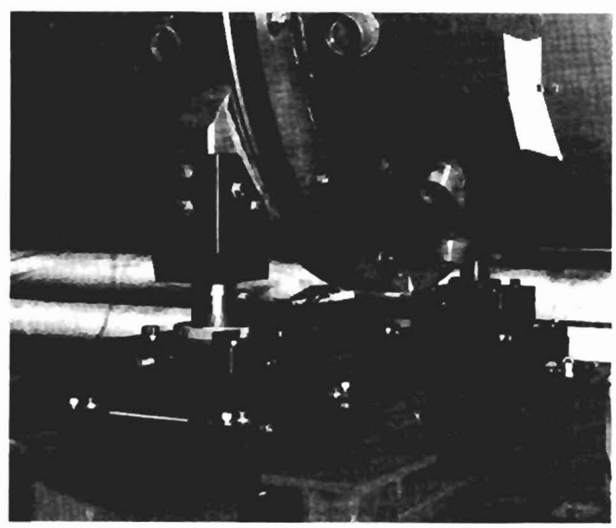

Fig. 2 201 MHz alignment mount and support pier

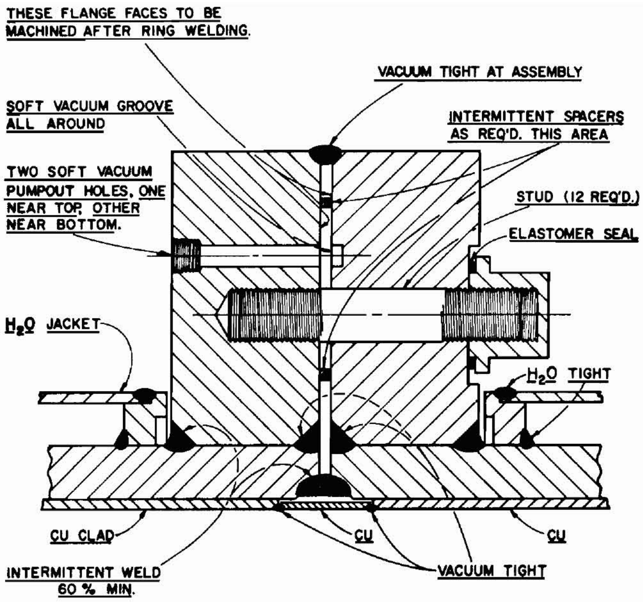

Fig. 3 201 MHz tank section joint

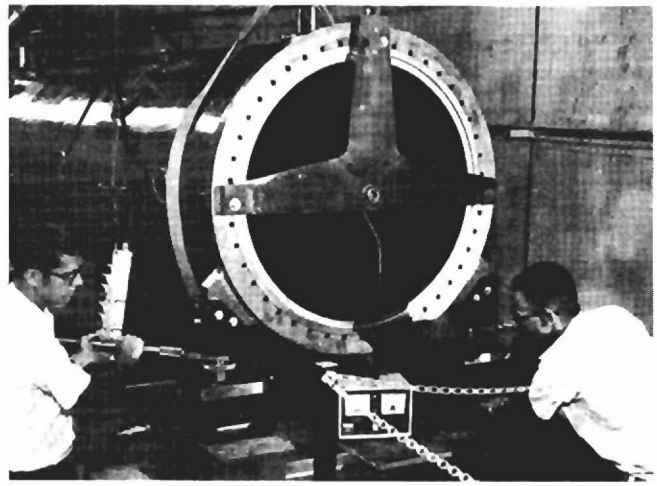

Fig. 4 Alignment fixture and laser target 201 MHz tank

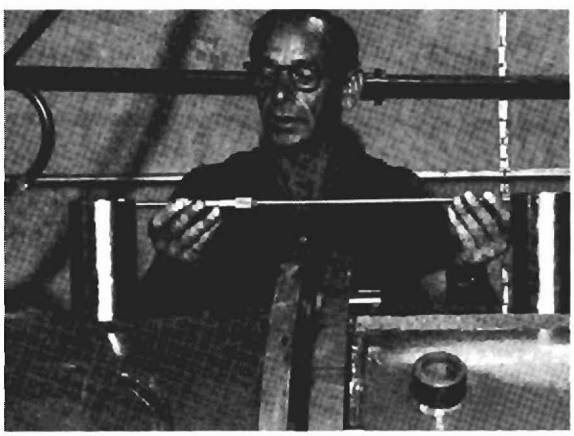

Fig. 5 Drift tube spacing measurement 201 MHz tank section joint

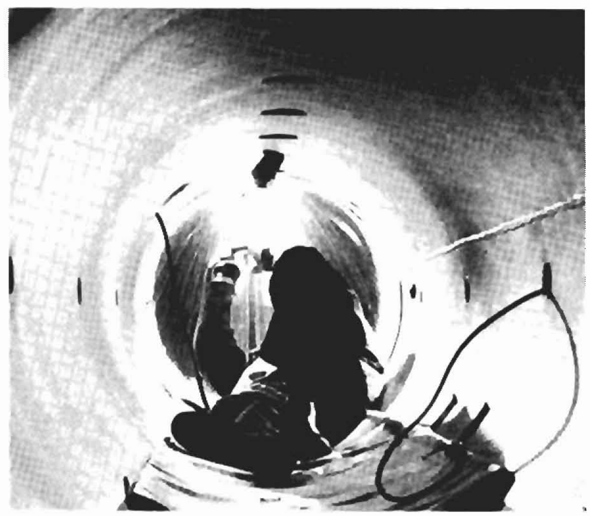

Fig. 6 Interior steel weld 201 MHz tank section joint

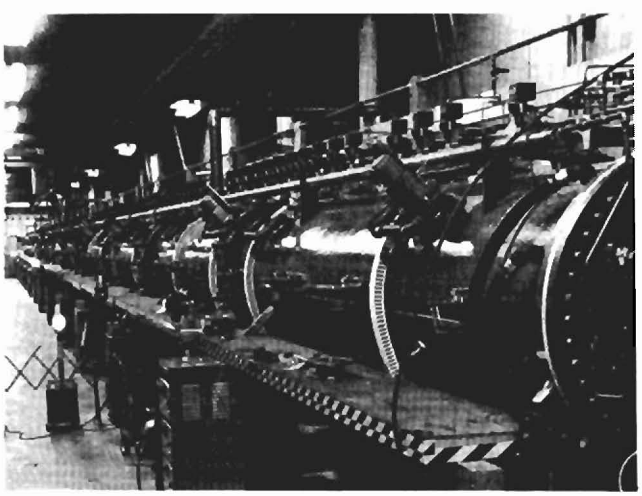

Fig. 7 LAMPF 201 MHz linac

Fig. 8 805 MHz tank support structure

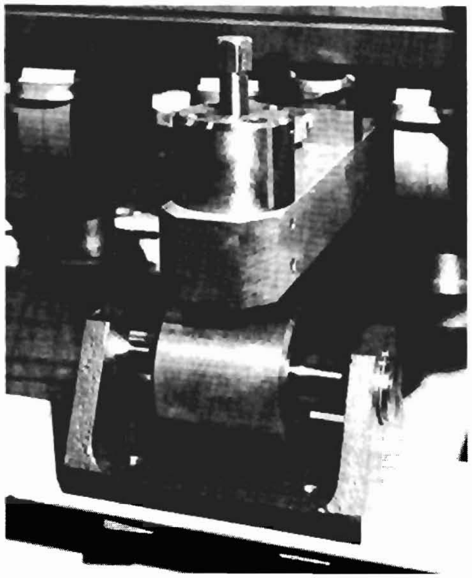

Fig. 9 805 MHz tank alignment mount.

805 MHz RF JOINT ASSEMBLY

CHECK LIST - Joint No. ____________

Date ______________

☐ 1. TAPE BORE & SLOT OPENING CLOSE
☐ 2. CLEAN GLASS BEADS FROM FLANGE HOLES
☐ 3. RE-TAP 5/16 - 18 HOLES
☐ 4. INSPECT KNIFE-EDGE SURFACE & CLEAR PUMP OUT HOLES
☐ 5. INSPECT O-RING SURFACE
☐ 6. CLEAN ALL SURFACES WITH ETHANOL
☐ 7. INSTALL STUDS
☐ 8. REMOVE TAPE OVER OPENINGS & CLEAN AREA
☐ 9. CHECK & REALIGN (IF NECESSARY) FIXED END OF TANK SECTION
☐ 10. RECORD "X" AND "Y" ALIGNMENT READINGS:

UPSTREAM: X __________ Y __________ DOWNSTREAM: X __________ Y __________

☐ 11. CLEAN, GREASE & INSTALL O-RING
☐ 12. INSPECT ALL OPENINGS AT JOINT FOR OBSTRUCTIONS, CHIPS, ETC.
☐ 13. POSITION RING CLAMP ON FIXED TANK SECTION.
☐ 14. ALIGN, POSITION & BRING TANK SECTIONS TOGETHER SLOWLY
☐ 15. LUBRICATE STUDS
☐ 16. INSTALL WASHERS & NUTS - TORQUE DOWN JOINT IN SMALL INCREMENTS
☐ 17. TORQUE STUDS TO 250 - 300 in.-lb.
☐ 18. REMOVE RING CLAMP & LEAK CHECK JOINT
☐ 19. RECORD ROTATION STATUS __________

REMARKS

INITIALS _____

Fig. 12 805 MHz rf joint assembly check list

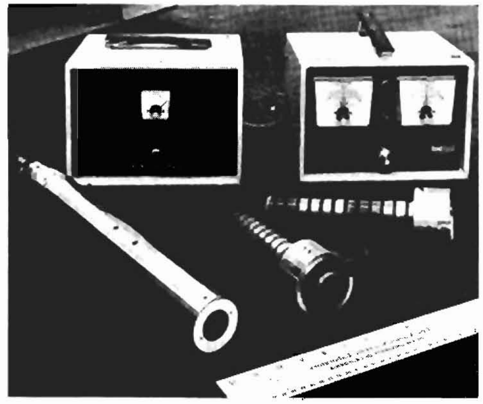

Fig. 10 Laser alignment target fixture 805 MHz tanks

Fig. 13 805 MHz tank section hoisting into position on rails

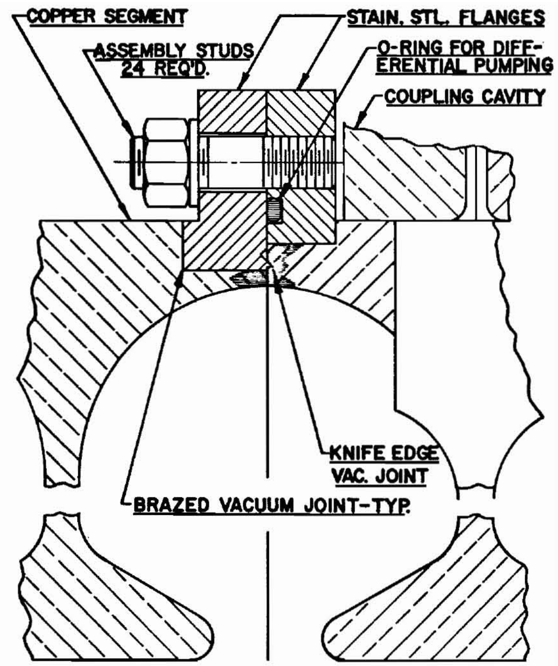

Fig. 11 805 MHz tank knife edge joint

Fig. 14 Preparation and inspection 805 MHz tank joint

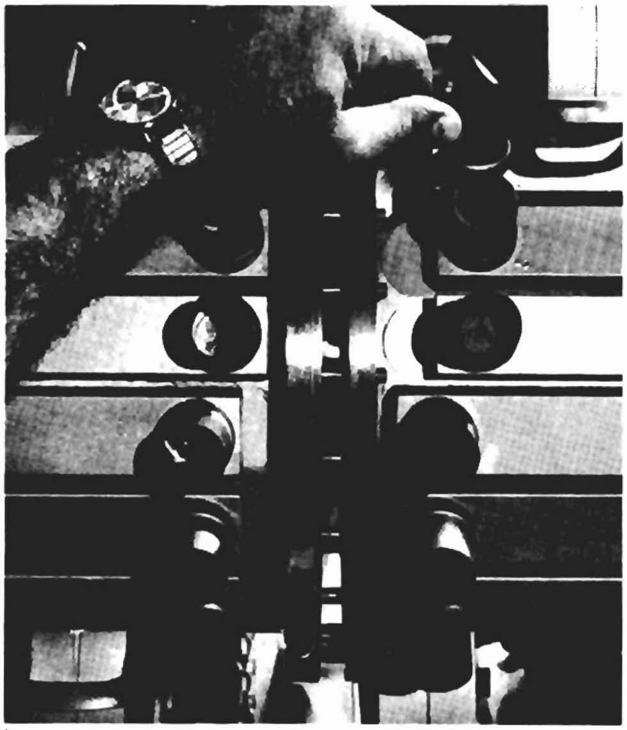

Fig. 15 805 MHz tank joint assembly

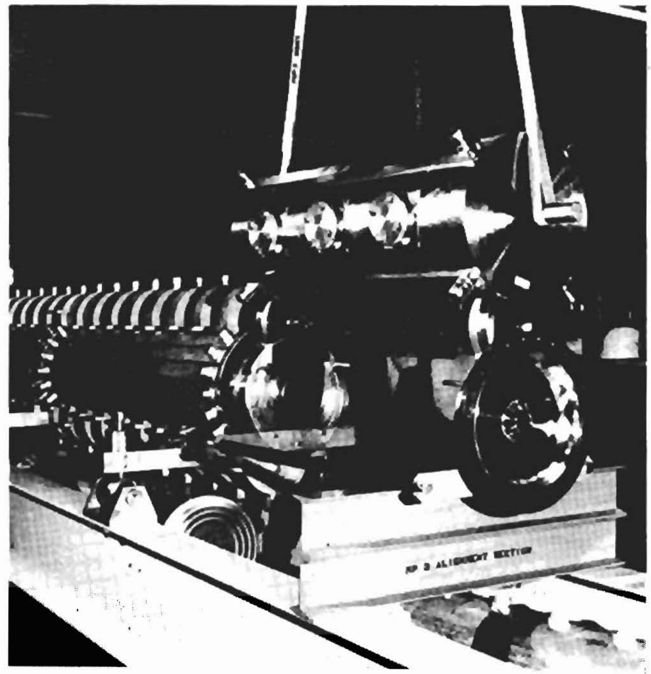

Fig. 16 805 MHz bridge coupler assembly

Fig. 17 300-foot tooling tape and vernier

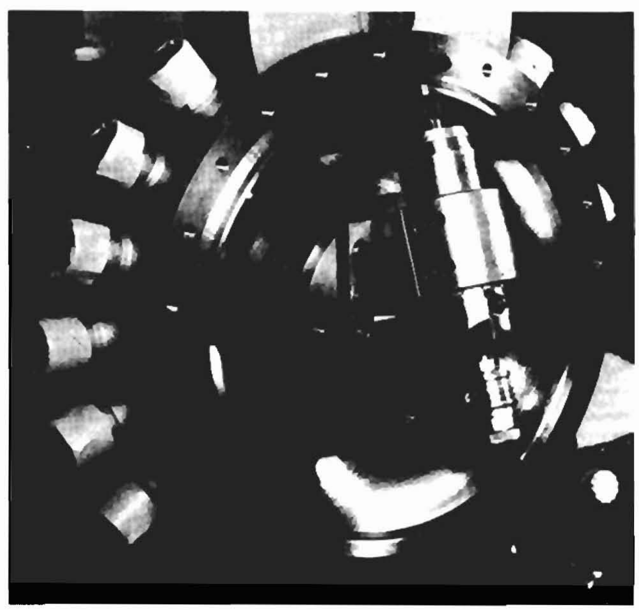

Fig. 18 Grinding tool for knive-edge joint rework