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PAPER 2.1

UPDATING OF EQUIPMENT FOR THE POST IRRADIATION EXAMINATION OF ADVANCED GAS COOLED REACTOR FUEL ELEMENTS AT WINFRITH

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SUMMARY

After 11 years operation of the 7 cave line at Winfrith for the post irradiation examination of water and advanced gas cooled reactor fuel, refurbishing and re-equipment was undertaken. A primary requirement of the re-equipment was that it should cause the minimum disruption to the examination programme.

The paper describes selected items that have been manufactured to fulfill the needs of fuel element examination and discusses the policy on which the re-equipment was based.

1. INTRODUCTION

The 7 cave line at Winfrith was refurbished and re-equipped for the examination of fuel elements from water and commercial advanced gas cooled reactors (CAGR's) in the early 1970's and began operation in 1974. Since that time pins from ~ 25 water reactor fuel elements together with over 500 CAGR fuel elements and components have been examined. Although during the 11 years of operation various modifications to the in-cave equipment were made it was decided to embark on a major refurbishing scheme in 1983.

The present paper sets out the policy followed during refurbishing and describes selected items of equipment.

2. DESCRIPTION OF THE 7 CAVE LINE

The layout of the Winfrith 7 cave line is shown in Fig. 1. A receipt and dispatch cave for flask loading, crane maintenance and equipment transfer is located at the end of the line (cave 7) and immediately adjacent to it is the storage and bottle handling cave (cave 6). Caves 4 and 5 are used for the inspection, testing and breakdown of complete fuel elements and the adjacent cave 3 is reserved for pin cutting, multi pin stress rupture testing and waste disposal. Detailed inspection, measurement and testing of fuel pins takes place in caves 1 and 2. At this end the line is terminated by an unshielded transfer chamber which is used for equipment transfer and crane maintenance. Each cave has a work station (a zinc bromide filled viewing window plus a pair of manipulators) on the front and on the rear face.

Three hoists are available within the line for lifting and transfer and in-cave manipulation is carried out by NEL number 9 or VNE 80 heavy duty manipulators. Roof posting facilities are available for the introduction of small items of equipment and above cave 2 there are 2 shielded flasks into which fuel pins can be drawn for γ scanning. Sliding partition doors are available at each end of the line and between caves within the line.

3. REMOTE HANDLING POLICY

When cave operation began in 1974 the equipment, as far as was possible, was designed so that it could be removed for major repair or disposal. Items that were fixed were the storage carousel and the multi pin stress rupture rig. As described later the latter item caused many problems.

The policy of remotely removable equipment was retained during refurbishing and on each item drive motors were arranged to be remotely removable so that day to day breakdowns were not unduly disruptive. On the measurement machines computer control was introduced wherever possible to ensure that a prearranged schedule was followed and that preliminary assessment of the results could take place as measurement proceeded.

4. EXPERIENCE WITH THE ORIGINAL EQUIPMENT

The free standing items of equipment gave good service and this experience formed the basis of the re-equipment policy. Some items were insufficiently robust to cope with the work load and these required improvement.

The original decision to fix the multi pin burst test rig into the bench was a mistake as loss of fuel fragments from failed pins into the base of the rig caused major contamination problems. However, few problems were experienced with the fuel storage carousel and when attention was required it proved relatively easy to enter the cave after all active material had been removed.

The receipt and dispatch cave is cleaned and entered at the end of each posting sequence. The major source of contamination in this cave is the transfer of active dust from the remainder of the cave line by the hoist power supply cable as it passes through cave 7 to the reeling drum.

There have been few problems with the manipulators and the only problems with the windows occurred when internal sealing gaskets used on the work stations on the rear face broke down after ~ 5 years irradiation. These gaskets were replaced with improved materials and now, after a further 6 years, leaks from the zinc bromide containment tanks are apparent. Two of these were replaced in 1984 and it is intended to replace the remainder over the next few years.

Because of contamination problems in cave 2 caused by the multi pin stress rupture rig it was necessary to carry out a major cave decomtamination programme in order to allow man entry for its removal. The techniques used for this are the subject of a separate paper that is being presented at this meeting (Ref. 1).

5. DESCRIPTION OF SELECTED ITEMS MANUFACTURED IN THE RE-EQUIPMENT PROGRAMME

5.1 General

On the basis of previous experience together with the requirement that interruption to the work programme be minimised during the change over period, all equipment was designed to be free standing. The equipment was used either on the flat bench top or located on the service track that runs in front of the windows, according to need. Thus it was not necessary to close the cave line for installation.

All services were supplied through ports in the cave wall and could be remotely connected and disconnected. Although it was possible to post out complete rigs smaller items, such as drive motors, were arranged to be remotely removable so that outage time in the event of a breakdown could be minimised.

Selected items from the re-equipment programme are described below. They are grouped under the headings of fuel element handling, measurement and operational procedures.

5.2 Fuel element Handling

A CAGR fuel element is a bulky object being about 1 m long, 240 mms in diameter and weighing ~ 50 kilos (Fig.2). Since this is well beyond the lifting capacity of manipulators all in cave movement is made with travelling hoists and appropriate lifting grabs must be available for this. The fuel elements are received and dispatched vertically but all cave work is done with the element horizontal so that a mechanism for tilting the element is essential.

5.2.1 Debottling

Since fuel elements for post irradiation examination (PIE) are required in the as discharged condition i.e. dry, they are sealed in a nitrogen atmosphere in stainless steel transparent bottles at the power station. The first operation on arrival in the cave line is to remove the element from its bottle.

The majority of the bottles used are of the Hinkley type and consist of a base unit (on which the element rests inside its liner) with a valve and locking bolts and the bottle body which can be sealed to it. The debottling machine with a bottle in place is shown in Fig.3.

The first stage is to release the overpressure of nitrogen by operating a plunger to depress the valve in the base (see Fig.3b). The bottle gas is collected and sampled for Kr^{85} at this stage and this has proved to be a sensitive test for failed fuel pins. It has been possible to detect defective pins, which have an apparently normal internal gas composition, by this technique. When the internal pressure has been released the base locking bolts are withdrawn by the upward movement of a second plunger. The bottle body can then be lifted clear to expose the fuel element.

In this apparatus all the mechanisms are activated by air pressure and, in the event of a fault developing, it is possible to lift out the complete unit for repair. Since the unit is recessed into the bench, to give head room and allow viewing of the top of the element for lifting, location of the bottle must be automatic.

The previous unit worked well for over 8 years and the new unit is essentially a replica with improvements and refinements to the actuating mechanisms for the plungers.

5.2.2 Dungeness B Bottle Lifting Grab

This bottle is different from all others in that it retains the conventional principle of a sealing lid at the top end. Thus once the lid has been removed and the element recovered it is essential to have a method of lifting the empty bottle. The method adapted is shown in Fig.4 and relies on trapping a series of retained balls under a lip formed by a reduction in bottle diameter. When the grab is first picked up the actuator at the top rotates to engage on and move the outer cage upward with respect to the inner allowing the floating balls to retract into a recess (Fig.4b release). In this position the grab can pass over the largest diameter of the bottle. When it is lowered over the bottle the grab first contacts the top trapping the inner cage and further lowering allows the outer cage to move downwards and trap the floating balls against the bottle lip. At the same time the actuator is rotated so that it no longer acts on the outer cage and when the grab is lifted the bottle is picked up. When the bottle is set down the process is reversed and the grab is freed.

A major advantage of this system is that only the crane is required so that it is possible to pick up and set down bottles without the use of manipulators.

5.2.3 Fuel Element Tilting Cradle

This piece of equipment (Fig.5) is used to tilt the fuel element from the vertical to the horizontal plane. After loading the fuel element with the carrying bucket upright the upper end is clamped by operating a cam with the manipulator (Fig.5 detail). The element is then lowered onto a horizontal cradle by an actuator driven by a electric motor. When the upper clamp is released the cradle can be slid along the track to free the element from the carrying bucket. The fuel element can be rotated or swivelled on the cradle to any desired position.

This is a simple functional piece of equipment that is in frequent use and easy and reliable operation is essential.

5.2.4 Fuel Element Inspection Turntable

The first stage of the examination process involves detailed inspection and photography of the external surfaces of the fuel element. To achieve this the fuel element is mounted on a turntable that enables any surface to be presented, at various angles, to a 'through-the-wall' viewing optic. The turntable (Fig.6) allows the fuel element to be rotated, moved towards and away from the viewer or swivelled so that particular features can be precisely presented for examination. All the drive motors are remotely removable so that replacement units can be installed immediately a breakdown occurs.

It is essential that this apparatus operates with a high availability since any delay at this first stage of examination is carried on to all subsequent stages.

5.3 <u>Measurement Systems</u>

5.3.1 General

A number of measurements are made on the complete fuel elements immediately after examination and some typical examples are set out below.

5.3.2 Optical System For Assessing Pin Locations and Bow

A requirement of the examination programme is that the clearance of each pin within its location cell in the top brace and the extent of pin lateral distortion between the braces (bow) can be measured. To achieve this an automated system has been developed in which each pin can be directly aligned with a travelling telescope, the movements of which are computer controlled. To relieve operator fatigue the image is displayed on a TV screen and telescope movement is controlled from this image (Fig.7).

A computer controlled sequencing system is used to bring the telescope to each pin and then direct alignment is achieved by operator control. To measure pin to brace cell clearance accuracy of movement of better than 0.1 mms is required whereas the measurement of pin bow is only recorded in steps of 0.5 mms.

The new arrangement considerably reduces operator fatigue and automatic data recording speeds up the measurement process.

5.3.3 Graphite Sleeve Permeability and Burst Strength

In order to assess operating conditions within the reactor core it is necessary to know the rate at which the carbon dioxide coolant is able to leak through the fuel element sleeve and how this changes with irradiation. It is also important to determine how graphite sleeve strength varies with time in response to the competing processes of strengthening (due to irradiation hardening) and weakening (due to graphite corrosion).

The rig built to make these measurements is shown in Fig.8. The element is loaded into the rig and seals are clamped to the end faces by air pressure. The inside of the sleeve can then be pressurised and the rate of leakage through the sleeve determined. Since Dungeness B fuel elements have a slightly smaller diameter than the other designs an adjuster is provided which moves the carrying rollers to maintain a constant centre line position.

When the apparatus is used for sleeve burst testing the first stage is to machine a through wall defect of known length at the top end. This is blocked with a pliable sealing compound to reduce the leakage rate and the sleeve ends sealed as before. The internal pressure of the sleeve is then raised until the defect propagates. A perforated cover allows the pressure at which crack propagation occurs to be determined by direct observation and prevents ejection of graphite fragments.

This apparatus has proved simple to use and has shown few faults. The permeability of every element received is measured and selected elements are burst tested. A substantial body of information is now available on graphite sleeve properties.

5.4 Operational Procedures

5.4.1 General

In this section the method used to release fuel pins from the cluster is described together with two of the procedures used for the testing of fuel pins.

5.4.2 Fuel Pin Deepening

The fuel pins are held in the bottom grid of the support structure by rolling over an extension piece (fitted to the bottom end caps) to a larger size than the grid cell diameter. At the same time the pin is pulled downward so that a raised location collar is held firmly against the top surface of the grid. To release a fuel pin from the cluster the rolled over metal must be machined away so that the pin can be pushed free of the grid. When this has been done the pin is easily withdrawn through the braces from the top end.

The rig used for this operation is shown in Fig.9. It consists of a support trolley, which is locked to the location track, on which the fuel element can be rotated. At the end of the unit there is a location clamp mounted on a slide which holds the air driven deepening and pushing heads in turn.

The first stage of the operation is to present the top end of the fuel element so that identification and orientation tags can be pressed into the top end caps of the pins. The fuel element is then turned round to give access to the bottom face of the grid. Rotation of the element brings the desired pin to the horizontal central plane and the deepening head is moved sideways to locate with it. After the rolled over region has been machined away the deepening head is changed for the pin pushing head so that the pin can be freed from the grid. Positioning of the heads is made by the manipulators and the operation is controlled by direct viewing.

This simple rig has proved to be efficient and easy to use and differs from the machine originally installed only in minor engineering improvements.

5.4.3 Pin Piercing Units

For all reactor systems knowledge of the rate at which fission product gases build up within fuel pins is of crucial importance. With CAGR fuel pins gas release can only be assessed by collection and analysis and the apparatus for this is described below.

The pin is inserted into a close fitting rubber collar located in the piercing head and a vacuum tight seal is made by compressing it onto the pin by turning the capstan (Fig.10b). The apparatus is pumped out, the piercing head sealed off and then, after routine leak rate tests, a cam operated knife is driven through the can wall (0.4 mms thick stainless steel). The pressure in the piercing head (which is of known volume) is measured and the gas withdrawn for analysis.

In the original apparatus active particles were removed from the gas by a filter unit on the cave operating face. However, it was found that the background radiation was becoming unacceptable so that in the redesigned apparatus the filters were located within the cave, adjacent to the piercing head and arranged to be remotely changeable.

For day to day working two pin piercing units are used to give a total throughput of 4 pins a day. They have proved simple to use and maintenance has been minimal. Adjustment of the height of the pin support studs and the internal diameter of the sealing collar allows water reactor fuel pins to be punctured in the same apparatus.

5.4.4 Multi Pin Stress Rupture Rig

Because of the need to determine the mechanical properties of irradiated cladding tests have been carried out in a rig (based on an original Windscale design) in which several pins could be pressurised at temperature in order to determine the the time to failure. Although the original rig worked well for many years some operational problems were encountered and the object of the redesign (Fig.11) was to simplify the loading operation and to make the rig free standing.

The test specimens consist of fuel pins that have been cut in half and have had a specially designed pressure fitting brazed to the cut end. Four pins are tested at one time at a fixed temperature. Since each pin is fed from a separate pressure line the stress conditions can be varied from pin to pin. To load the rig the retaining cap, which covers the pressure block, is lifted by a cam and then each pin is entered and slid sideways

"circumferential elongation"
post-test measurement!

until it drops into the location socket in the pressure block. Turning the cam again drops the retaining cap and locks the pin into position (Fig.11b). The furnace assembly is then lowered over the pins. Temperature control is achieved by use of thermocouples located in a central column situated between the pins.

Since a test can last for many days leak tightness of the pressure lines is extremely important as undue pressure (and hence stress) fluctuations during the test must be avoided. Careful assembly and testing of the pressure control console and service lines is required to achieve this.

The original rig worked well and achieved throughputs of $\sim$ 150 pins/year. Its disadvantage was that it was fixed into the bench and was difficult to decontaminate. The present rig is simpler to operate and since it can be uncoupled and removed from the cave line remotely no major problems are foreseen.

5. DISCUSSION

Although this paper describes only selected items from the 7 cave line refurbishing scheme the principles adopted are the same throughout. The new rigs are based on equipment that has worked well for $\sim$ 11 years and the changes introduced are intended to make the equipment more robust and easier to operate and maintain remotely. With regard to the latter aspect it has been found consistently that simplicity of design brings considerable rewards.

Over the years the value of equipment that is free standing has been amply demonstrated. It confers versatility to cave working arrangements since it is relatively easy to vary the cave layout. This means that it is possible to change test schedules and examine a range of fuel elements and pin designs with relatively little disruption. Thus although the 7 cave line has been set up for CAGR fuel examination, water reactor fuel work is often carried out at the same time. When remote repair is not possible the rigs can be moved to the transfer chamber for attention or modification without the need to close the line for man entry. A flat bench top is also easier to keep clean and decontaminate. Use of stainless steel for construction of equipment also eases decontamination.

Since the start of the CAGR project in 1977 the 7 cave line has operated with high throughputs (~ 100 fuel elements/year) and has required only 3 shut downs for man entry. Following the current refurbishing we expect this work rate to be maintained and believe that throughput increases of 10 - 20% are feasible.

6. REFERENCE

Decontamination and Refurbishing of the PIE Caves at Winfrith
G. Smith, J. Stern, C.D. Hallett, M.J. Saunders and W.D. Curren.
Paper 2.3. This Meeting.

FIGURES

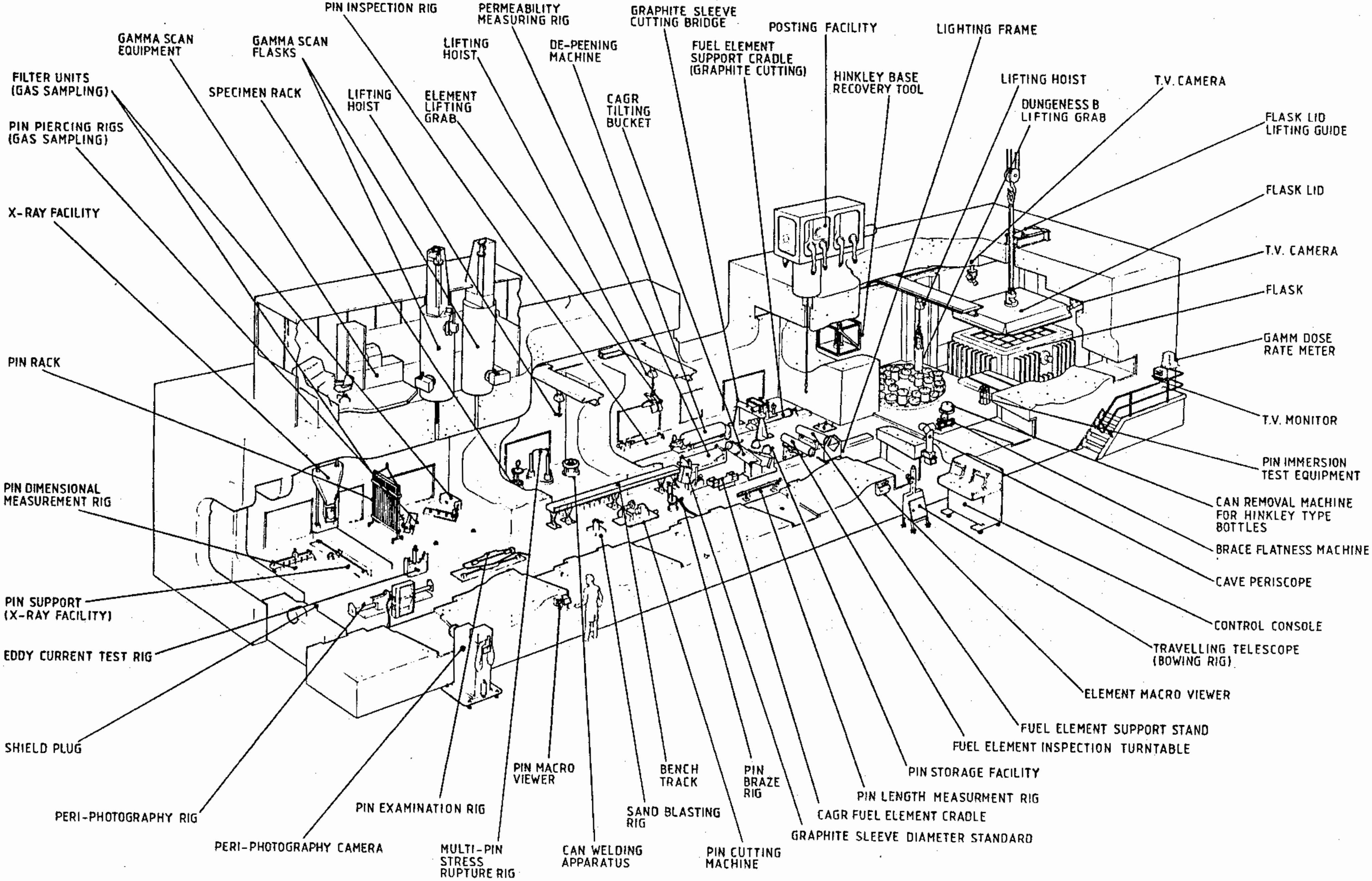


FIG1. LAYOUT OF 7 CAVELINE AT WINFRITH
(MAY 1985)

(50 kg)

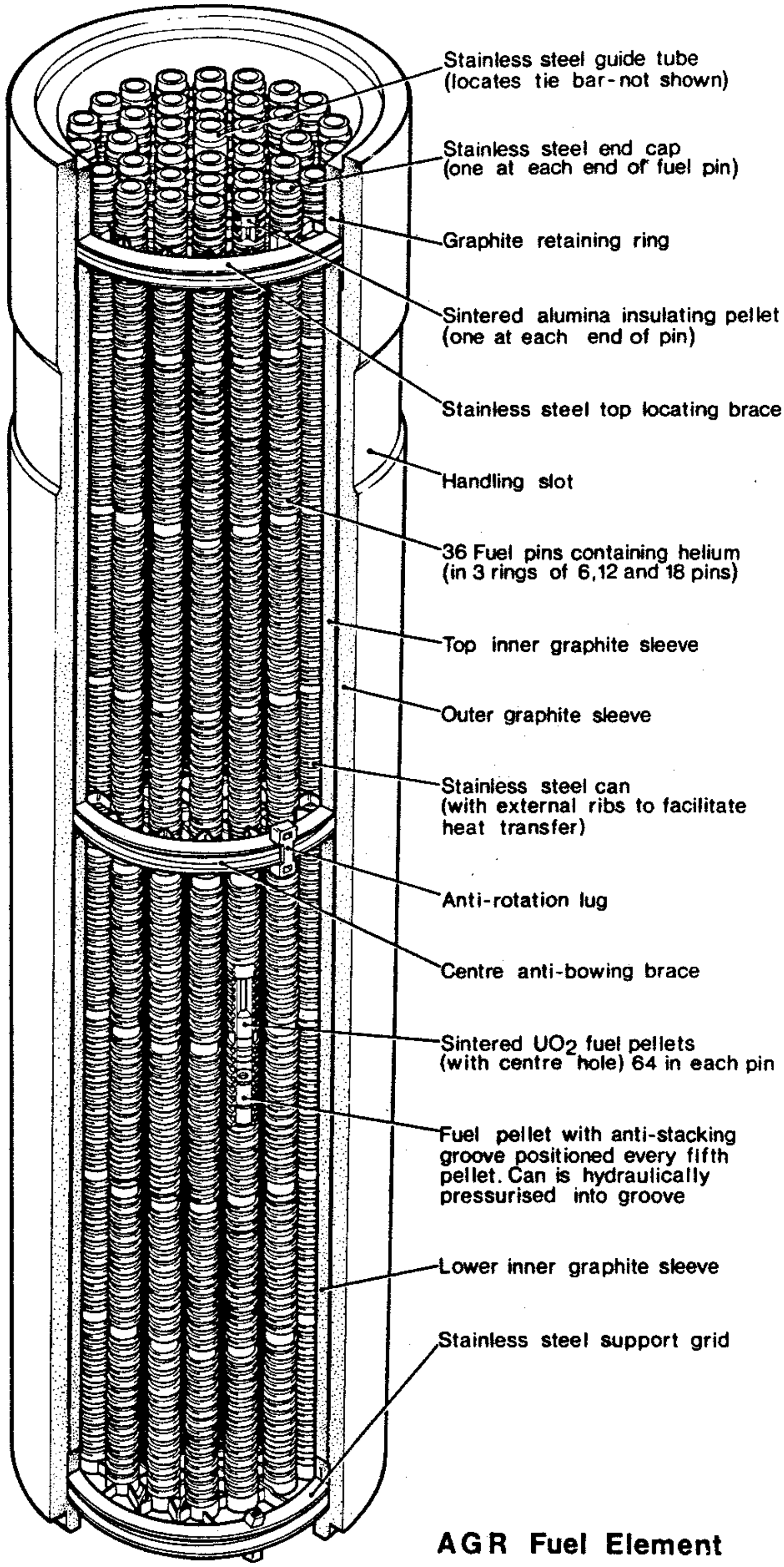
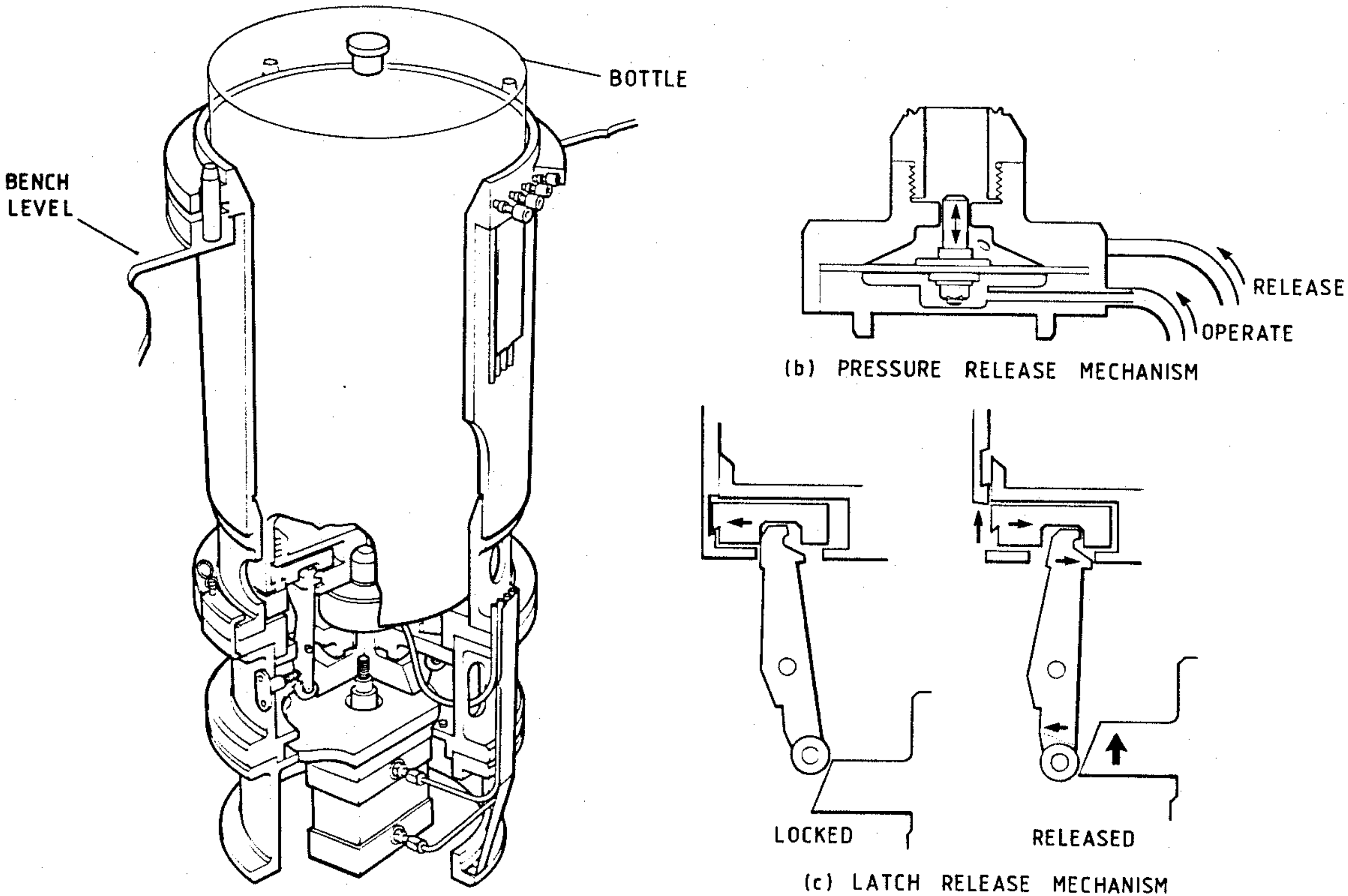


Fig. 2 Cut-away Diagram of the CAGR Fuel Element.

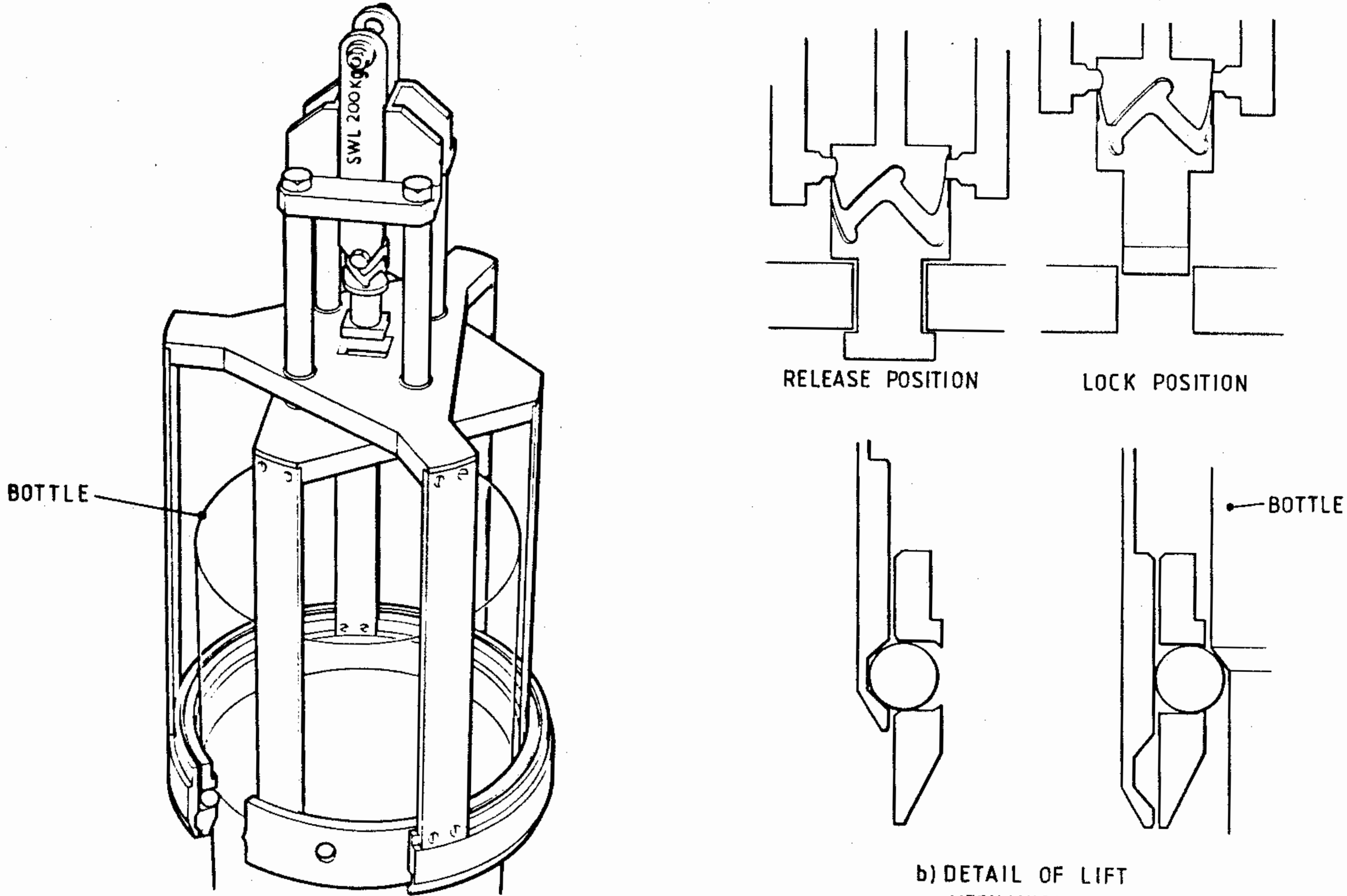


(a) GENERAL LAYOUT

(b) PRESSURE RELEASE MECHANISM

(c) LATCH RELEASE MECHANISM

FIG.3 CAP REMOVAL MACHINE FOR HINKLEY TYPE BOTTLES



a) GRAB READY TO LIFT

b) DETAIL OF LIFT MECHANISM

FIG.4 DUNGENESS 'B' BOTTLE LIFT GRAB

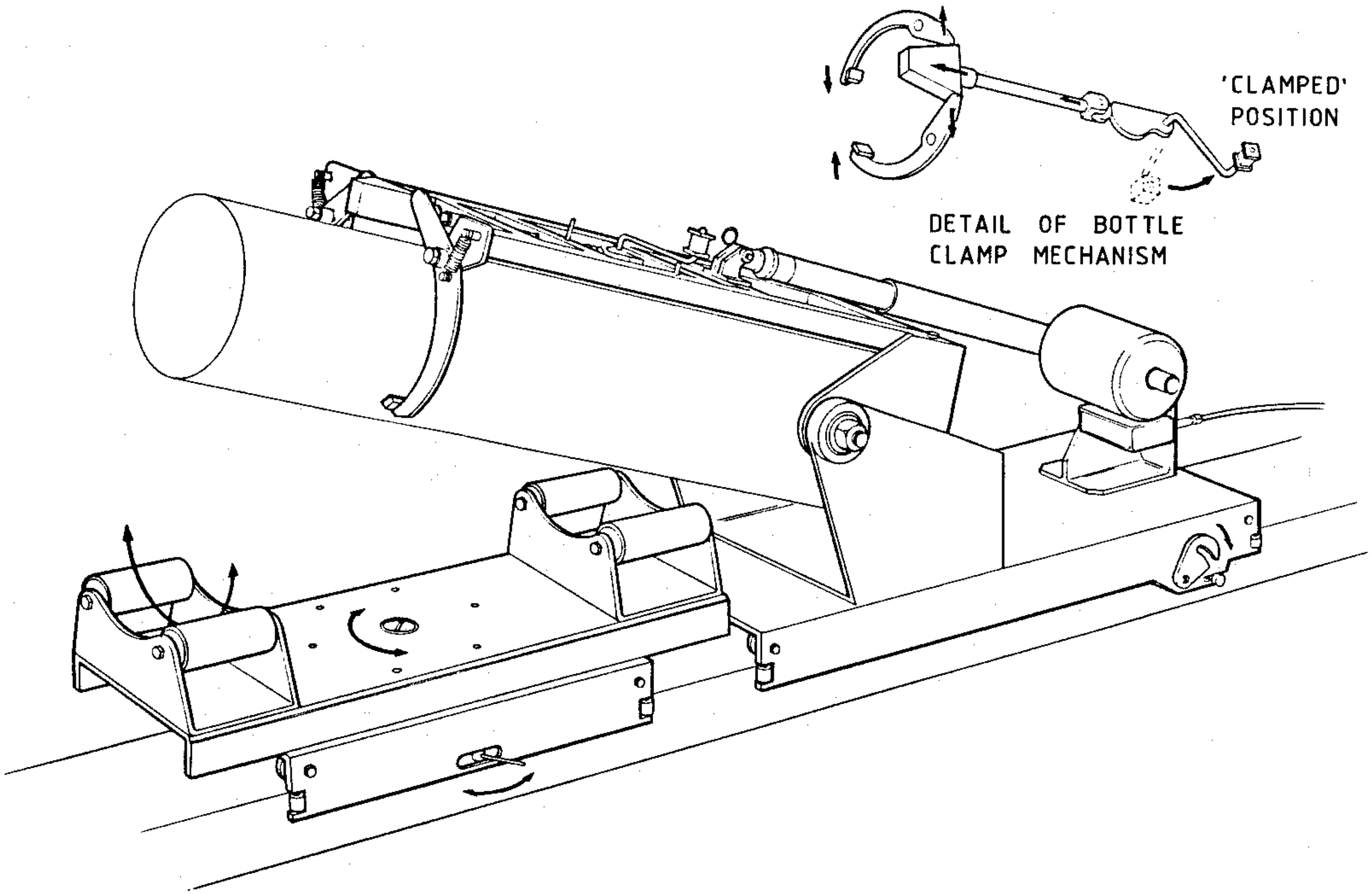


FIG. 5 CAGR FUEL ELEMENT TILTING BUCKET AND CRADLE

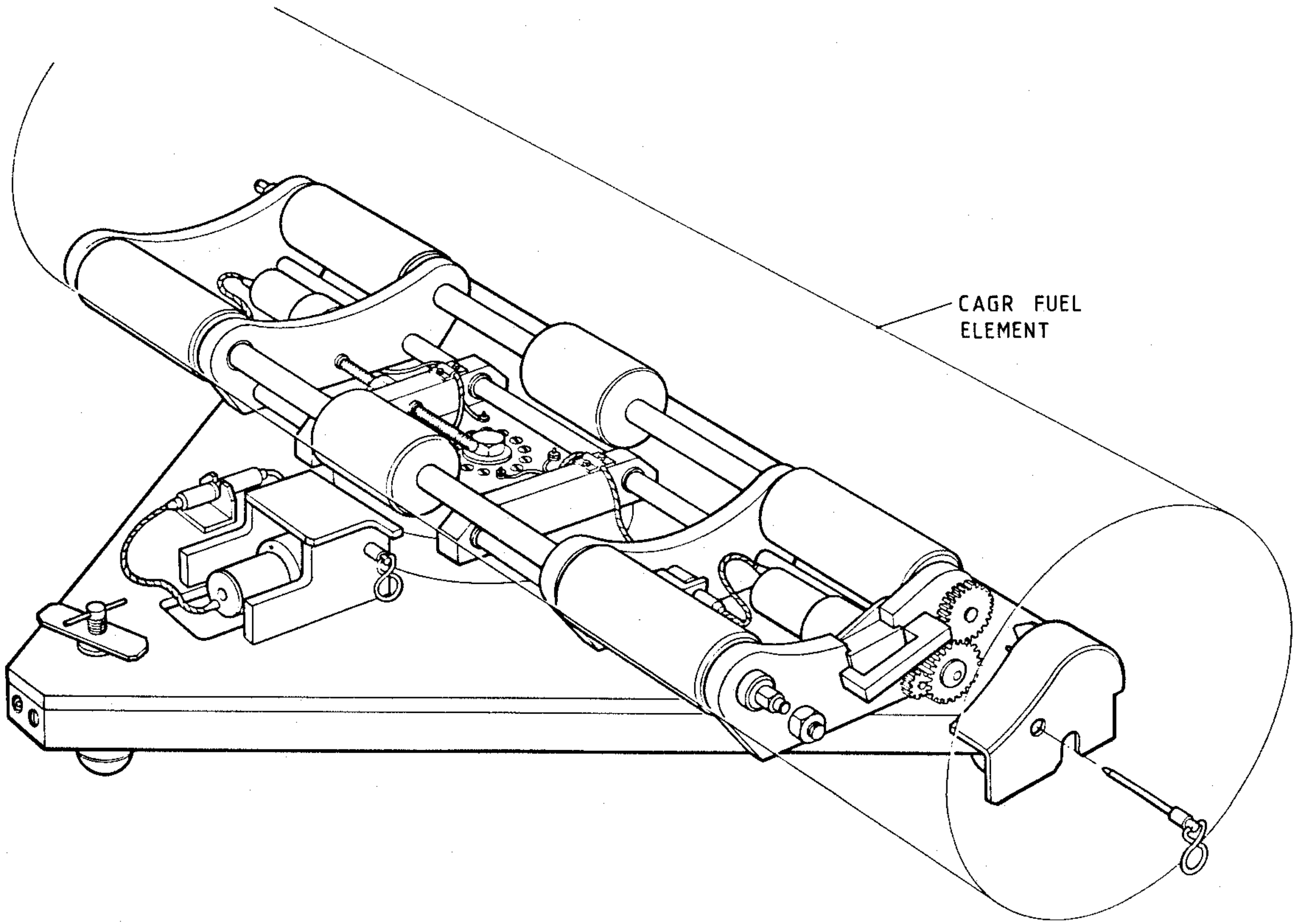


FIG 6 FUEL ELEMENT INSPECTION TURNTABLE

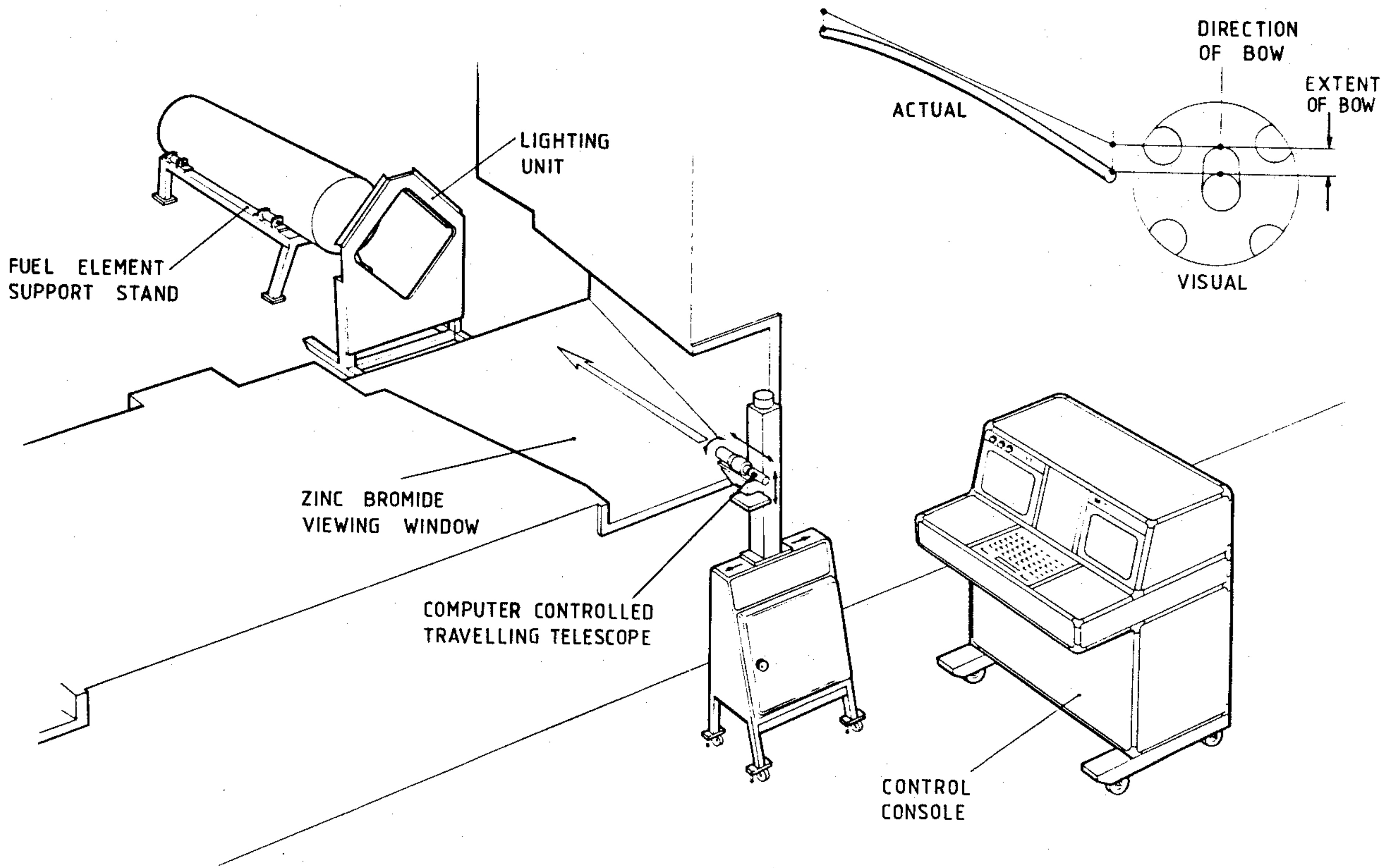


FIG.7 OPTICAL MEASUREMENT SYSTEM FOR PIN LOCATION AND BOWING

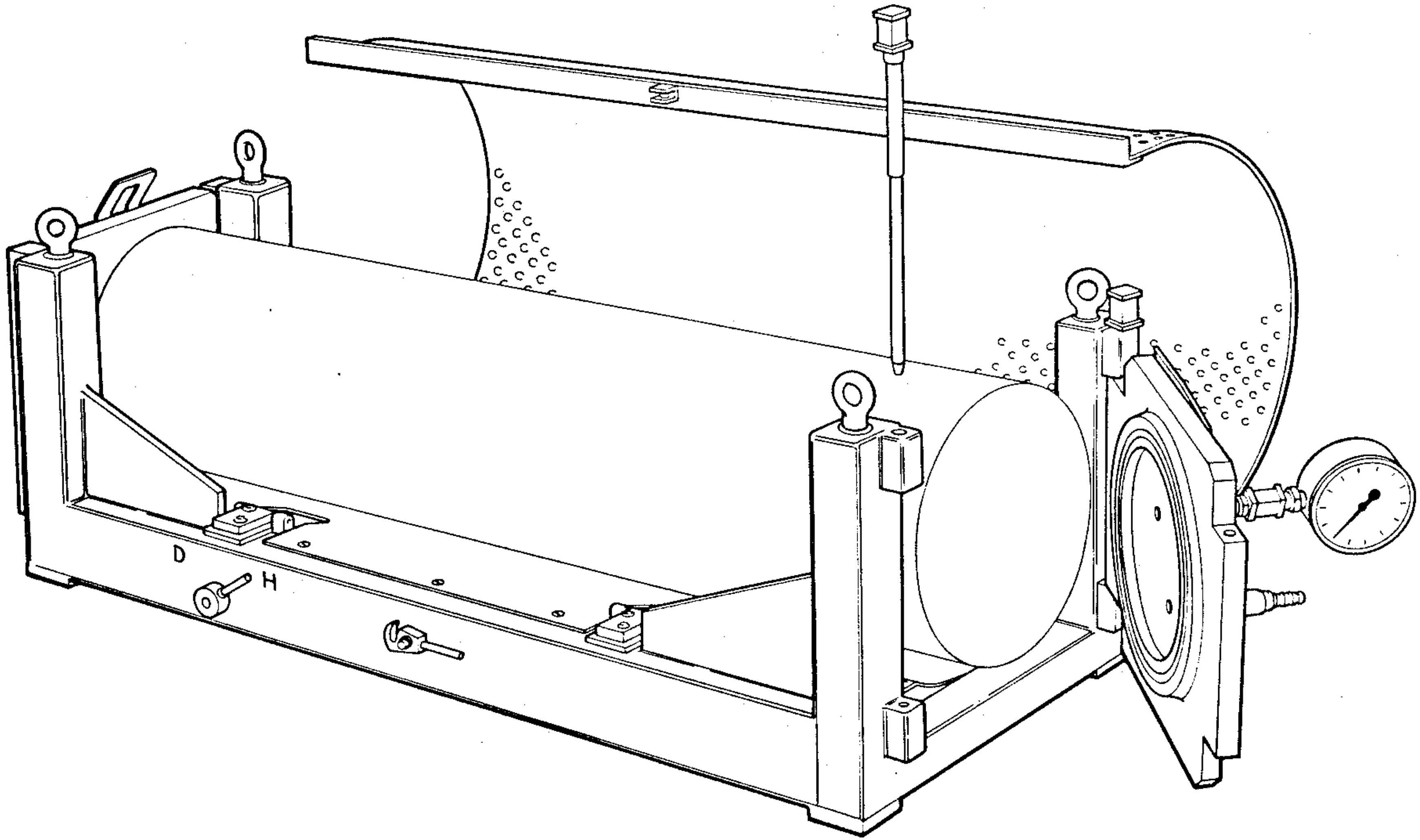


FIG. **8** GRAPHITE SLEEVE PERMEABILITY AND BURSTING RIG

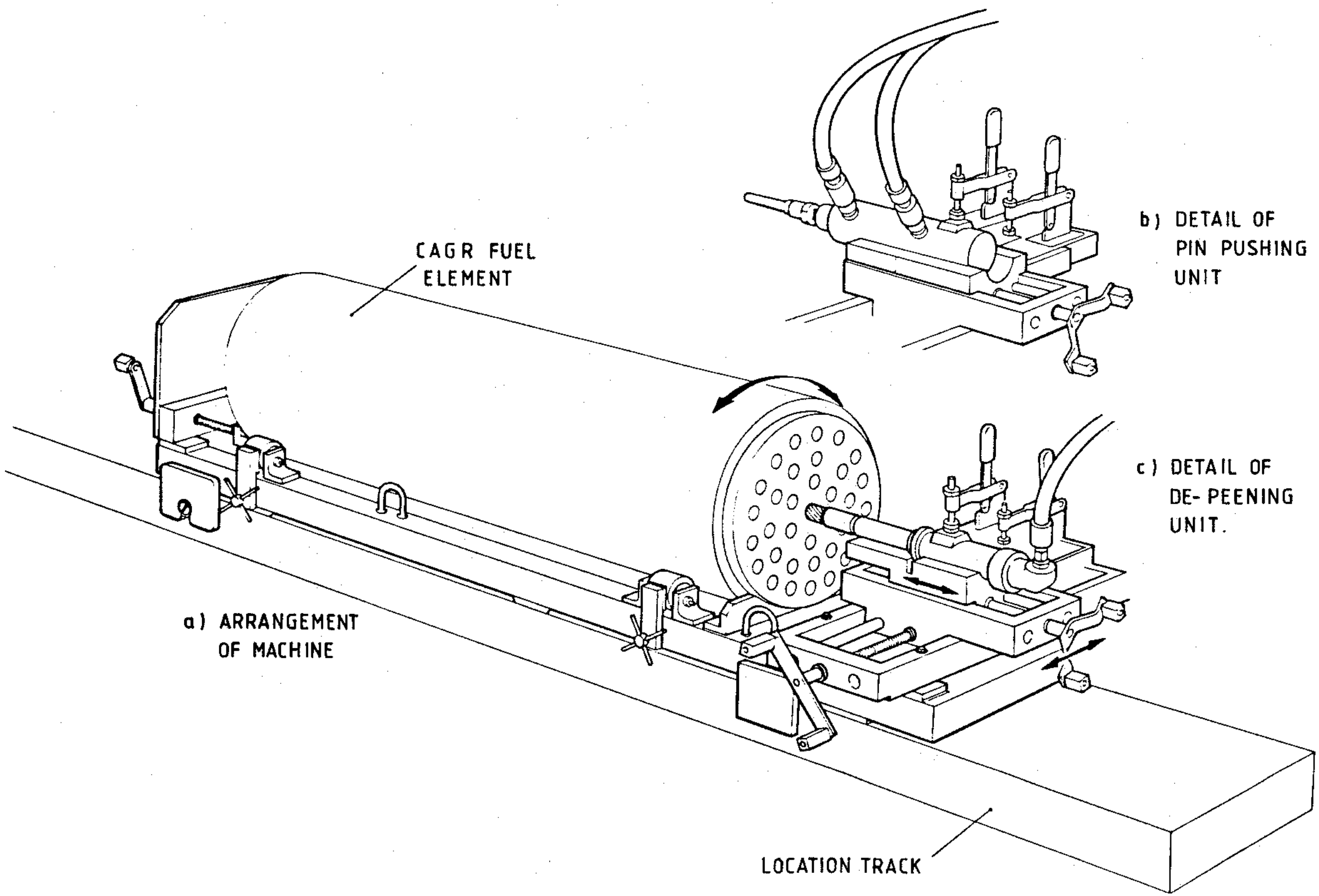


FIG.9 FUEL PIN DE-PEENING MACHINE

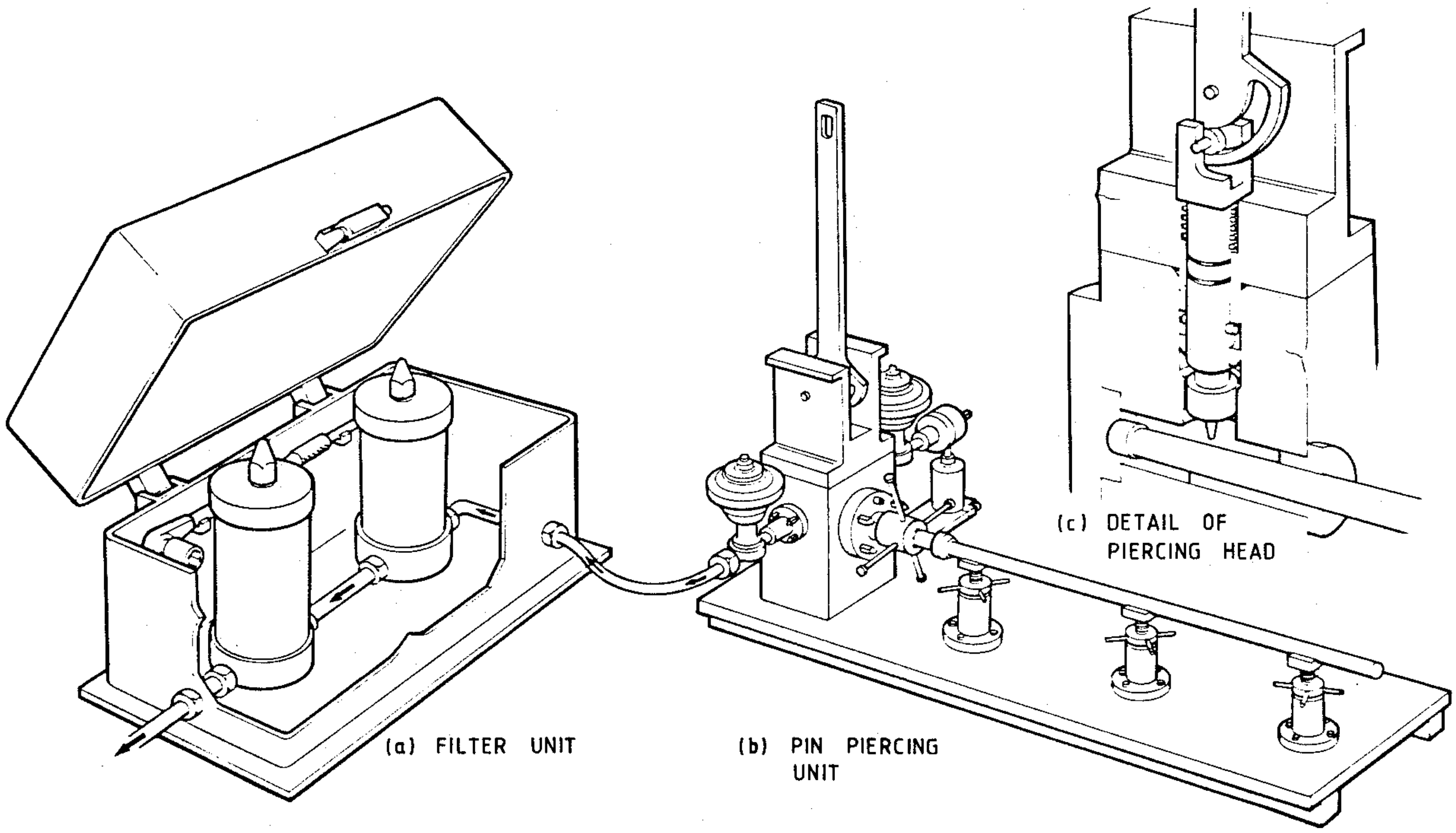
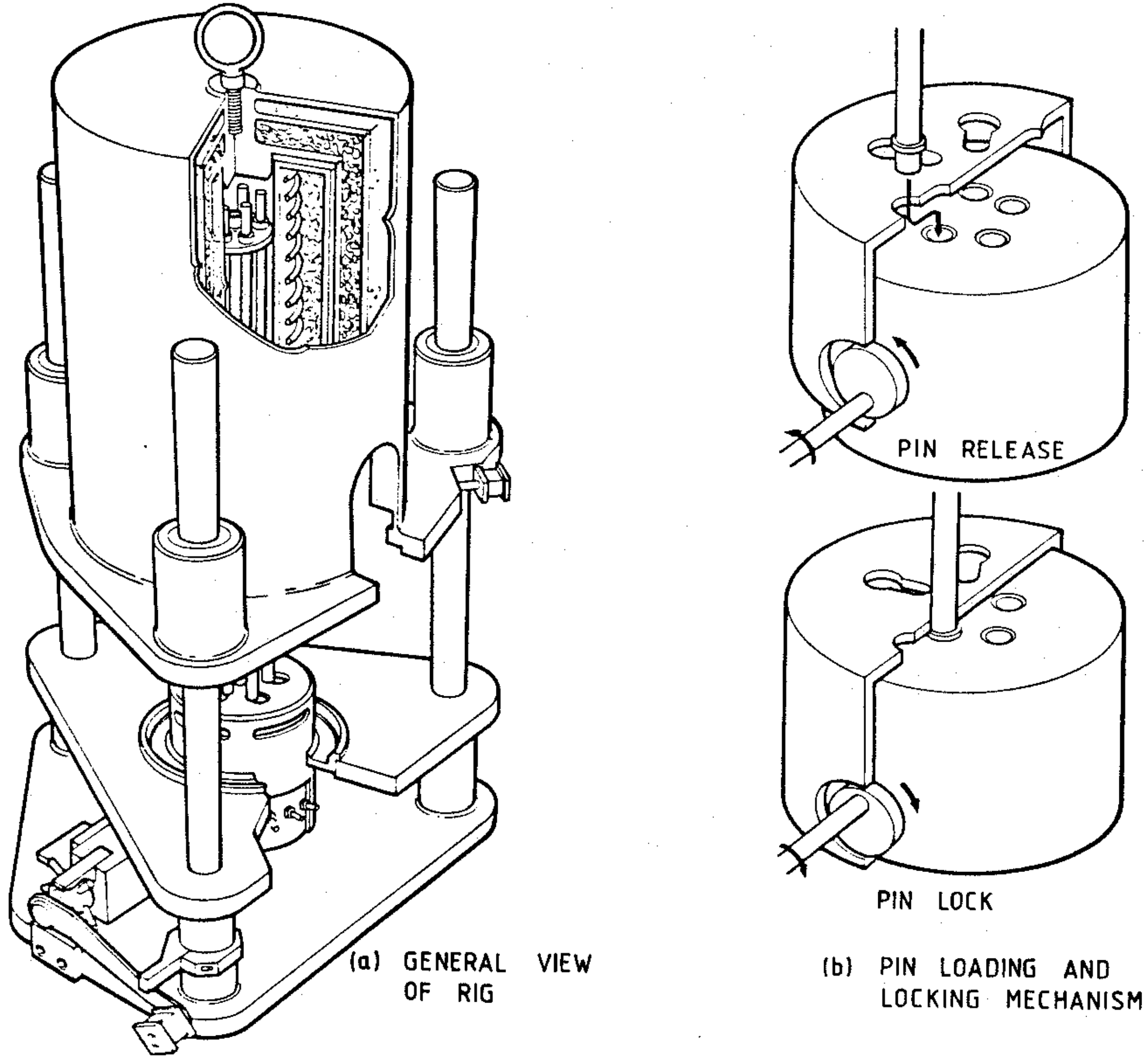


FIG.**10** PIN PIERCING RIG AND FILTERS FOR FISSION GAS SAMPLING



(a) GENERAL VIEW OF RIG

(b) PIN LOADING AND LOCKING MECHANISM

FIG. **11** MULTI-PIN STRESS RUPTURE RIG

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