THE ALIGNMENT OF TANKS AND DRIFT TUBES FOR THE NAL 200-MeV LINAC USING A LASER LIGHT BEAM

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ABSTRACT

The equipment, fixtures, and techniques used in aligning the tanks and drift tubes of the NAL 200-MeV linac are described. An alignment optical laser is used and targets are placed in the drift tubes to allow readout during positioning. Reference lines established external to the linac tanks permit periodic realignment of the tanks without future reference to the drift-tube positions.

Introduction

The assembly of the NAL 200-MeV linac required the alignment of the drift-tube quadrupoles and setting the gap between the drift tubes to a close tolerance. Previous linacs have been aligned using the highly developed optical system. At distances beyond 50 or 60 feet, the accuracy drops off in the optical system and there is always the communication problem between the man adjusting the drift tube and the man calling out the deviation from the optical axis. At NAL, it was elected to use a laser alignment system in conjunction with other electronic measuring devices. This put a visual display of the deviation of the drift tube from the six axes of motion at the drift-tube adjuster's position.

Cavity-Alignment Procedure

The cavity was brought into the tunnel and positioned roughly over the reference line marked on the floor. Targets were placed in the cavity drift-tube opening at top and in the post-coupler opening on both sides. This pattern was set at both ends and at the center support area. A jig transit was set up on the reference line and adjusted in line with the reference points on the floor. An N3 level was set off line but close enough to see into the cavity past the jig transit and then leveled to the reference points on the tunnel wall. The cavity was then adjusted on the stand until the center of the drift-tube openings for the three points at the top of the cavity were in line with the jig transit sight. The cavity was also rotated and elevated until the post-coupler targets on the side were level and at the reference elevation. The single support at the mid point of the cavity was adjusted vertically until the post-coupler openings were level with the end.

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With the cavity adjusted on-line, a cross with locating dowel pins was bolted on the end of the cavity using premachined flats on the cavity ring to locate dowel pins (Fig. 1). A 2-1/4 in. optical target was placed in the adjustable center holder and adjusted until the target was in line with the jig transit and level. This was repeated on the other end of the cavity and established the preliminary drift-tube axis.

Drift-Tube Alignment Procedure

The alignment laser was mounted on the stand as shown in Fig. 2 and a 2-1/4 in. laser target replaced the optical target. The laser mount was adjusted on the stand until the laser beam was in line with a target at both ends of the cavity. A laser target was then mounted on a tooling stand beyond the cavity and adjusted until in line with the laser axis as a third reference target.

The crosses were removed from the cavity and the cavity end plate with half drift tubes mounted were bolted to the end of the cavity. Using the four adjusting screws, the half drift tubes were adjusted until both ends of the drift tube were in line with the laser axis (Fig. 3). The end plates were then drilled and pinned to the end of the cavity. The end plates were removed and the crosses replaced to retain the reference axis for drift-tube alignment in the cavity.

The laser target is a quad-cell detector that has opposite cells balanced with a readout unit that reads zero when there is equal light energy. The gain can be selected for three ranges: ±0.001 in., ±0.010 in., or approximately ±0.100 in. The two vertical cells read on the y strip and the two horizontal cells read on the x strip of the readout as shown in Fig. 4 on the top shelf.

To mount the laser target in the drift tube with easy removal, a target holder was made as shown in Fig. 5. There is a plate that fits into the bore of the drift tube with the surface against the drift tube ground perpendicular to the ground plug fitting into the bore. A similar plate is mounted on the other end of the drift tube and the two plates held in place by four constant-tension springs. The plate on the upstream side extends high enough to provide a measuring plane for the axial position measurement. The laser quad cell is mounted in a housing that can be slipped in and out of the holder and is shown mounted in the lower right of Fig. 5. With an x and y readout on both ends of the drift tube, there is provided to the drift-tube adjuster the amount of deviation in the lateral and vertical position from the laser axis as well as the rotation about the vertical support axis and rotation about the lateral axis.

The rotational position about the quadrupole axis in the drift tube was indicated by an electronic level mounted on the drift tube as shown in Fig. 5. The quadrupole magnet was positioned in the drift tube using the same reference point as the level support. Figure 4 shows the level readout in the lower right and on the most sensitive scale reads ±50 arc seconds for the full scale.

As mentioned previously, there is a plane extension of the upstream drift-tube face for measuring the axial position. On the upstream end of the cavity, a reference bar was mounted (see just above the horizontal leg of the cross in Figs. 1 and 2) and a stick mic used to measure the axial position of each drift tube. The stick mic was supported on the previously mounted drift tube as shown in Fig. 6. The end of the stick mic was held by a spring clip to the end reference bar and had a spring-loaded transducer at the drift-tube end. A readout of the axial position was displayed on the lower left unit of Fig. 4 and has a range of ±0.004 in. for full-scale displacement. The gap between drift tubes was also measured and the actual drift tube fabricated length was considered in determining the axial position.

During the early use of the laser, there were varying amounts of drift while aligning drift tubes. It was a function of thermal gradients and influenced by the man in the cavity, how far the target was from the laser, external thermal conditions, dust or moisture in the air, etc. It was found that stability was greatly improved by using a fan at the downstream end of the cavity to blow toward the laser and reduce thermal gradients and airborne particles.

With the readouts described, the technician aligning a drift tube has a visual display of all degrees of motion as he adjusts. A fixture to move the drift tube in all motions is shown in Fig. 7 and was previously reported.[1] As the drift tube was moved on any one axis, the change was visible on that axis as well as any effect on the other axis. This was helpful also during the transfer from the fixture to the torqueing of the nuts onto the cavity. When the drift-tube mount was secured to the cavity, a final set of readings was taken of the drift-tube position. The x and y readings of the laser reference targets on both ends of the cavity were taken and the recorded drift-tube position was corrected to the zero axis of the cavity position.

External Alignment Reference System

There was concern about the stability of the linac tunnel since concrete was poured on earth without supporting piling. A method of checking the alignment of the cavity without coming up to air and sighting through the drift-tube bore was considered desirable. Also, it should be accomplished during a scheduled maintenance shutdown without interfering with the maintenance. A two-line external system was added to the NAL linac to achieve the above objective.

Following the alignment of drift tubes in each cavity, there was a transfer of the drift-tube axis to a target on each side of the cavity. This target is a 2-1/4 in. tooling ball with adjustable cup mount set on a bracket bolted to the cavity. An optical target was used and adjusted until it was level with the cavity axis with 27.500-in. displacement. The same procedure was repeated on the other side of the cavity. A line of sight was established through the end targets and the tooling ball mounted near the center support of the cavity was adjusted in line.

A laser is mounted on the cavity and adjusted to the line of a laser target mounted in the holders at three points on cavity 1. This establishes the direction of the laser beam through the targets and succeeding cavity targets. Figure 8 shows the laser mounted on the cavity and target to the right. The laser is capable of projecting a beam for about 300 feet and this is sufficient to look through five cavities. The laser is then repositioned on cavity 4 and adjusted on axis with the target of 4 and three targets of cavity 5 that were just surveyed to establish the continuation of the beam line through cavity 9. A laser mount has been placed on cavity 3 to look back through cavities 2 and 1 and check on the preaccelerator and transport-system alignment.

The thermal and airborne-particle problem on laser-beam stability was also experienced on the external line. A tube line was built between targets as shown on the right side of the cavity in Fig. 9. The beginning of this tube is also shown on the right of the target in Fig. 8. This isolation has been sufficient to give a stable beam line.

A set of readings at each target point will be taken and recorded at each scheduled shutdown and the history of cavity movement plotted. Corrections can be planned and scheduled for correction at future shutdowns to maintain the linac alignment in tolerance.

Acknowledgments

The optical setups were made by B. Testin and the laser alignment of drift tubes was done by the team of W. Carl, G. Erickson, D. Leifheit, D. Matias, and D. Tokarz. Their skill, comprehension, and interest were important in making the system work and completing it ahead of schedule.

Reference

[1] John O'Meara and Maxwell Palmer, Mechanical Design Features of the NAL 200-MeV Linac Injector, Proc. of the 1968 Linear Accelerator Conference, Brookhaven National Laboratory, p. 30.

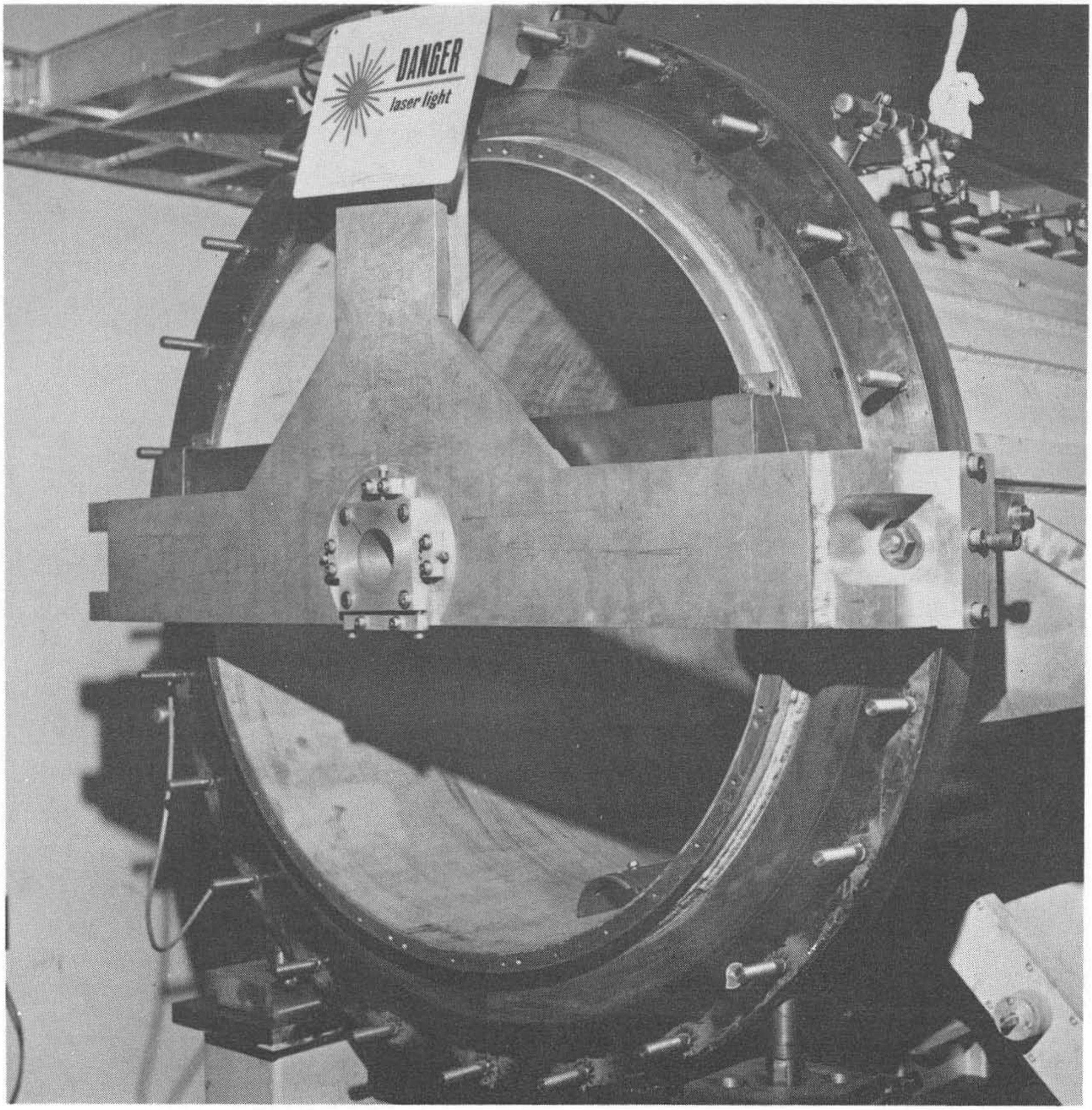

Fig. 1. Cross-holding target on end of cavity.

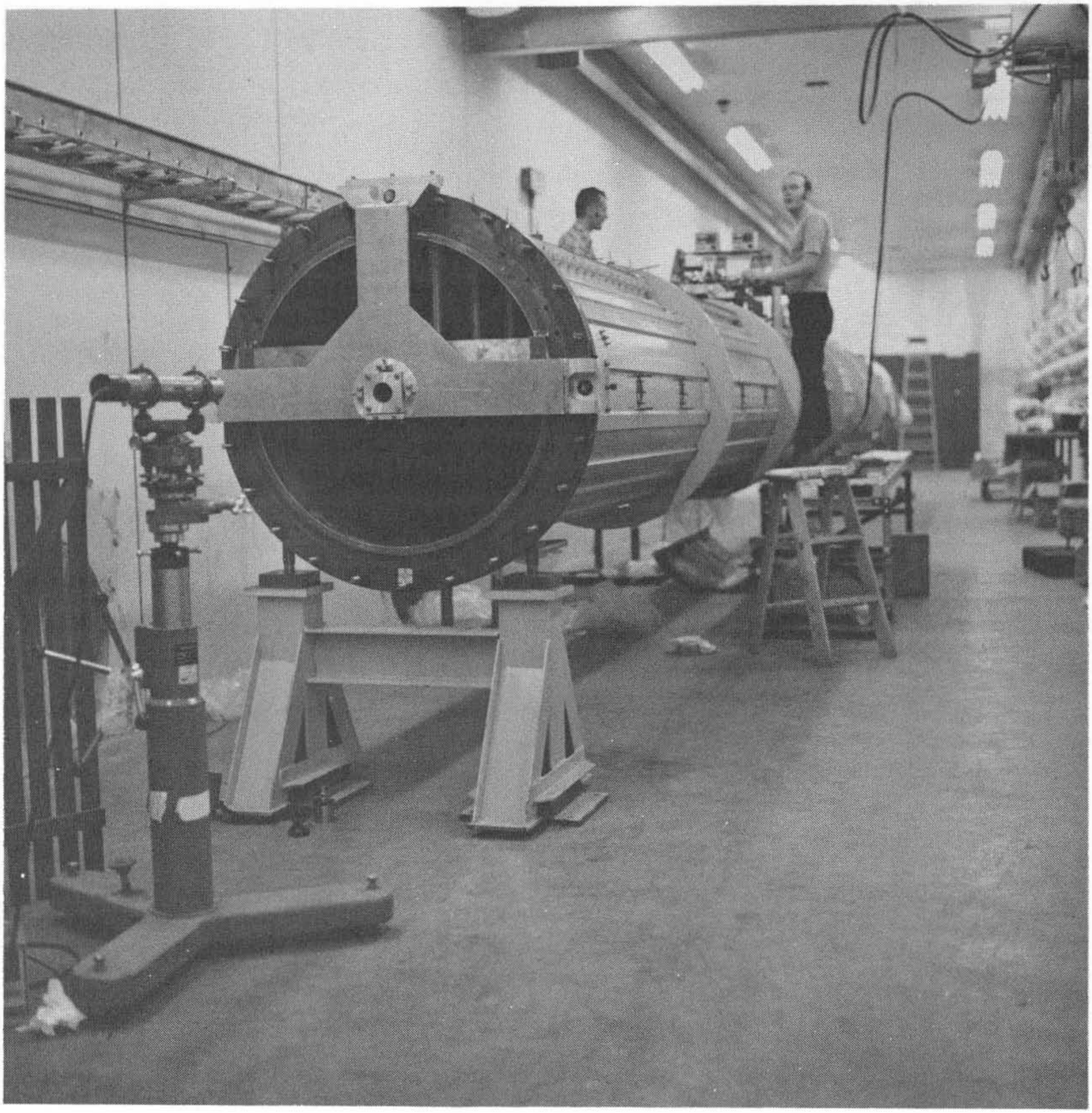

Fig. 2. Drift-tube alignment with laser.

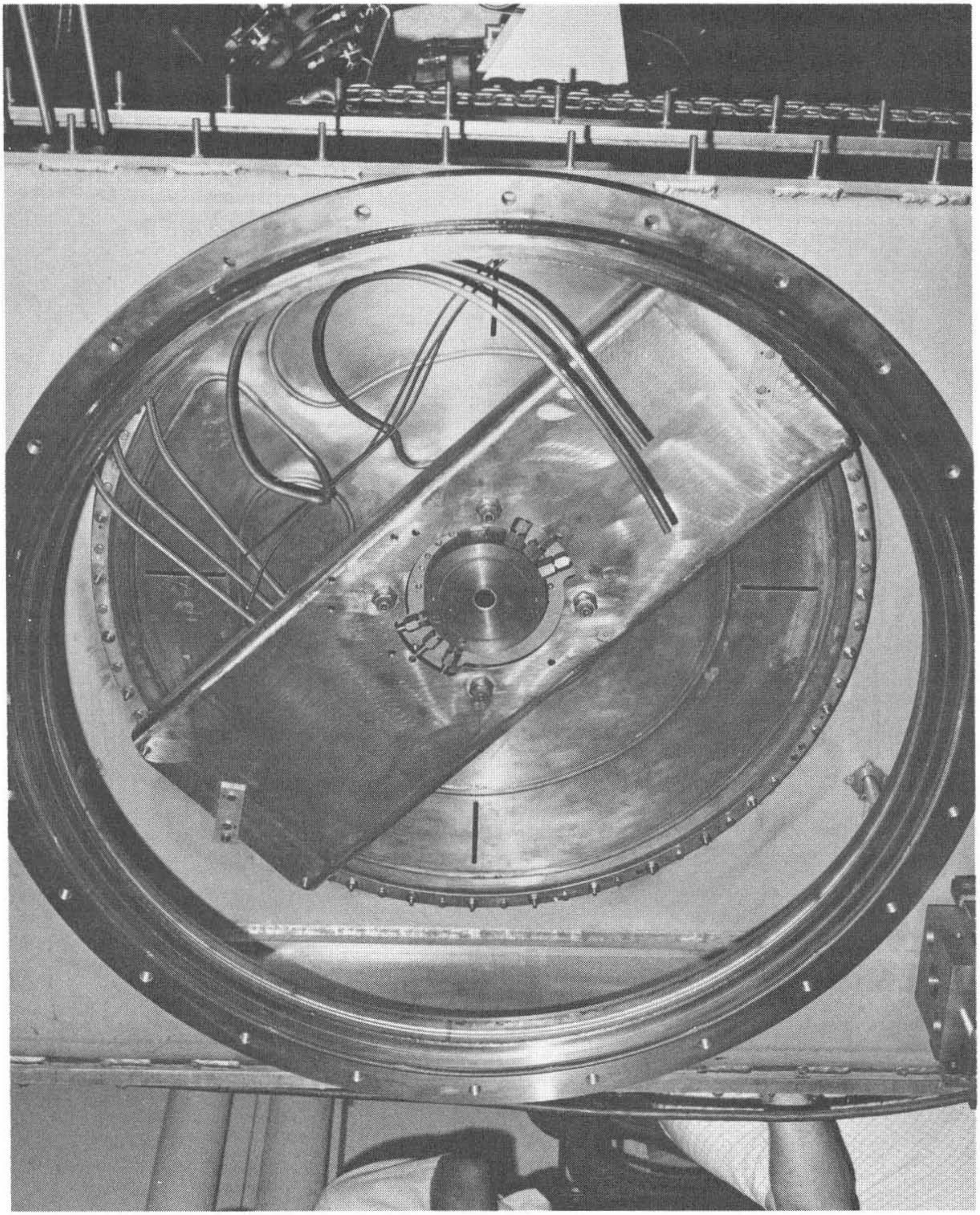

Fig. 3. End plate of cavity with half drift-tube mounting.

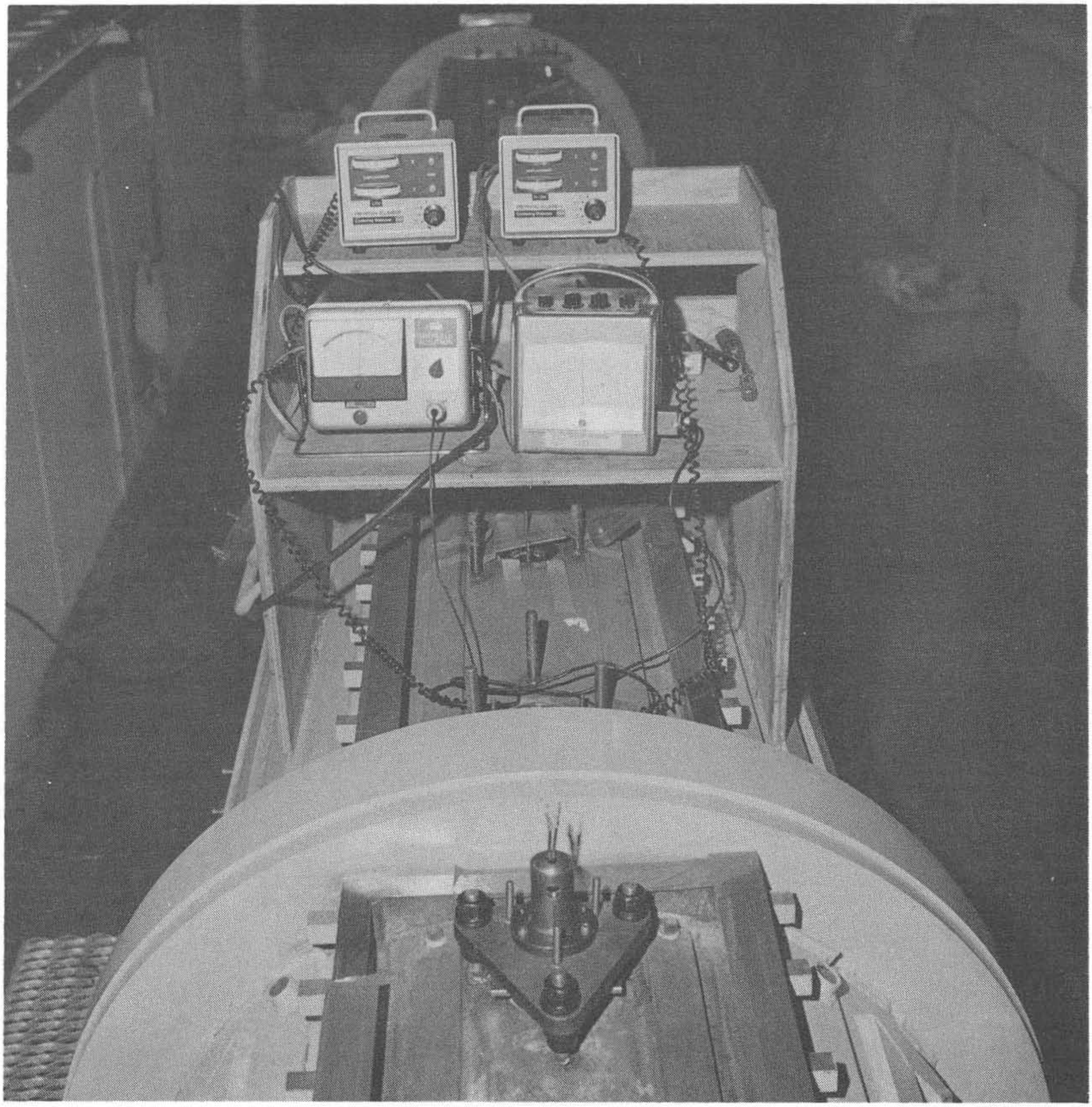

Fig. 4. Laser-alignment readout units.

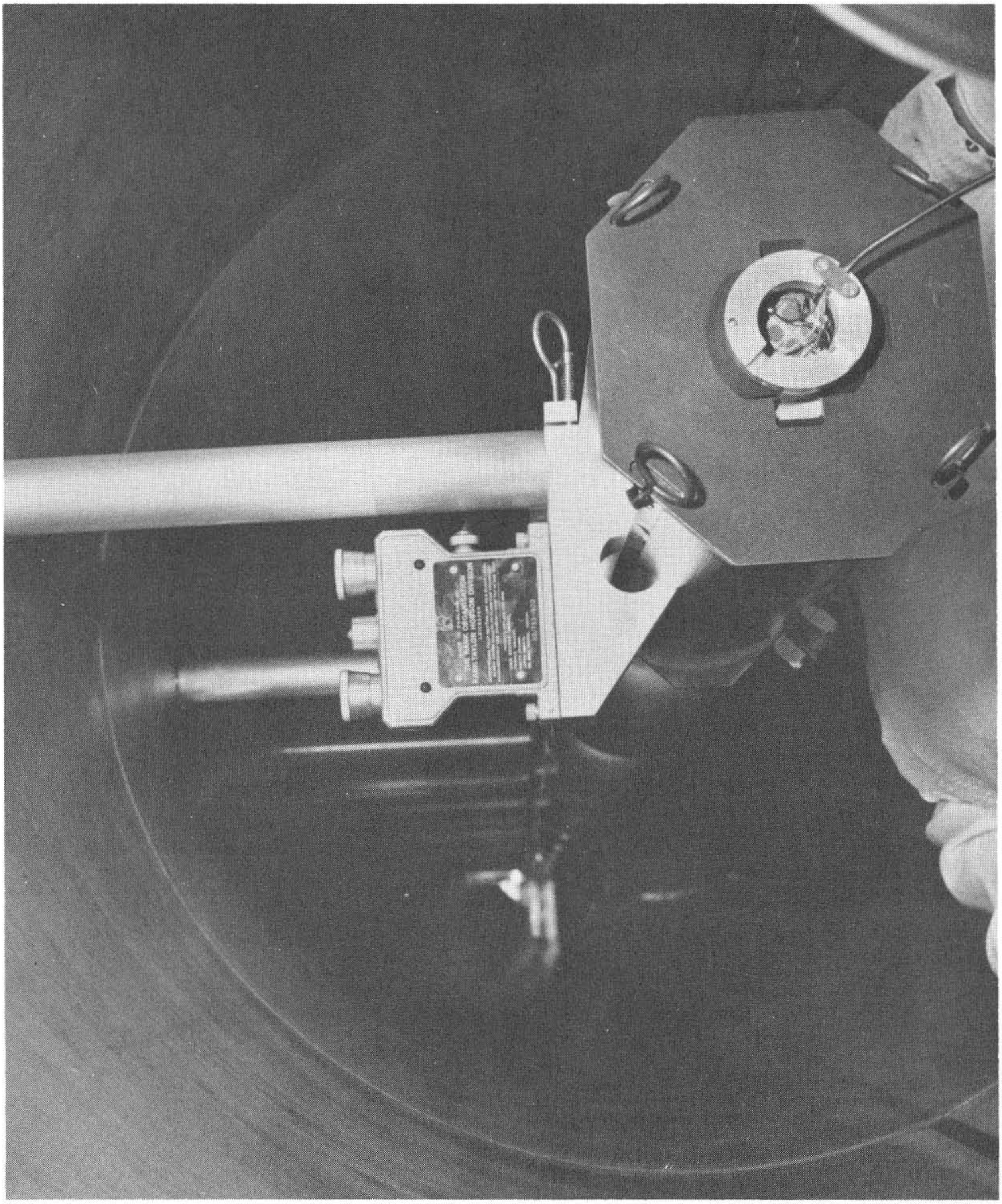

Fig. 5. Drift-tube target holder and electronic level.

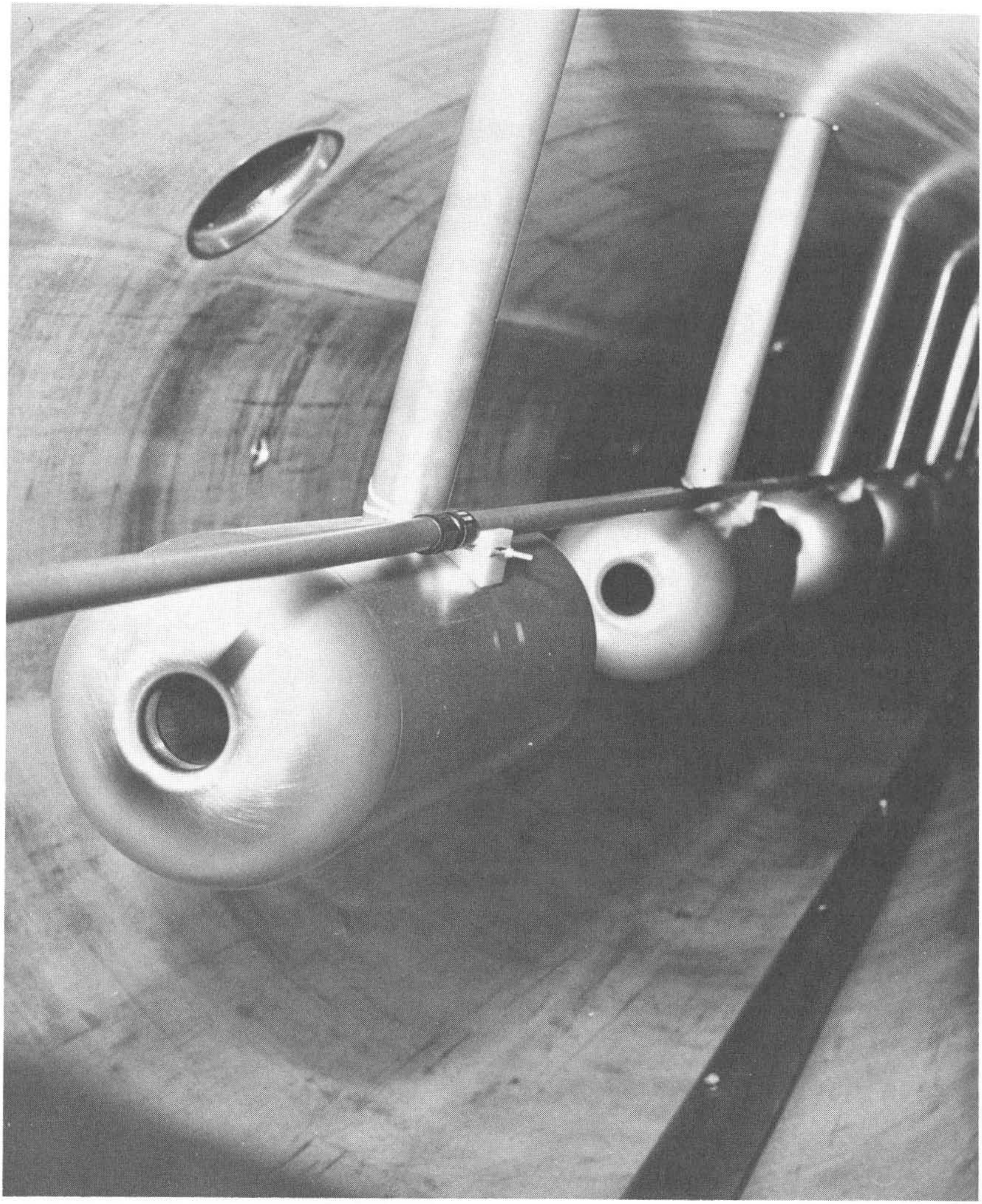

Fig. 6. Stick mic supported on drift tubes.

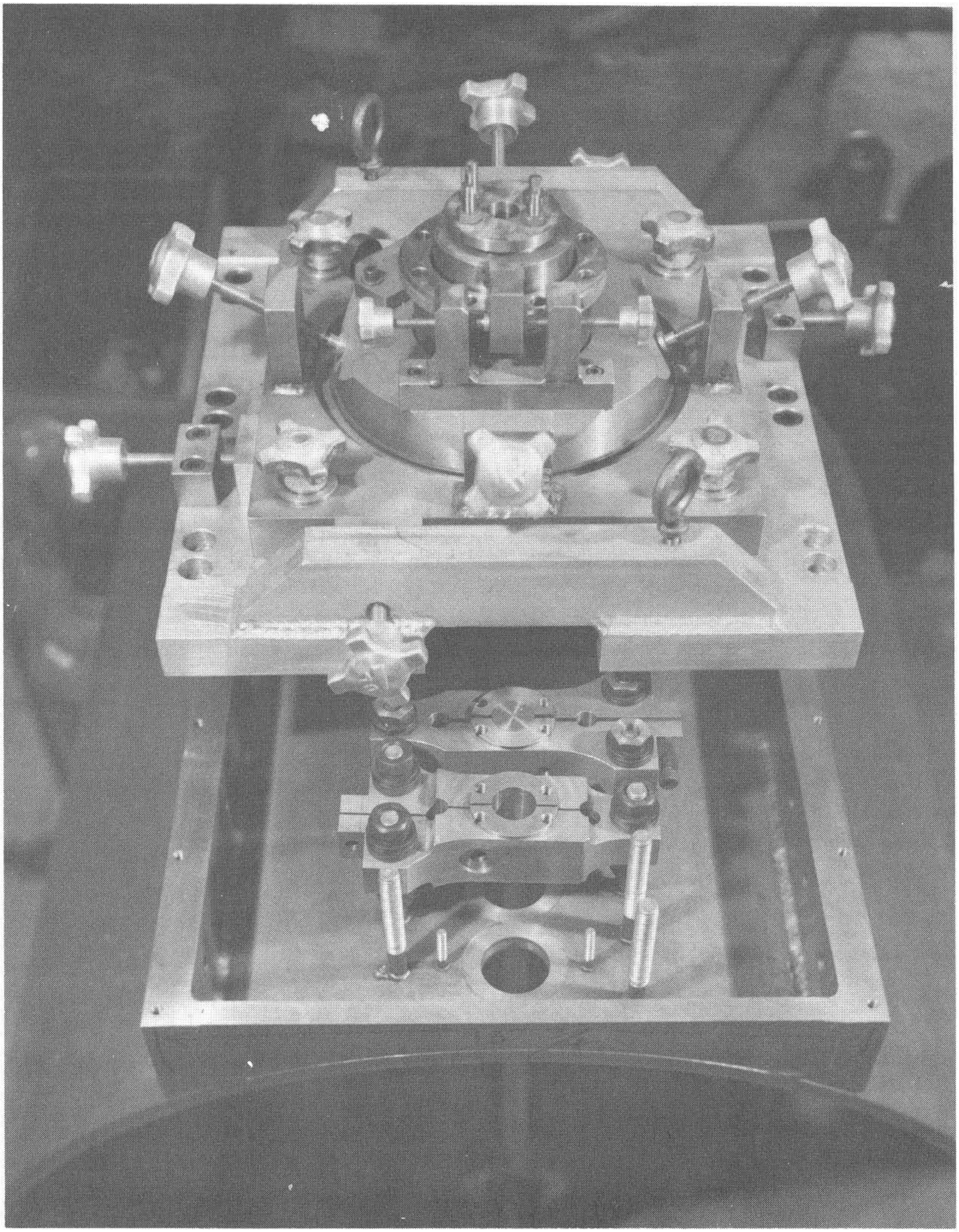

Fig. 7. Drift-tube alignment fixture.

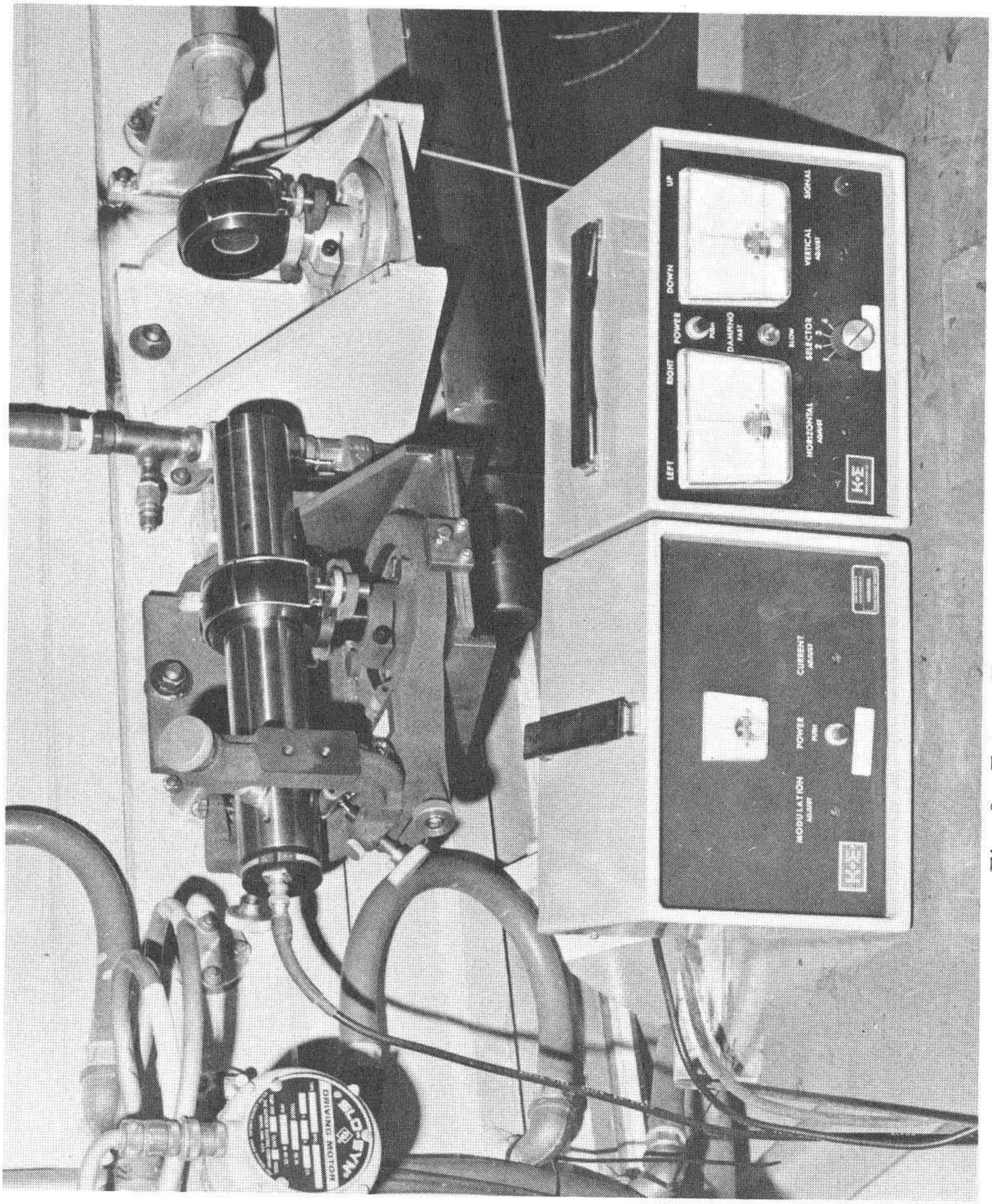

Fig. 8. Externally-mounted laser and target.

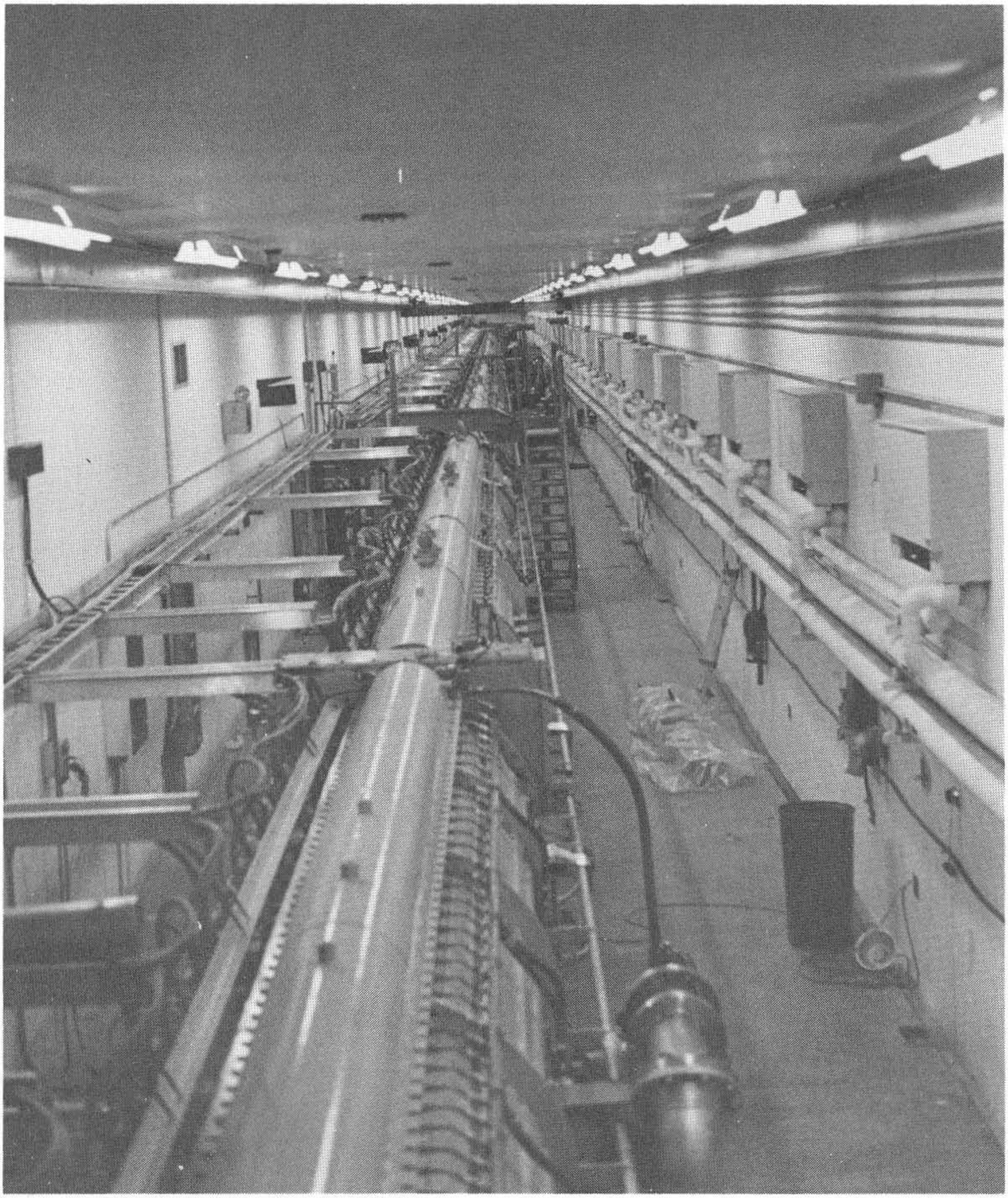

Fig. 9. Assembled linac.