MECHANICAL DESIGN FEATURES OF THE NAL 200-MeV LINEAR ACCELERATOR*

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ABSTRACT

The design of the mechanical systems of the NAL 200-MeV linac were reported at the BNL Linear Accelerator Conference 1968. Experience with the 10-MeV prototype cavity has resulted in a number of design changes. Also, details are presented in this paper regarding the fabrication of drift tubes, the adjustable cavity end plates including the half drift tubes mounted thereon, the cavity bulk tuners, the post couplers and their adjustment mechanisms, and the intertank system.

Introduction

The National Accelerator Laboratory started the construction of a 10-MeV linac in May, 1968. The mechanical design features of the 10-MeV prototype were published in the BNL Accelerator Conference Proceedings of May, 1968.[1] Features of the NAL 200-MeV linac that are a departure from the prototype report or were not a part of the prototype will be covered in this paper.

The 10-MeV prototype linac was completed and protons accelerated on June 26, 1969. The prototype was operated, with modifications being made, until December 1969, when it was moved to the permanent site. This is essentially the same structure that is now in operation. Cavities 2 and 3 were installed on line with the prototype, and the three cavities operated at 66 MeV on July 30, 1970. Cavities 4, 5, and 6 have been installed on line and were operated at 139 MeV on September 25, 1970. The last three cavities will be installed and operational at 200 MeV about the first of 1971.

Figure 1 is an interior photo of a NAL linac cavity showing the relative position of the drift tubes, post couplers, slug tuners, bulk tuner, rf drive loop, and vacuum pump ports.

Drift Tubes

The drift tubes for cavities 2 through 9 are dimensioned from the data of MESSY-MESH computer program[2] as were those in cavity 1. The construction is shown in Fig. 2. The body is made from two forged OFHC copper cylinders. A continuous water passage is milled in the inner sleeve with an axial passage every 45°. The

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two cylinders are then joined at both ends by electron-beam welding to make a water-tight body.

The drift-tube support stem is made of three copper tubes, concentrically assembled, with a water passage plug at each end and all joints were electron-beam welded. This assembly was then centerless ground to size for the braze fit in the body and to remove any roughness in the o.d. surface due to handling up to this point. The support stem was then brazed to the body in a dry hydrogen atmosphere furnace.

The drift-tube assembly was heated in an oven to 200° F to provide clearance for inserting the quadrupole magnet and on cooling resulting in a light shrink fit. This provided a good heat transfer contact as well as holding the magnet in position. All quadrupoles used in the drift tubes are the BNL design and were fabricated by the same commercial contractor.

The end caps were made by the same method as previously reported for the 10-MeV prototype. Two more dies were made for the 3- and 4-cm bore drift tube end caps. In one pressing operation, an annealed copper plate, 1/4-in. thick × 9 in. diameter, was formed cold to the outside radius and the hole for the bore tube pierced. In a second operation, a ball was pushed through the bore hole to open to size and to obtain some additional length of copper back from the face. A machining cut was made in a tracer lathe to obtain the toleranced size and a 32 micro finish. End caps were welded to the body and the monel bore tube by electron-beam welding on both ends to make a vacuum-tight body.

Mounting of the drift tube in the cavity is shown in Fig. 3. This is the same general arrangement as on the prototype. The D-spring used to make rf contact from cavity to drift-tube stem has functioned satisfactorily and simplified drift-tube alignment. When the contractor connected the stainless-steel water tubes to the drift-tube water collet, there was sufficient strain to move some drift tubes off alignment tolerance. Bellows have been added in the line to eliminate the problem.

Half Drift Tube

The half drift tube was made with similar construction to the full drift tube. Mounting of a half drift tube is shown in Fig. 4. A ring was welded to the body to provide a mounting point and was machined with a slope on the back side to form the rf contact to the end plate at the outer diameter. A backup ring was used to sandwich the end plate to the drift tube.

Mounted across the end of the cavity is a channel with four double mounting bolts that connect to the half drift tube backup ring. The inner bolt pulls and the outer sleeve pushes and by this adjustment, the end plate can be oil-canned in the axial position and the half drift tube tilted to bring both ends on the alignment axis.

All drift tubes have been aligned using an alignment laser and this procedure is covered in another paper in these proceedings.[3]

Post Couplers

The location of the post coupler to the drift tube was shown in Fig. 1 and a cross section of the post coupler with the adjusting fixture in place is shown in Fig. 5. Before closing the end of the cavity, the gap between each post coupler and drift-tube body was measured with an inside micrometer, and the counter was set for the measured gap. As the field tests proceeded, the post coupler was positioned radially from the drift tube by rotating the hand knob to settings indicated by the counter. The tab on the end of the post coupler was rotated by the keyed sleeve. When all post couplers in a cavity were in the final position, the clamp was tightened to the cavity mounting bracket. The adjusting fixtures were then removed and used for setting the post couplers in the next cavity.

With the adjusting fixture removed, the post coupler is shown in Fig. 6. The rf contact is the same D-spring assembly used with success on the prototype cavity drift tubes. Water cooling may be required and can be added with the fitting shown. The operation of post couplers is covered in a referenced paper of these proceedings.[4]

Bulk Tuner

Coarse tuning of a cavity was accomplished with a section of copper tube. A 3-1/2-in. diameter tube was cut lengthwise and the sections joined together to form a half tube the length of a cavity. Initially, the sections were joined by brazing but later the copper welding technique developed in cavity fabrication was used. Figure 7 shows the high-energy end of a bulk tuner with one support post and other support posts are spaced about 2 ft apart. The terminal block has two knife edges that are matched to the cavity contour for rf contact, and the D-spring at the top makes contact with the tube. A water cooling line was added after some distortion due to heating was experienced.

Slug Tuner

To provide a continuous fine tune for the cavity, one of the slug tuners in each cavity from 2 through 9 has been motorized as shown in Fig. 8. A geared-up Slo-Syn motor has been mounted to the worm drive system to move the 5-in. diameter slug through 4 in. of travel. A linear position pot and limit switches were added to feed back to remote control.

Since cavity 1 does not have post couplers, it was not possible to use a motorized slug tuner without seriously tilting the field. A smaller motorized slug of 2-in. diameter with 2 in. travel, Fig. 9, was mounted about midpoint on the side of the cavity.

Intercavity

The space between cavities is limited and particularly in the early units where diagnostic equipment is needed. Between cavity 1 and 2 there is only 22 cm from end plate to end plate and a considerable amount of this is occupied by the backs of the half drift tubes. Figure 10 shows the NAL arrangement of a large stainless-steel box with four removable covers. This permits servicing of the cavity and exchange of diagnostics, such as the toroid shown.

Between cavities 2 and 3 there is 60 cm. In order to provide as much diagnostic space as possible and still isolate the cavity vacuum, a special end closure was built, Fig. 11. A 2-in. cylinder operated vacuum gate valve was built into each end plate. This only occupies 2 in. of axial space each and leaves over 8 inches of space for diagnostic. Four access covers are provided and a beam scraper is shown mounted on one cover. A retractable Faraday cup has been mounted on another cover. This same arrangement is used between cavities 3 and 4 with the axial space being about 14 inches.

Following cavity 4 there is 1 meter between cavities. Figure 12 shows the arrangement from the end of a cavity to a standard 2-in. vacuum valve. A segmented beam scraper is mounted on the half drift tube. A toroid is mounted in the end bell enclosure. Between valves there is presently a beam pipe, but this will be replaced by chambers as need for future equipment.

Acknowledgments

The authors wish to acknowledge the design effort of Don Breyne, the Linac Machine Shop under Luther Hardy that made it possible to have components when required, the weld shop under Pete Surman who had a man when needed to fit our schedule, and all the technicians under Jim Hogan who put it together to make scheduled after scheduled dates.

References

[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.

[2] B. Austin et al., The Design of Proton Linear Accelerators for Energies Up to 200 MeV, MURA Report 713, 1965, p. 4 (unpublished).

[3] Maxwell Palmer and James Hogan, The Alignment of Tanks and Drift Tubes for the NAL 200-MeV Linac Using a Laser Light Beam, Proc. of the 1970 Proton Linear Accelerator Conference, National Accelerator Laboratory, p. 719.

[4] C. W. Owen and J. D. Wildenradt, Experiences with Post Coupler Stabilized Structures in the NAL Linac, Proc. of the 1970 Proton Linear Accelerator Conference, National Accelerator Laboratory, p. 315.

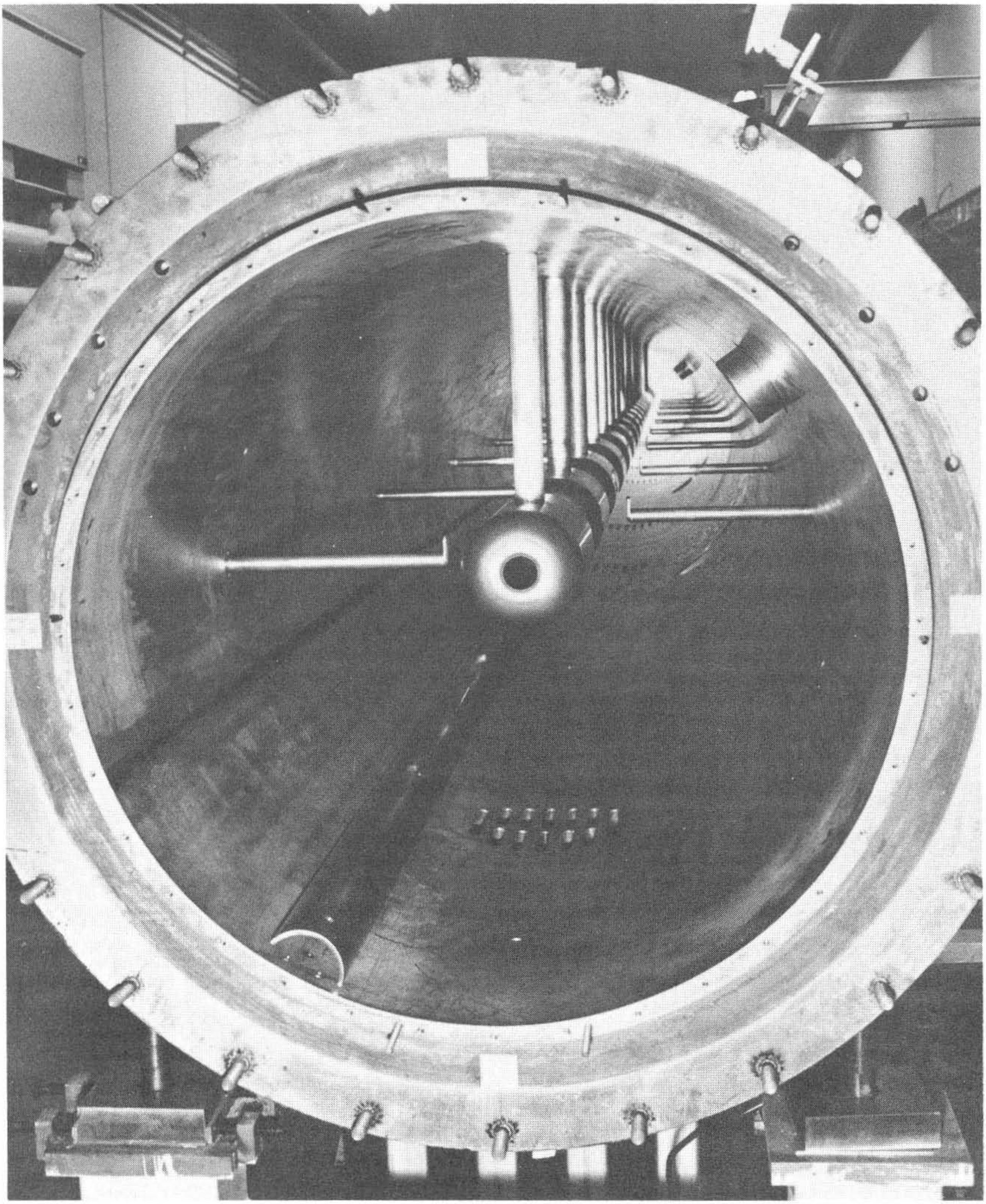

Fig. 1. Interior of linac cavity.

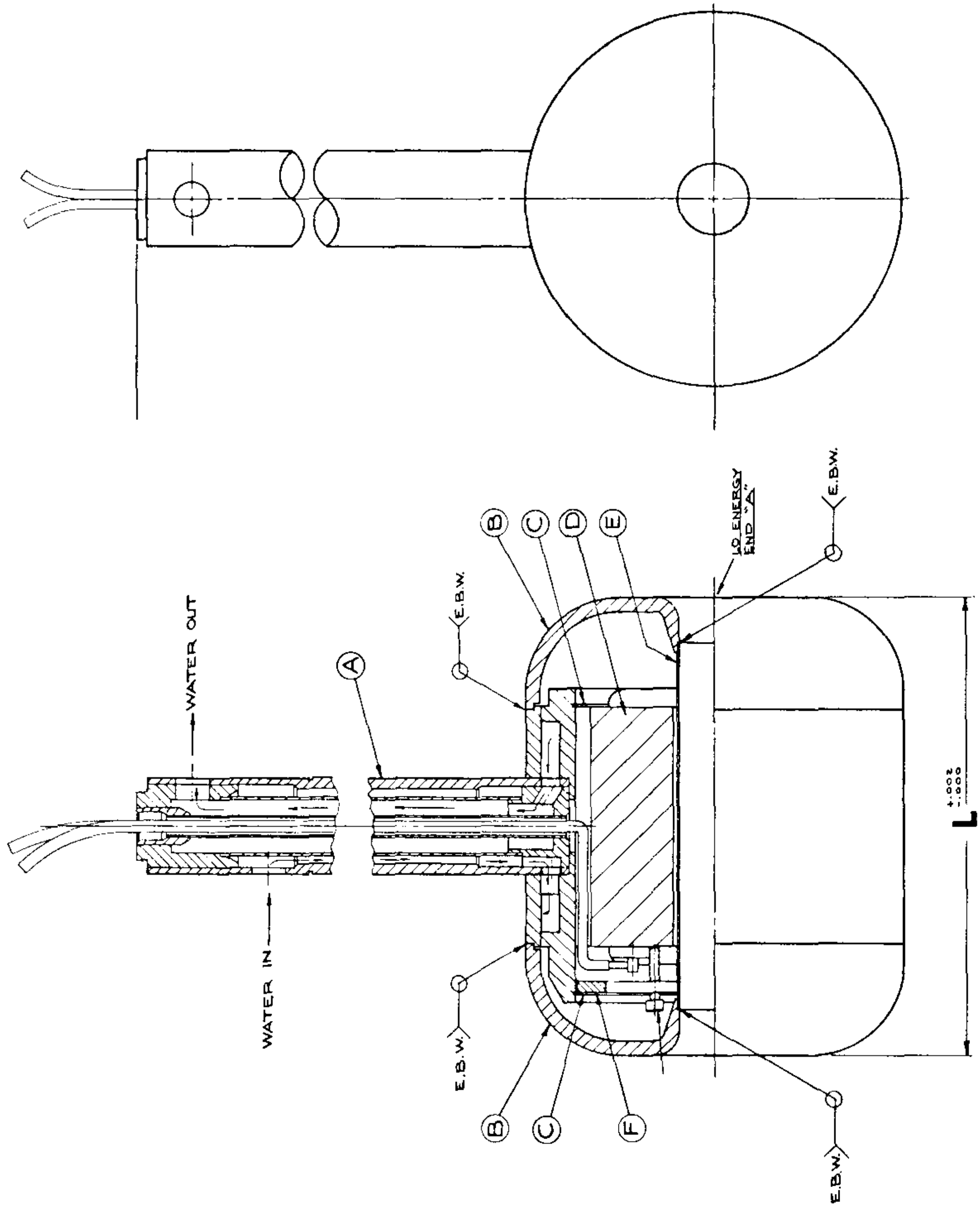

Fig. 2. Drift-tube construction.

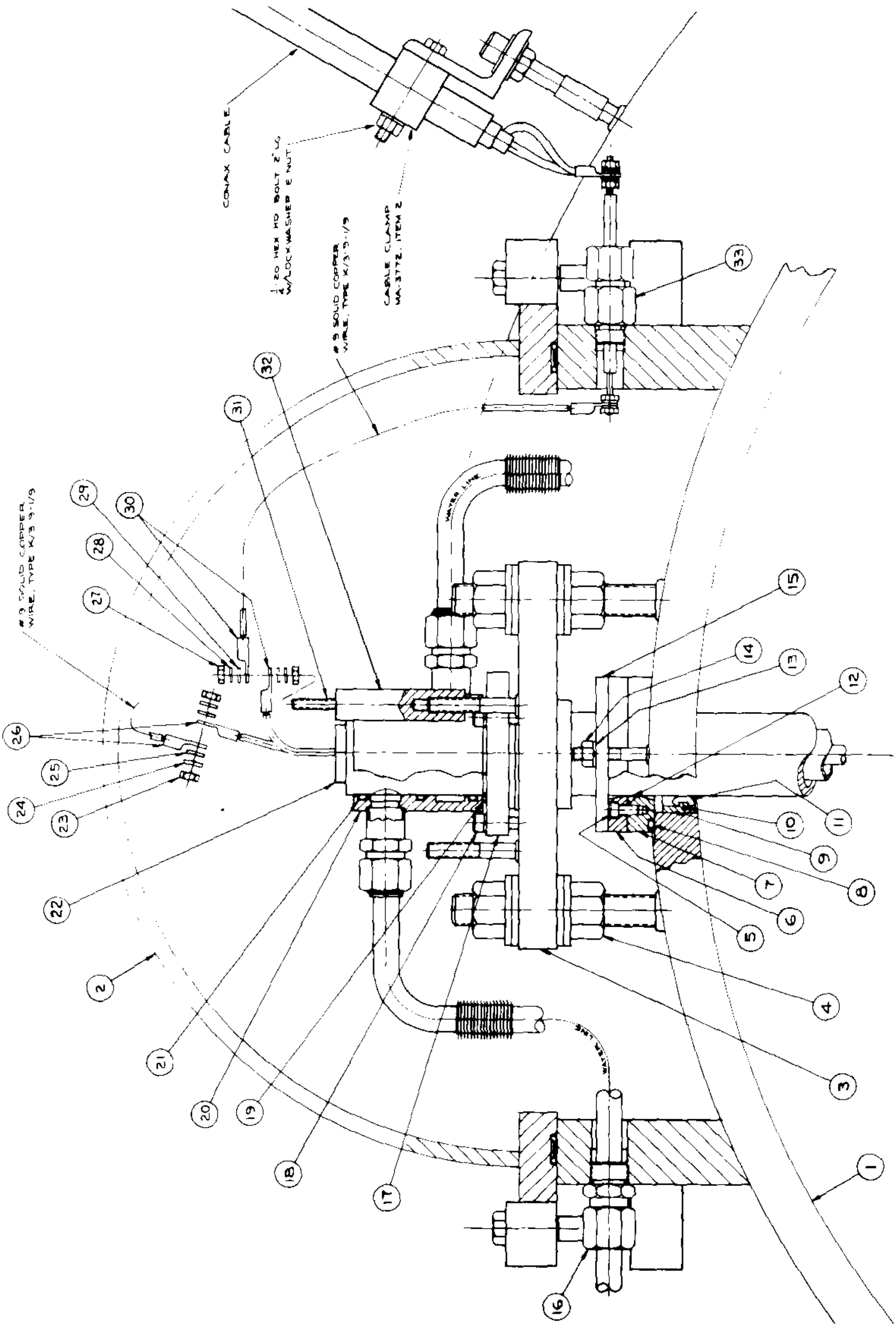

Fig. 3. Drift-tube support and service.

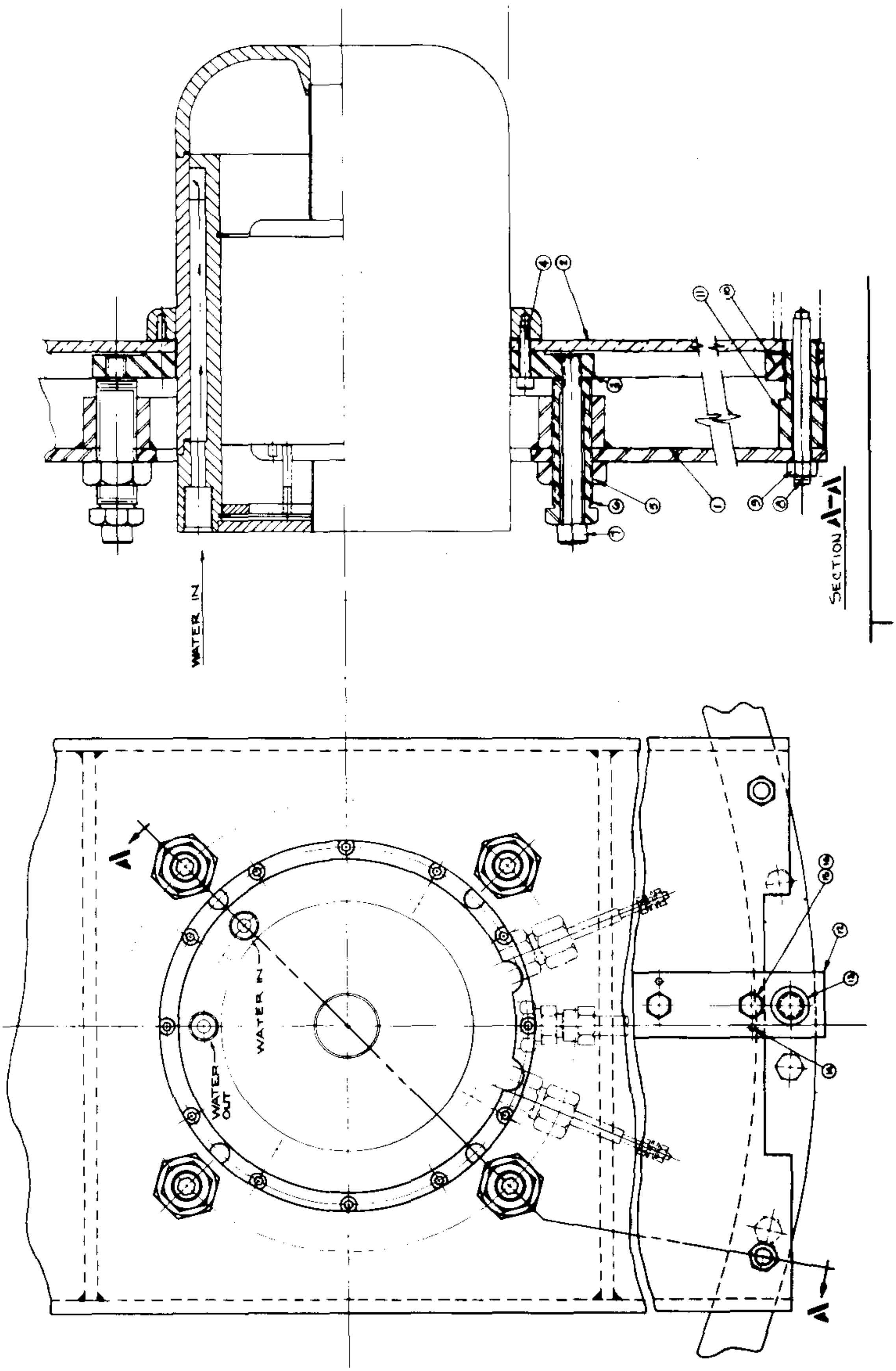

Fig. 4. Half drift tube and axial adjustment.

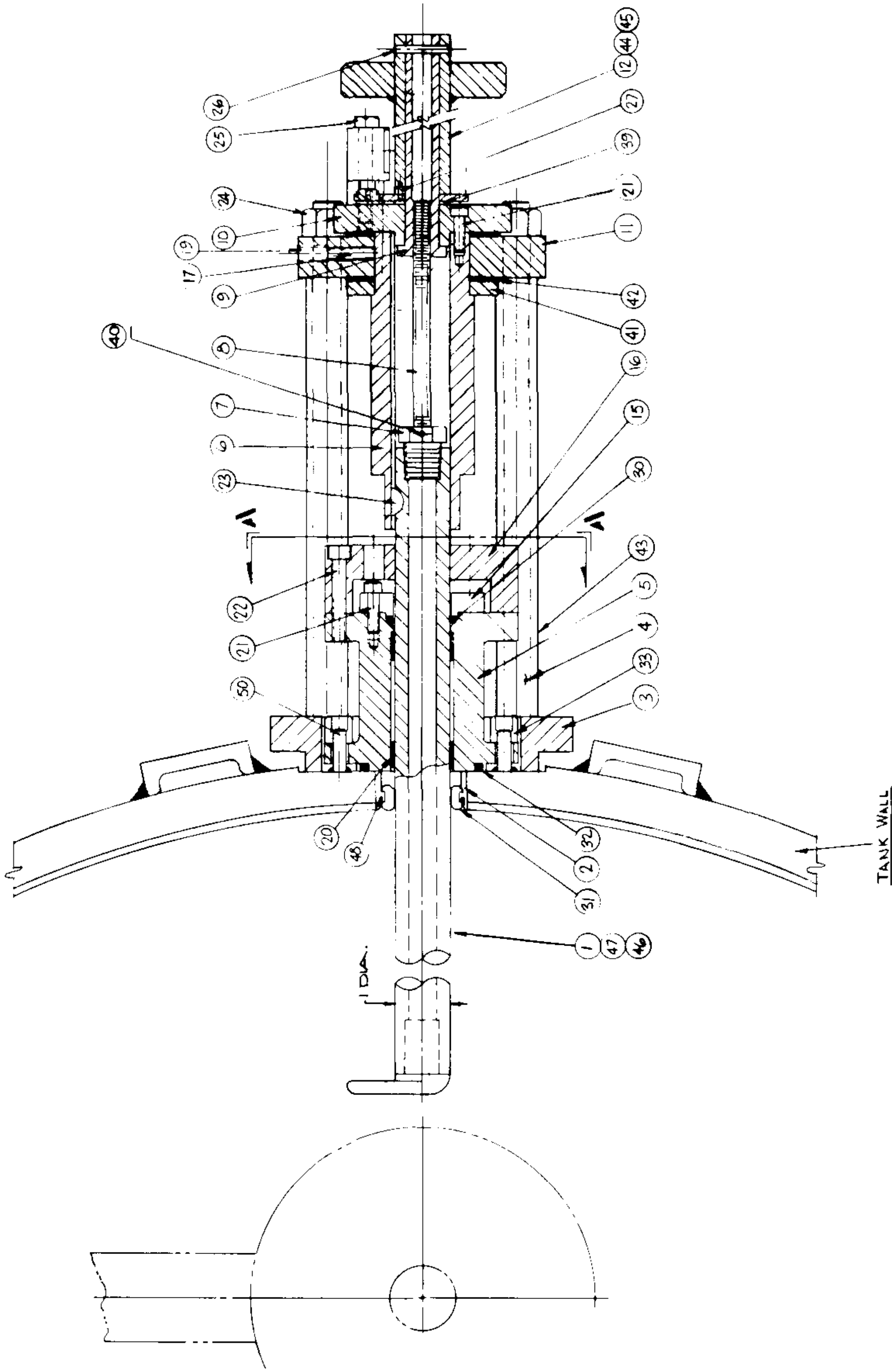

Fig. 5. Post coupler with adjusting mechanism.

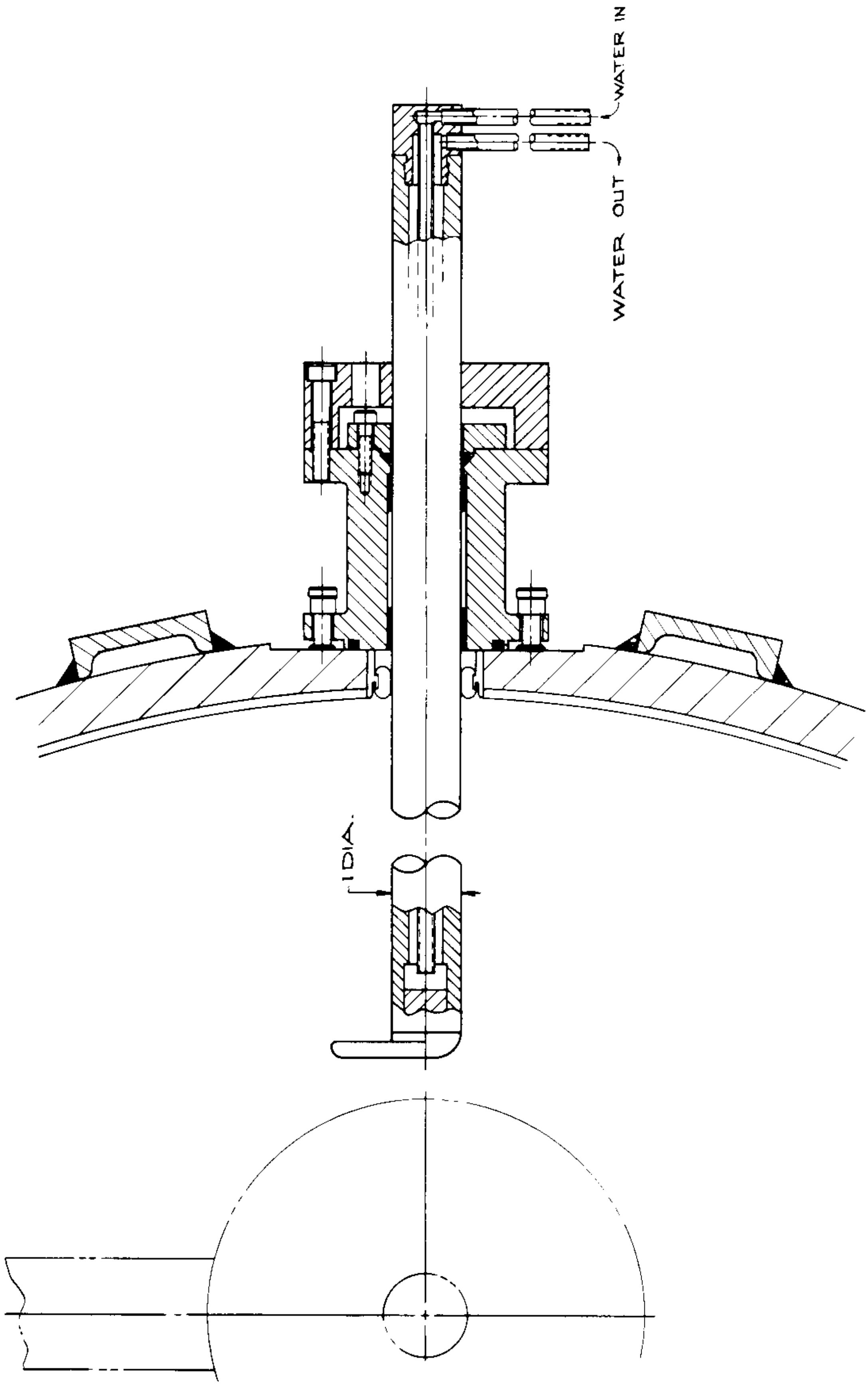

Fig. 6. Post coupler in operating condition.

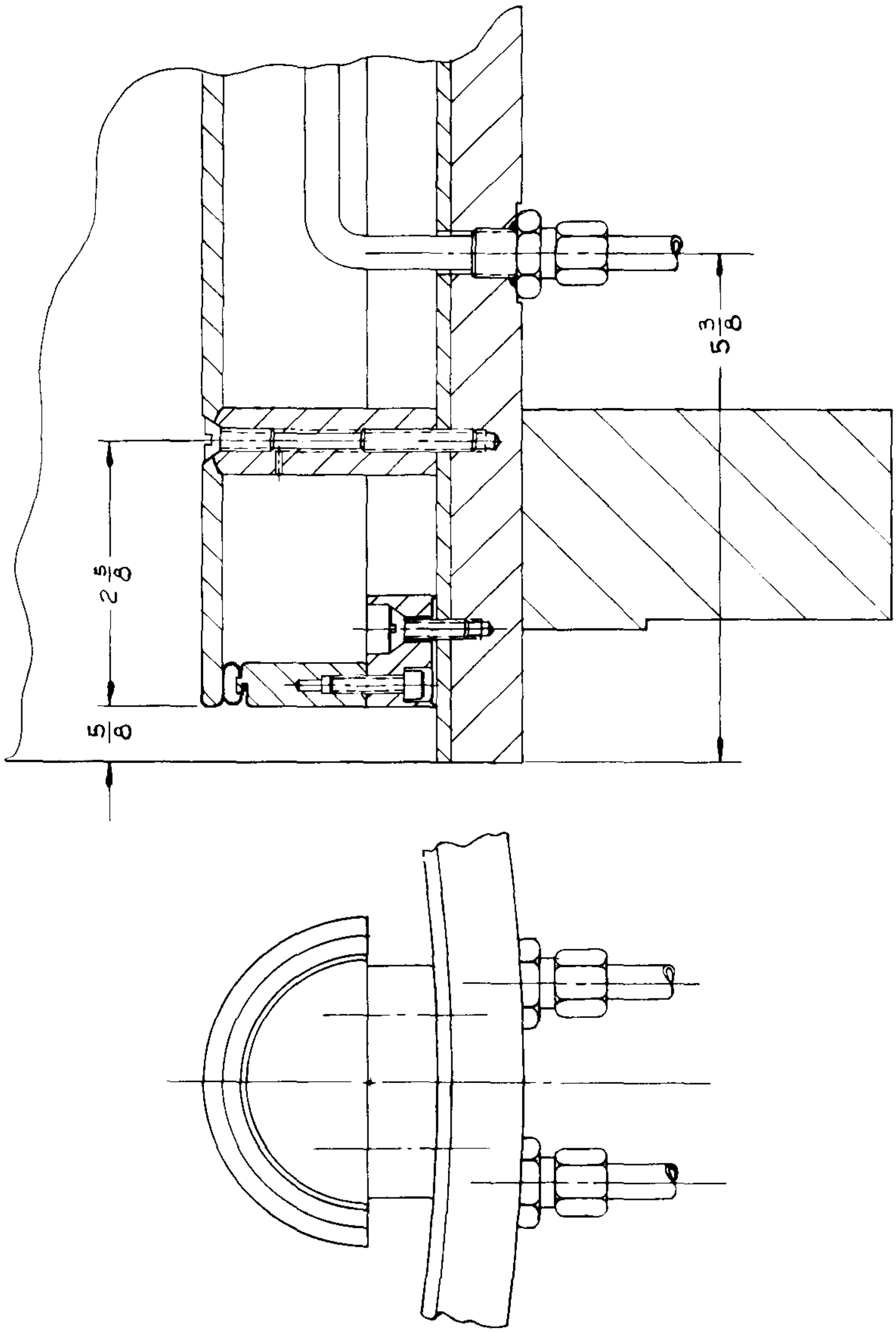

Fig. 7. Bulk tuner.

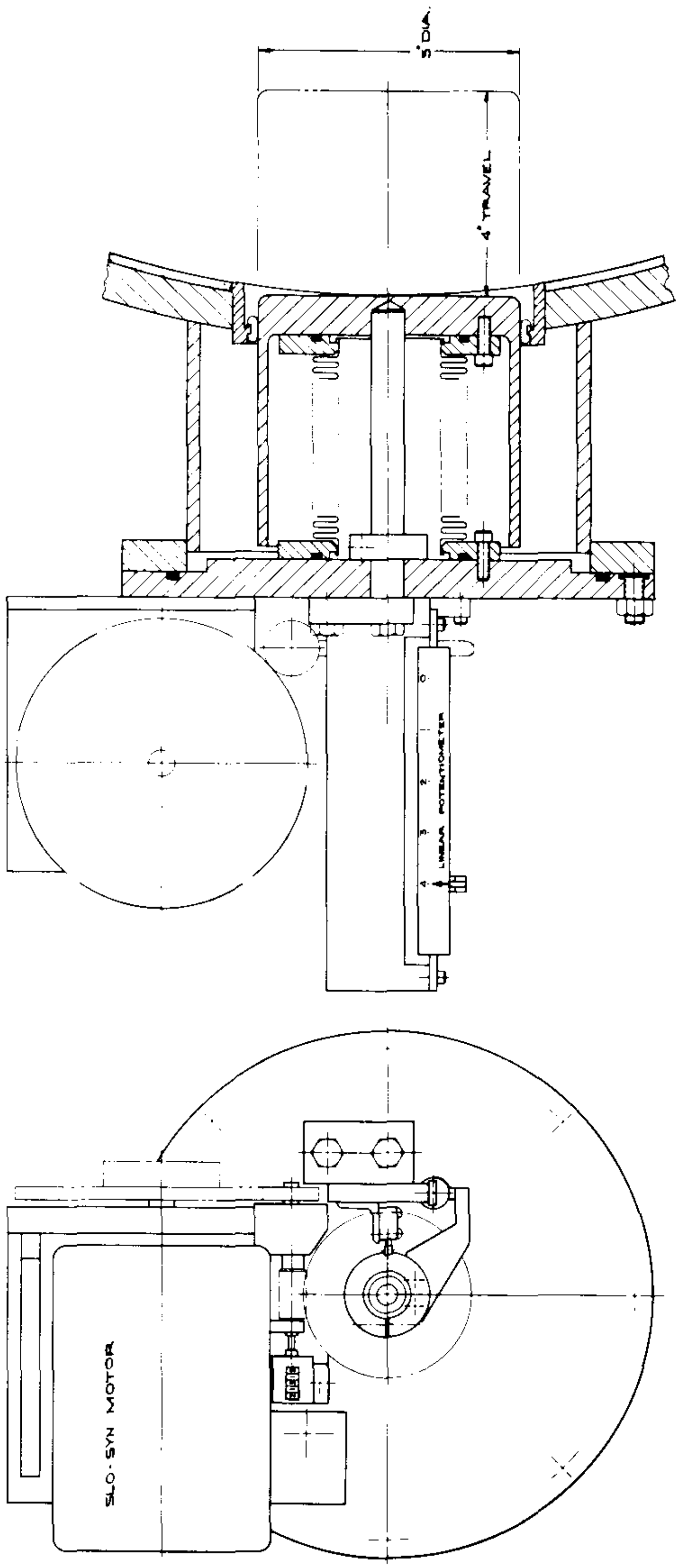

Fig. 8. Motorized tuner--cavity 2 through 9.

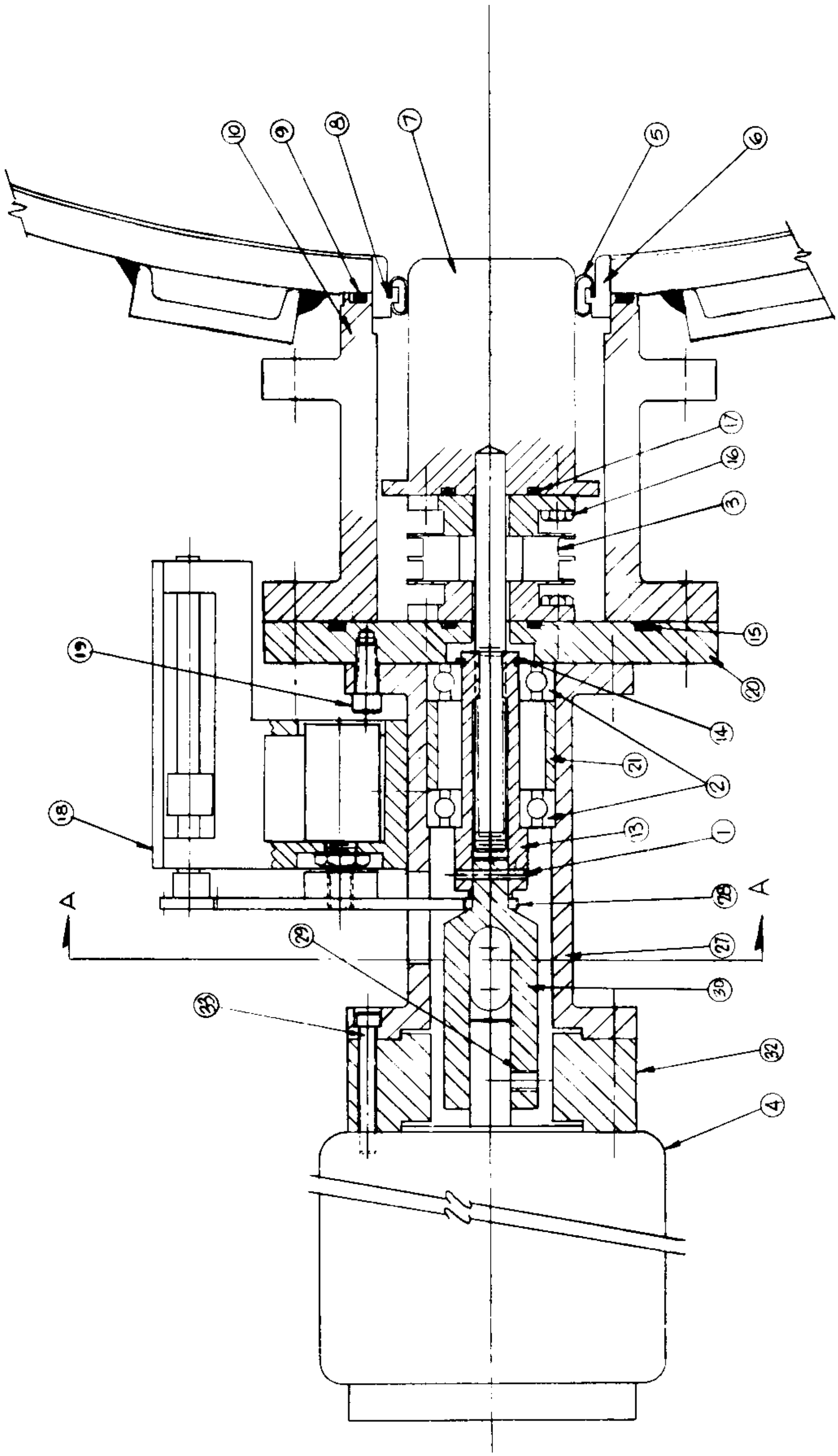

Fig. 9. Motorized tuner--cavity 1.

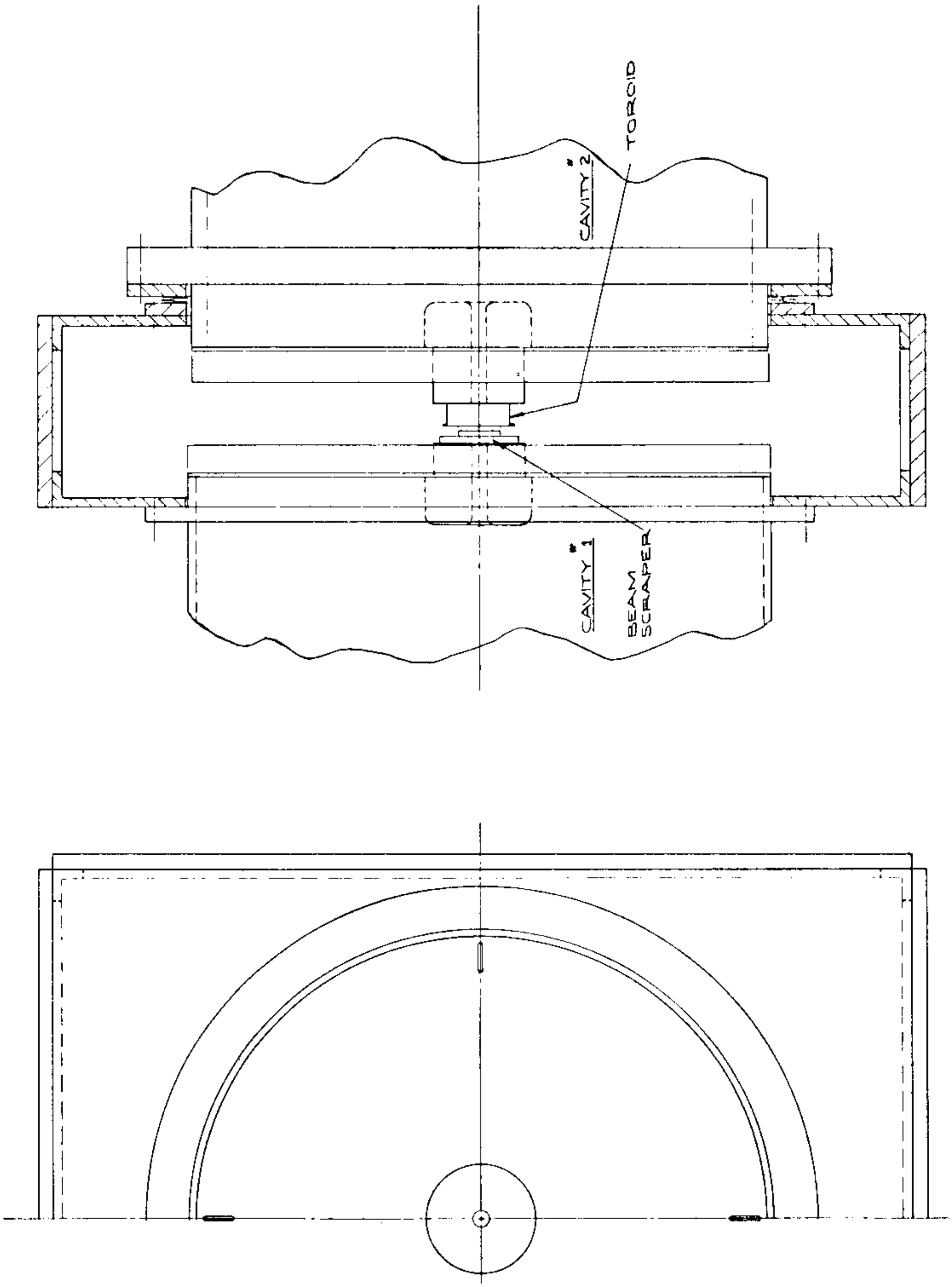

Fig. 10. Diagnostic area between cavity 1 and 2.

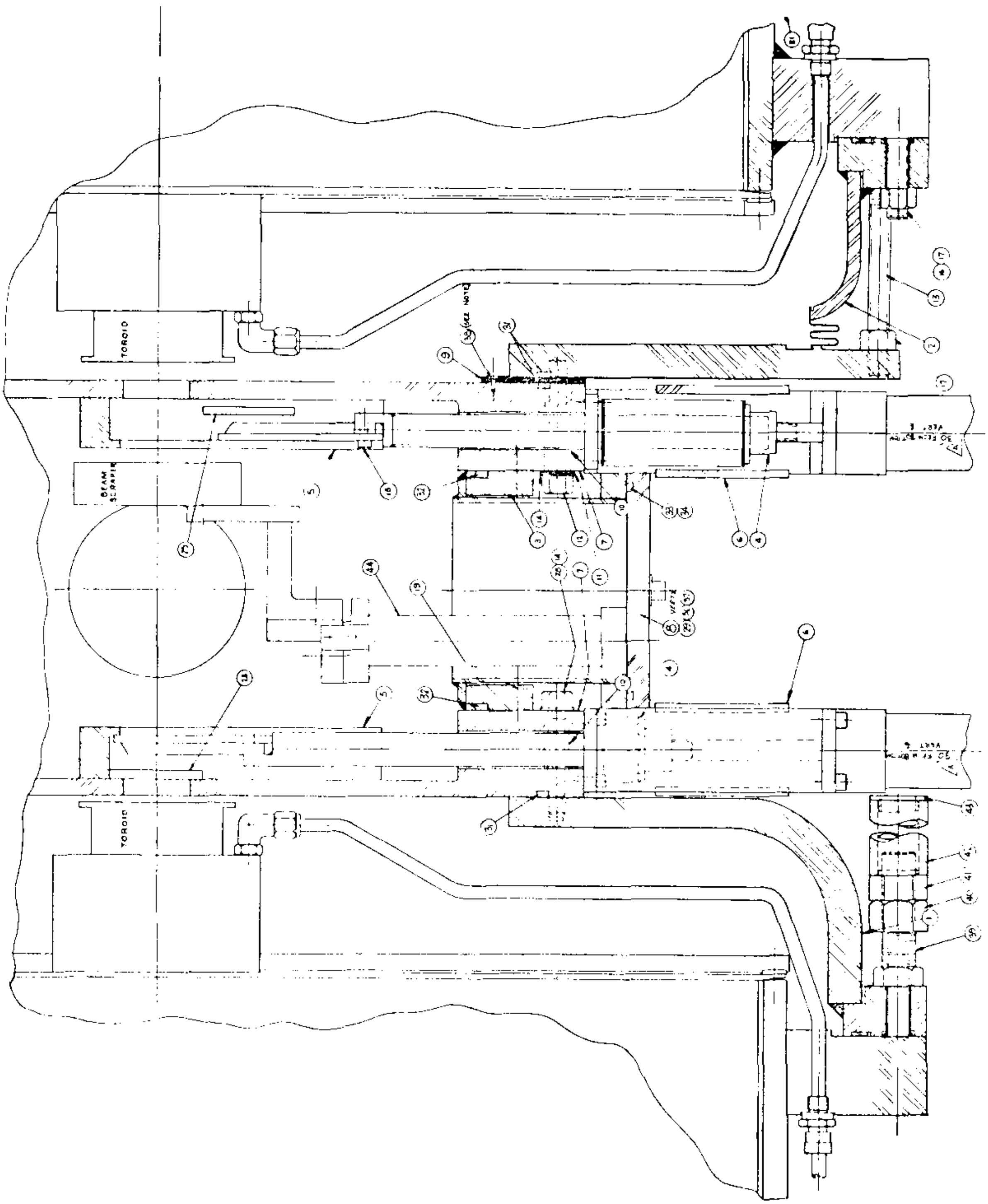

Fig. 11. Diagnostic space between cavity 2-3 and 3-4.

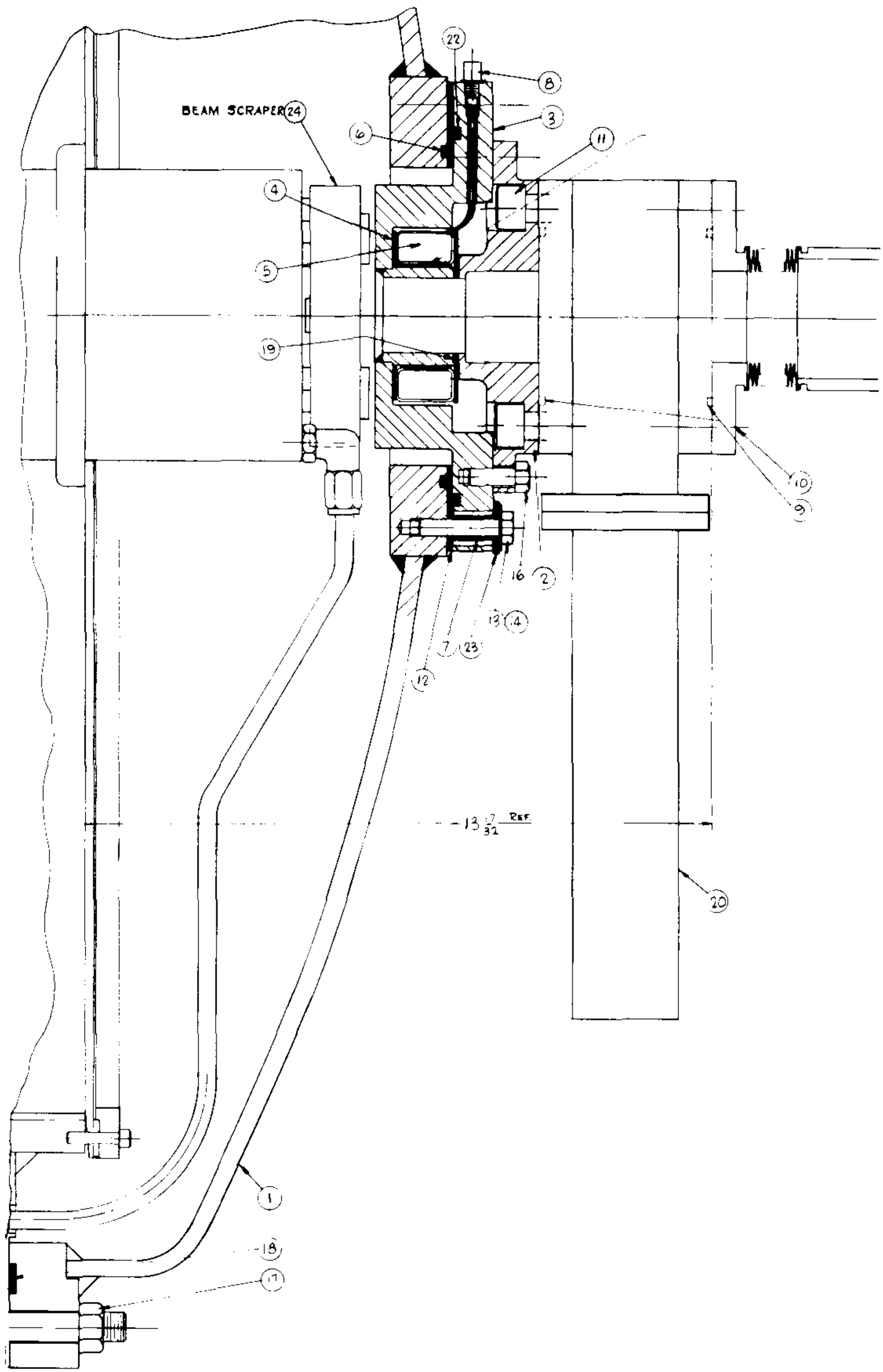

Fig. 12. Cavity termination 4 through 9.

DISCUSSION

J. P. Blewett (BNL): You mentioned the possibility of water cooling on the tuning bar and the tuning stubs--has that been used?

M. Palmer (NAL): It is being used now; I don't know how much is required. We do have water on the unit, but we don't have any way of knowing whether we are getting much heat out of it or not. We haven't done any monitoring of the water outlet.