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CoA Memo. No. 143

December, 1967

THE COLLEGE OF AERONAUTICS

DEPARTMENT OF MATERIALS



High temperature creep properties of ceramics

United Kingdom Atomic Energy Authority

Agreement No. SP0/A30081/EMR

- by -

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## Introduction

An existing high temperature rig, originally constructed for torsional creep on graphite<sup>1</sup> was adapted for work on the high temperature creep properties of ceramics. Use of the rig, with minor modifications, for torsional creep on ceramics was not successful and major modifications to enable creep in tension and compression were carried out.

## The torsional rig

Figure 1 shows the torsional rig, with only the grips modified from the original construction. The apparatus consisted of a high temperature furnace and control equipment together with apparatus for torque application and strain measurement. Briefly, the furnace consisted of a graphite tube supported from water-cooled copper electrodes and surrounded by carbon, molybdenum and stainless steel radiation shields. These were housed in a cylindrical water-cooled mild steel vessel which was either evacuated or connected to a gas supply. The furnace element was connected to the secondary winding of a 10:1 step down transformer, the primary circuit of which was connected to a single phase high current mains supply through a saturable reactor. Power to the furnace was regulated by the saturable reactor which was controlled by the amplified out of balance signal from a potentiometric recorder. The temperature sensor which fed the recorder was either a total radiation pyrometer (above 1500°C) or a platinum-rhodium thermocouple (below 1500°C). Temperatures of up to 3000°C were possible.

The control of the hydraulic torque system proved to be too coarse for use with the ceramic specimens supplied, leading to failure on loading. Alumina specimens of gauge length 1" and diameter 0.090" were used in the trials and the torque required was of the order of 1 lb.ins. At this level of torque, the torque actuator could not be controlled. In addition, due to their small size in relation to the loading grips, a number of specimens were broken during handling prior to the tests and few data were obtained. Modifications to increase the sensitivity of the torque system were not a simple matter and it was considered easier to convert the apparatus to uniaxial straining initially in tension and subsequently in compression.

## The tensile rig

Figure 2 shows the rig converted for tensile use. The furnace system was retained. Application of tensile stress to the specimen was effected by suspending weights from the lower specimen grip. Attempts at placing the weights by hand were unsuccessful; the specimens, being very brittle, were fractured with the unavoidable twisting of the lower grip relative to the specimen. To eliminate this, a mechanical method of loading was devised. For this, the weights are carried on a sliding frame which was raised or lowered by means of an electrically driven jack. This allowed the weights to be positioned without twisting the specimen grip and without impact.

The jack, weights and sliding frame were contained in a vacuum tight mild steel box, which was supported from the under side of the furnace. A window was placed in the side of the box to allow observation of loading and movement of the lower grip during creep. This movement was followed with a travelling telescope system, positional changes in which were determined with an attached clock gauge.

The specimen grips were to be of graphite. Unfortunately this part of the construction has not been completed since the final design depends on the shape and size of the available specimens and it has so far not proved possible for the U.K.A.E.A. to manufacture specimens to the dimensions suggested by the College.

#### The compression rig

In view of difficulties of specimen preparation, it was decided to further modify the equipment for compression creep of ceramic cylinders which could be readily hot pressed and ground. The compression rig is shown in Figure 3 with again the furnace system unchanged. From the top furnace plate a water cooled housing supports the upper push rod. The lower push rod passes through a linear bearing held in a water cooled housing attached to the bottom furnace plate. Load is applied to the specimen by the lower push rod which is coupled to a lever system from which weights are suspended. This lever is pivoted on knife edges, as are the weight pan and the coupling to the push rod. The lever arms are in the ratio of 3 to 1.

Detail A, Figure 4, shows the housing for the upper push rod. Two graphite probes pass through the graphite push rod and are each joined to a steel rod that connects with a transducer. These transducers are coupled to measure the differential movement between the probes.

Detail B, Figure 5, shows the arrangement in the region of the specimen.

The upper push rod is capped by a ceramic disc (urania) for hardness and to distribute the stress. A tungsten shim separates this ceramic anvil from the specimen and both the shim and anvil are held in place with a graphite ring. Part of the shim and the anvil are cut away to allow one of the graphite probes to connect with the lower push rod. The other graphite probe is supported by the anvil.

The lower push rod carries the compression specimen which is cylindrical in shape, being 5 mm. diameter and 7 mm. long. A tungsten shim, ceramic disc and molybdenum disc with a ceramic ring to locate the specimen on the axis of the push rods are supported also on the lower push rod. All of these are kept in place by a graphite locating ring. A platinum/platinum-10% rhodium thermocouple enclosed in an alumina sheath is positioned just under the specimen in a hole along the axis of the lower push rod.

Detail C, Figure 6, shows the lower push rod housing. The graphite push rod is sleeved into a water cooled steel rod that slides in a linear bearing. A flexible gas seal is made between the rod and the housing. A coupling (not shown) connects the push rod to the lever system. Before application of the load the weight of the complete push rod and coupling are balanced out.

The measurement system for strain has been designed to eliminate, as far as possible, any movement apart from the creep of the specimen. This is necessary since the specimen is short and therefore only small total length changes, of about 0.010-0.015 inches, are contemplated. By not determining the creep deformation from the movement of the lower push rod relative to some 'fixed' point such as a point on the furnace case, it is possible to eliminate any creep in the push rods and movements caused by temperature variation in both the furnace case and the push rods. Any creep in the probes, which should be small because of the use of graphite and their light loading (about 25 p.s.i.) will tend to be cancelled because they are coupled differentially. The transducers (made by Sogenique Ltd.) are capable of detecting movements of  $10^{-5}$  inches, which is about 0.1% of the contemplated length change.

#### Conclusion

After a considerable amount of effort, an apparatus suitable for studies of high temperature creep in ceramics has finally been developed from the original rig constructed to study creep of graphite. Unfortunately difficulties with specimen preparation and handling prevented any useful results being obtained for torsion and tension stress systems. However initial trials with compression specimens indicate that useful results can be obtained with the final layout of the equipment.

#### References

1. 'Characteristics of the High Temperature Mechanisms of Creep and Recovery in Graphite', U.S. Army Contract No. DA-91-591-E.U.C. 1759, Final Technical Report No. 1, The College of Aeronautics, Cranfield, 1962.

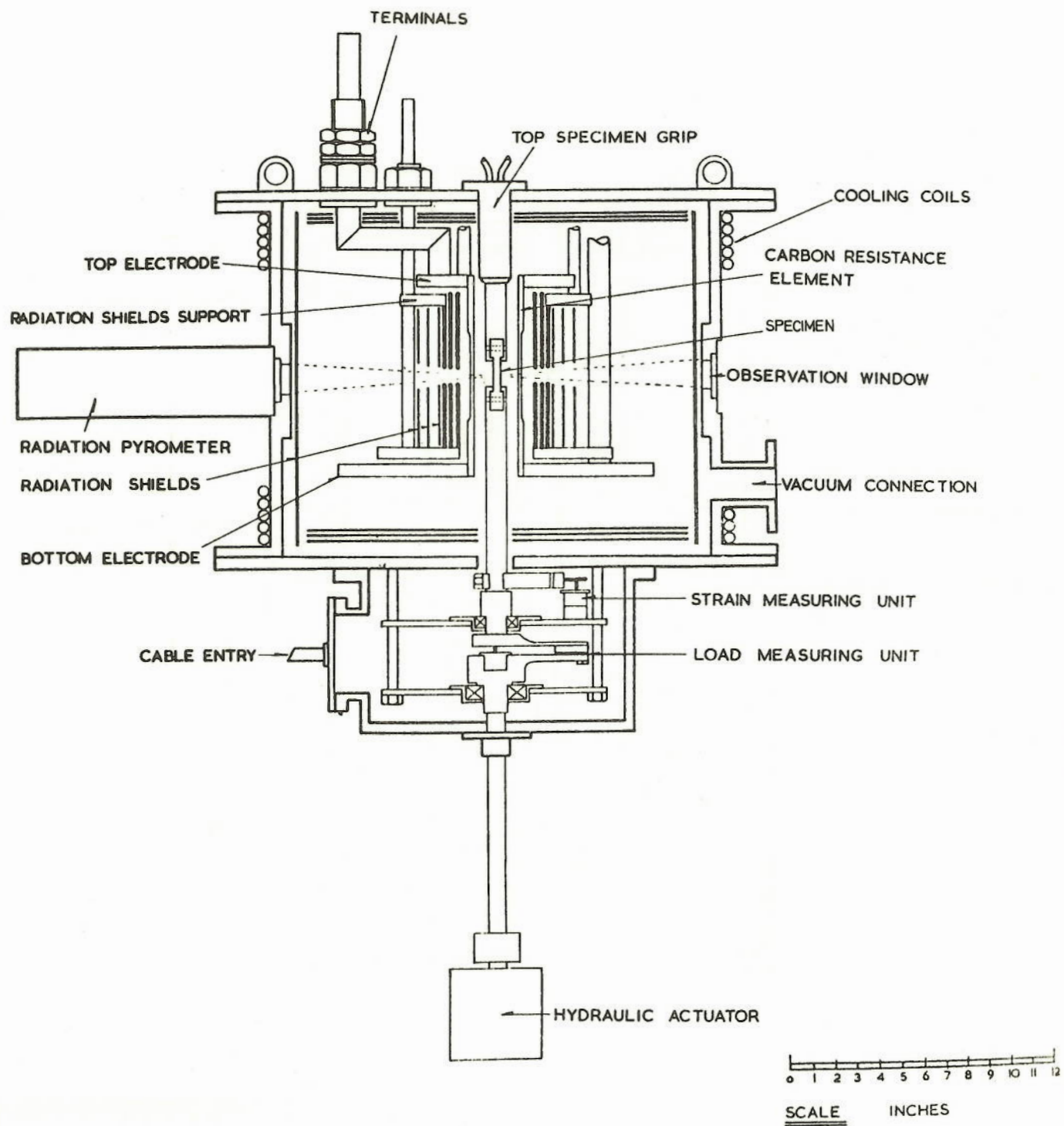


FIG. 1. DIAGRAM SHOWING GENERAL ARRANGEMENT OF UPPER AND LOWER CHAMBERS OF TORSION RIG

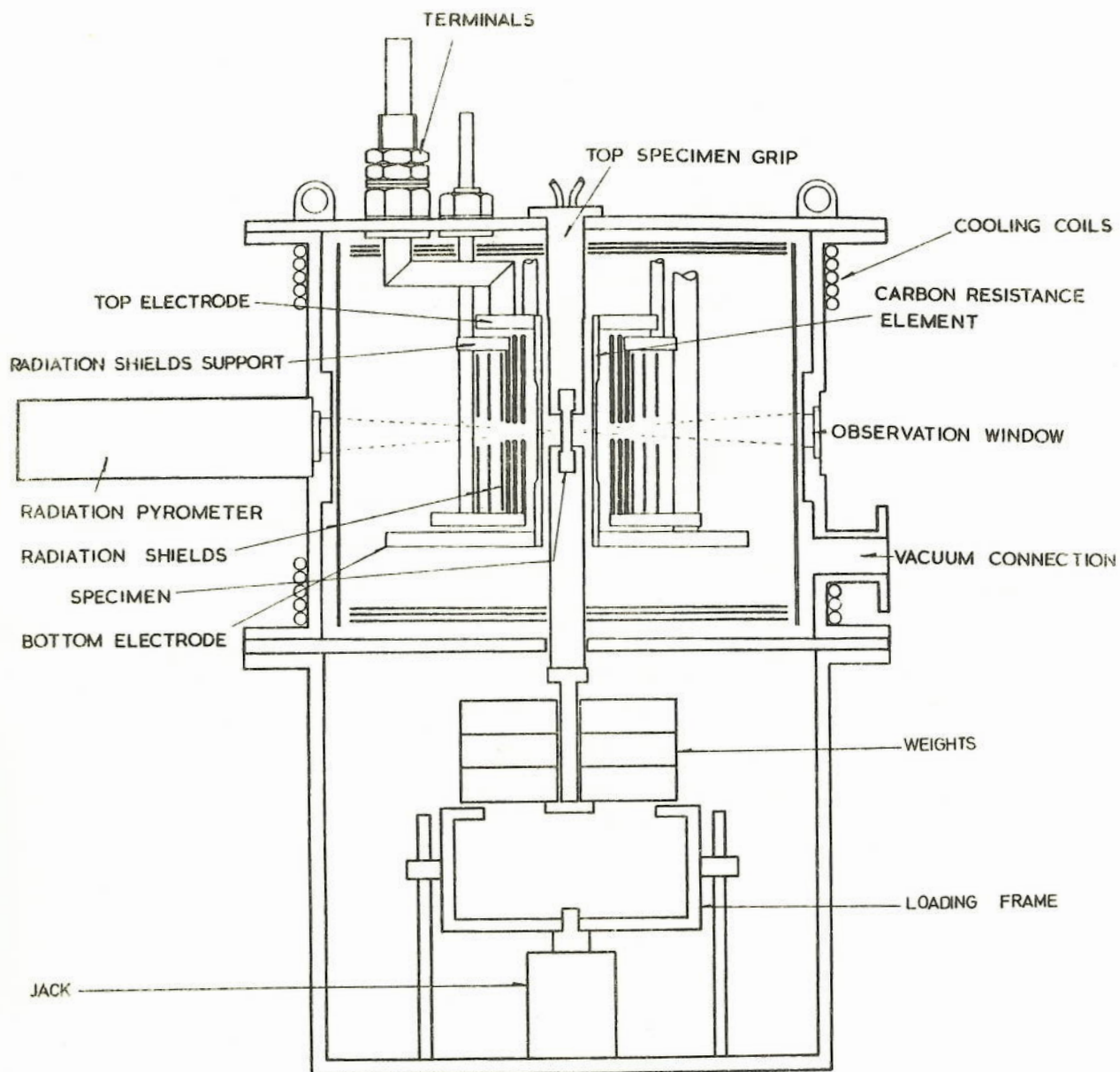


FIG. 2. TENSILE RIG.

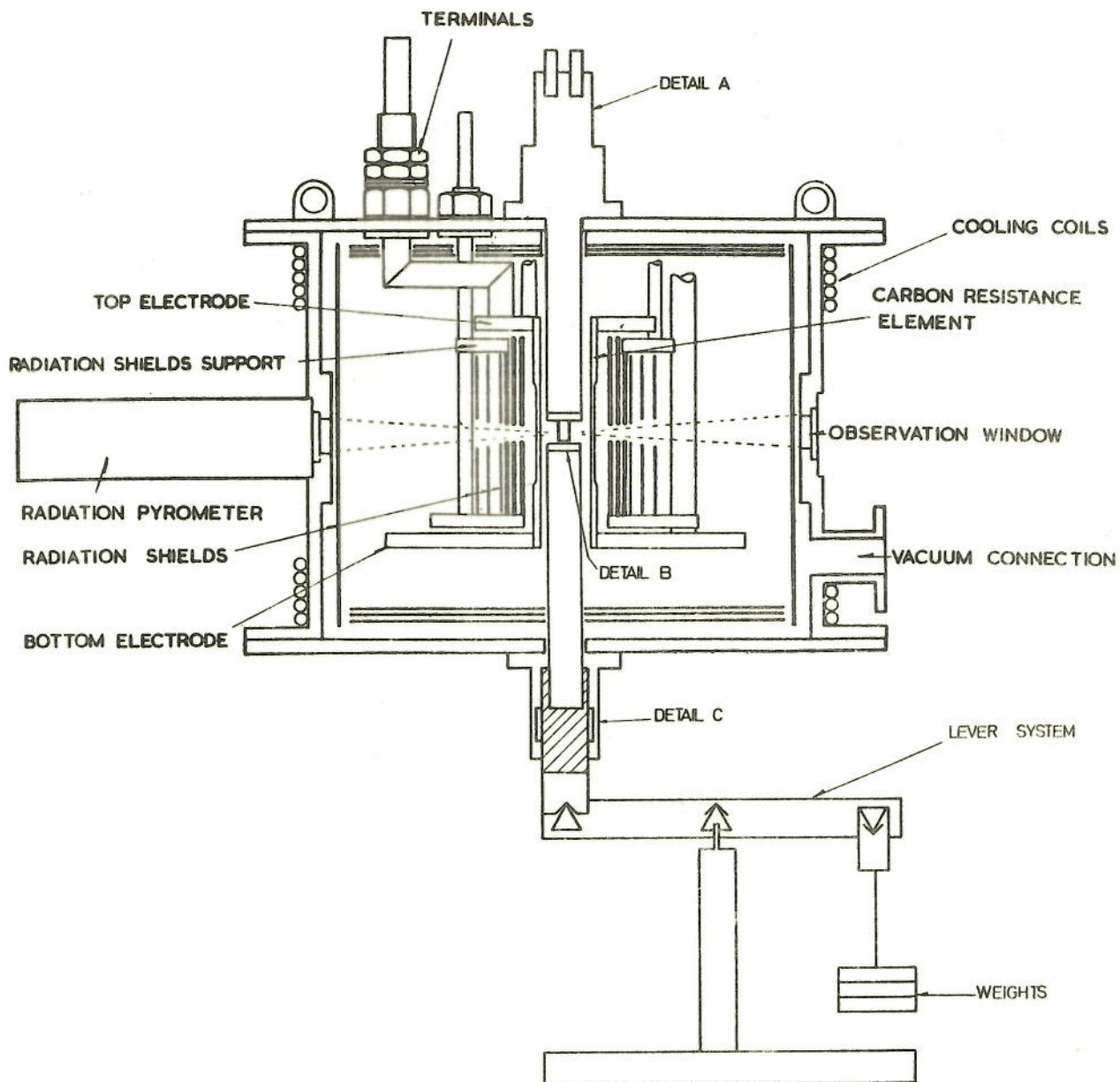


FIG. 3. COMPRESSION RIG.

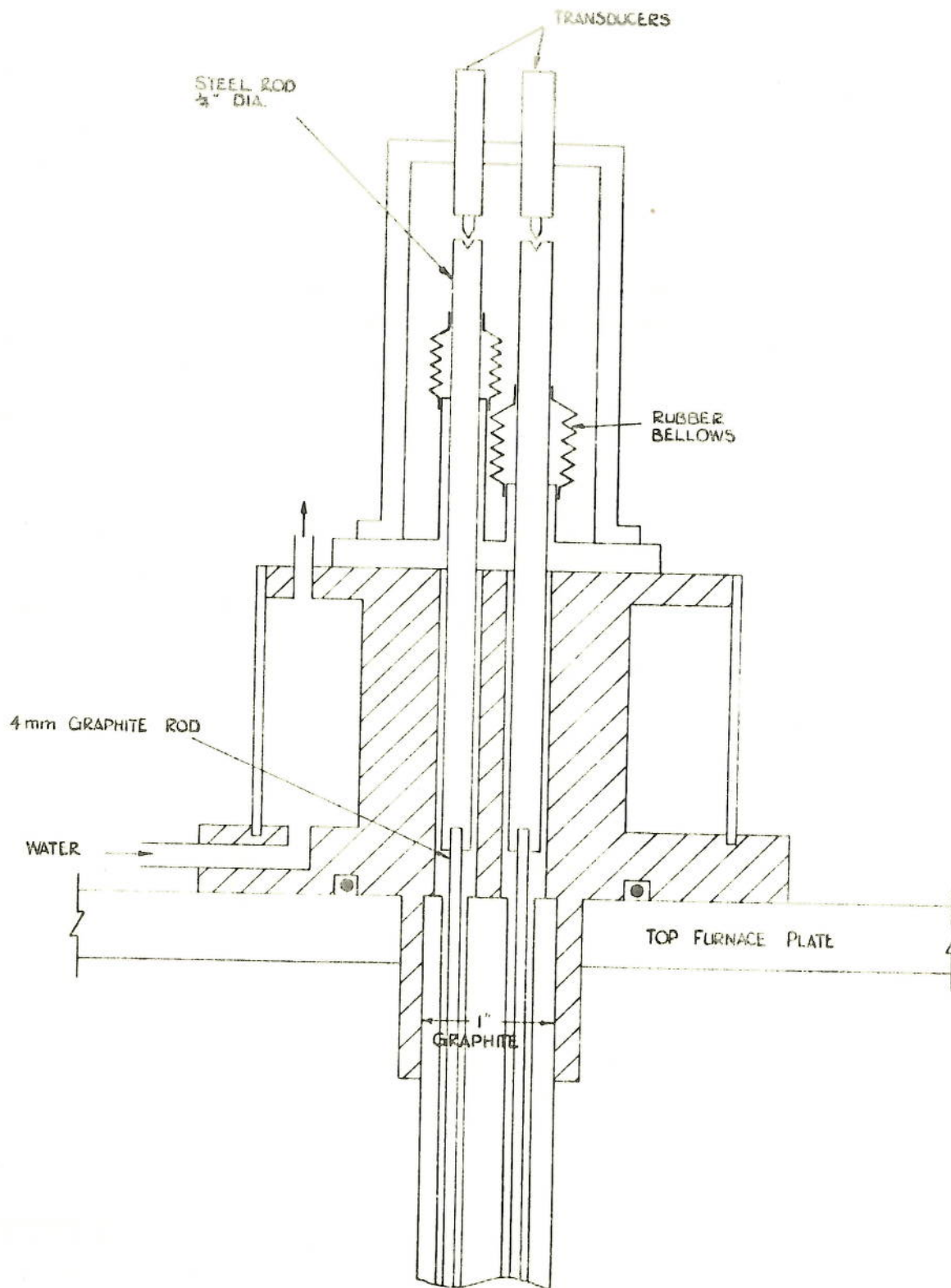


FIG. 4.

DETAIL A.

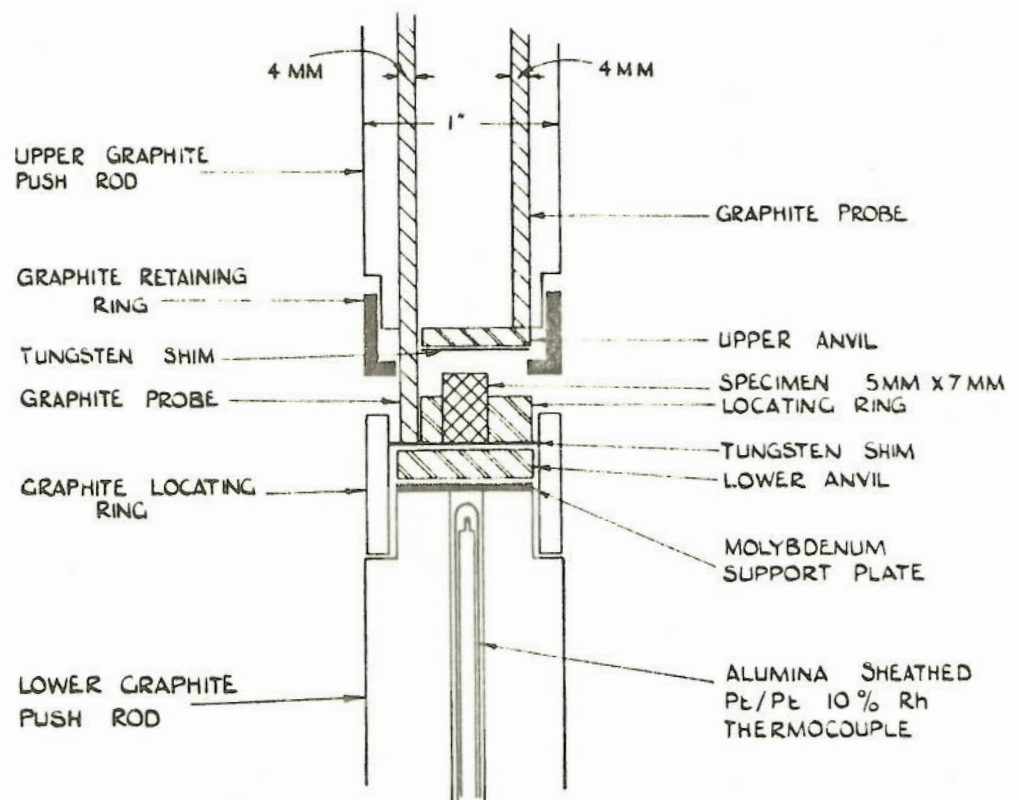


FIG. 5.

DETAIL B.

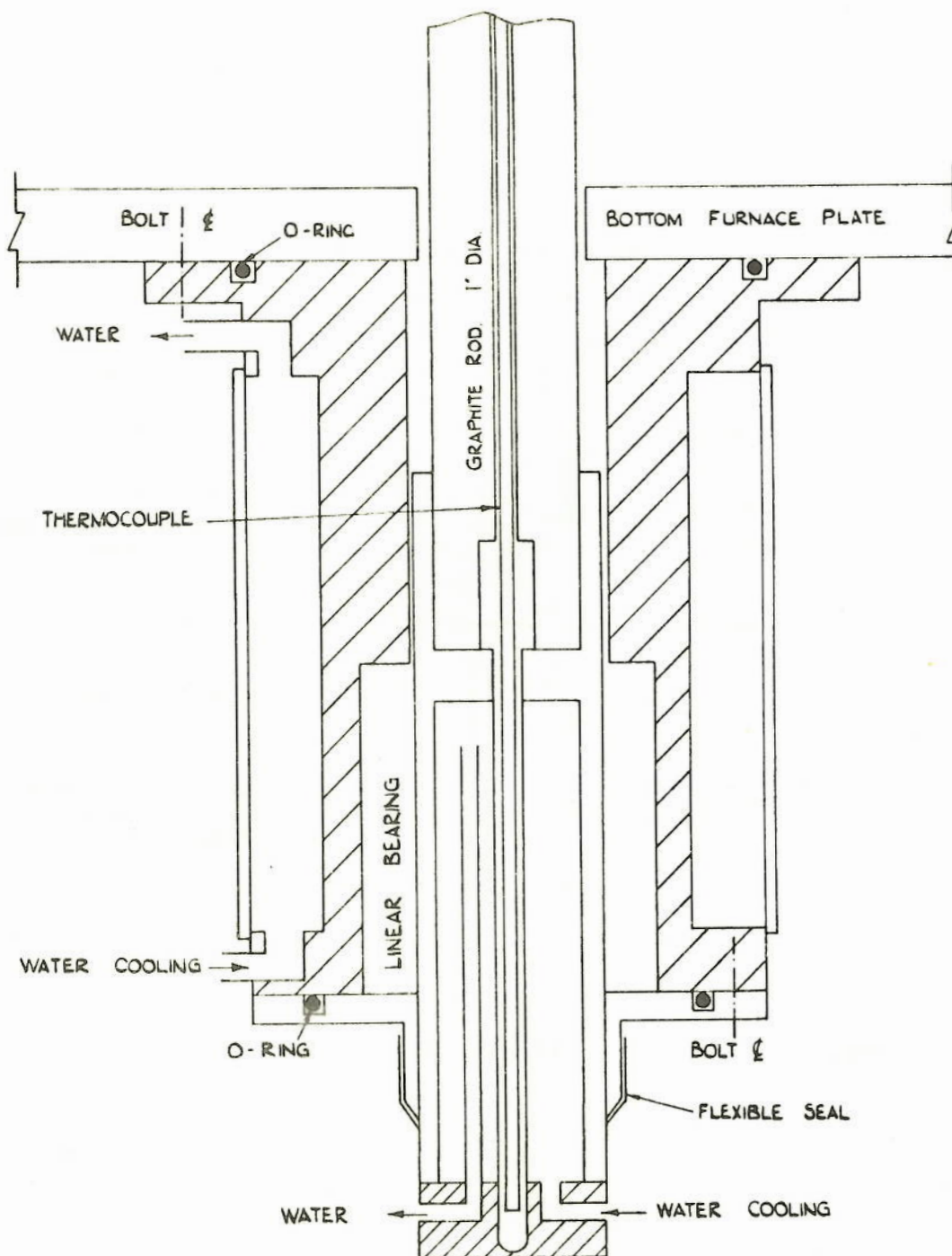


FIG. 6.

DETAIL C.