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THE MANIPULATION OF WATER REACTOR FUEL BUNDLES AT THE WINFRITH CAVES

C A Turier
T R Jay

Technology Division
Building A59
AEE Winfrith

EEC HOT LABORATORIES AND REMOTE HANDLING WORKING GROUP

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SYNOPSIS

The first water reactor fuel bundle (SGHWR) was delivered to the PIE Caves at Winfrith in 1968. Since that date PWR and BWR bundles have also been received.

This note describes the methods for horizontally transferring the bundles into the cave without damage. The techniques for stripping the bundles are also described, including pin handling methods.

The note also includes information on pond examination of bundles prior to moving them to the Caves. The problems of crud are discussed and details are given of its removal in a special rig.

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1 Introduction

The first water reactor fuel bundle (SGHWR) was delivered to the PIE Caves at Winfrith in 1968. Since that date, over sixty bundles have been examined and dismantled, ranging from 1 metre length to 4.0 metres and from 130 mm diameter to 200 mm square section and containing as many as 179 fuel pins. During the same period 160 bundles of up to 1 metre long have been examined and 315 have received pondside examination at the reactor.

The extent of the PIE work carried out varies with the needs of the reactor operators and fuel bundle designers but may be limited by the equipment available. In the very early examinations emphasis was more on finding the cause of fuel pin failures and evaluating crud deposition. In later examinations the use of NDT equipment gave more information and more effort was available to monitor the performance of standard fuel bundles and evaluate the behaviour of experimental fuel.

2 Description of Hot Cell and Equipment

The hot cell referred to in this note was initially constructed for use in the examination of metre long fuel bundles, and comprised two units separated by a sliding shielding door. One with a single operating station (Zn Br window and two manipulators) and the other with two operating stations.

The inner sliding shielding door and its two guide walls were removed, thus producing an open cell 10.0 metres long by 3.7 metres deep and 4.3 metres high, with three main operating stations. The cell contains benching over the full operating area and is served by two in-cell hoists and a power manipulator.

The need for a flexible facility for fuel bundle examination arose from the interest shown in substantially different types of fuel assemblies. All equipment, therefore, is simple, adaptable, and modular, rather being purpose built to perform one function only. Consequently, all units tend to be small in size or built up from small components so that they can be posted out of the cell for cleaning, modification, storage or disposal.

All the bundle handling equipment can be fitted onto one of the two channels running the full length of the cell. One channel is in line with the end door posting feature and the other gives easy access of the operating stations. Fuel pins are examined by NDT techniques, using a single pin drive unit in line with support rollers (Figure 1).

Flask Handling

The cell has provision for through-roof posting but it was much easier to transfer bundles from the flasks horizontally through the posting hole in the end door. The roof posting facility is used for the posting in of consumable items and transfer of active waste into smaller flasks.

In the transfer of large bundles from flasks to cave it is necessary to ensure that the flasks have provision for push rods, drain valves, and a shielded shutter at the end connected to the cell wall. It is important to ensure that the flask is securely fixed before any force is applied to the push rods for sliding the bundle through the wall. It is also important to put the fuel bundle in a carrier for protection during transit from the reactor pond to the cave. This carrier also serves as a secondary containment to protect the flask internal surfaces from contamination; it also acts as a sledge and makes transfers in and out of the flask easier.

Large, square section, PWR bundles have been transferred from large multi-barrel flasks, which do not incorporate a shielded shutter, but some special equipment and shielding had to be built.

In-cell cutting

In order to expose the ends of the fuel pins in a bundle it is often necessary to cut through the end lifting feature so that selected fuel pins can be withdrawn, and in the SGHWR bundles handled this is solid stainless steel 130 mm diameter. A reciprocating power hacksaw is used. It has a hydraulic power down feed on the cutting stroke and a means of lifting the blade clear on the return stroke. The machine cuts in an arc motion with a continuous cut which eliminates the work-hardening that so often occurs when machining stainless steel. No coolant or cutting fluid is used. A previous design of power hacksaw had a "flat" cutting stroke and remained in contact with the workpiece on the return stroke. This allowed the material to work-harden. The cutting time for the new machine is ten minutes, whilst the previous one took five hours. Blades are replaced after completion of the cutting operation on each bundle.

For cutting fuel pin specimens a 130 mm diameter fine grit diamond impregnated slitting wheel, has proved to be the most efficient. A total loss drip feed using inhibited trichlorethylene helps to extend cutter life, stop the release of airborne particulate contamination, and produce a good surface finish. Subsequent grinding and polishing prior to metallographic examination is minimal. The slitting wheel runs at 300 revs per minute, and has a force feed.

In machining graphite specimen a similar slitting wheel is used. It has a coarse grit and is driven at 750 revs per minute by an air motor without coolant or cutting fluid. Dust collection is achieved by containing the slitting wheel in a shroud connected to a suction device and disposable collecting bag.

Pin removal and bundle dismantle

A series of wire pulling grips with differing diameters, or adjustable collets are used to draw pins out of the bundles, but care has to be taken when drawing pins with "spacer pads" through the locating grids. Pulling loads up to 370 Kg have been needed to overcome the initial pin to grid reaction, although loads are more generally 18 - 24 Kg .

In all cases the pins are withdrawn on to guide rollers, and great care is taken because of the weakness of slender pins or the brittleness of Zircaloy clad pins which have been subject to hydriding.

Pins awaiting NDT are stacked on racks suitably positioned on the cell bench, to reduce radiation damage to the Zn Br window, and to control the possible radiation exposure which may be reflected through the unshielded MSM ports.

Return of pins to the Reactor pond

In some designs of bundles the end lifting feature can be cut off, the few chosen pins removed, and a special lifting feature fixed to the bundle, to enable it to be handled for transfer back to the reactor pond. Thus, eliminating the need to completely dismantle the bundle and therefore increase the total cell through-put.

When fuel bundles have been fully dismantled, the examined and surplus pins are packed into a stainless container whose dimensions and features are similar to those of the original bundle. It can then be handled in a similar way to the fuel bundle and returned to the reactor pond.

Decontamination of Fuel Bundles

After irradiation in the Winfrith SGHWR the cladding of the fuel elements are seen to be coated with 'crud'. The crud is usually 50 μ thick, or less, and consists mainly of corrosion products from the primary circuit which have collected on the clad surfaces. Normal crud deposits do not cause any deterioration in the performance of the fuel elements but do have consequential effects when the fuel bundles are removed from the reactor. The problem is due to the irradiation of the corrosion products in the core of the reactor; amongst other radioisotopes, Cobalt-60 is produced.

If a fuel bundle, coated with crud deposits, is taken into a hot-cell the coating rapidly becomes dry. The residue tends to be powdery and is easily scraped-off by anything that comes into close contact with it. Thus, the very radioactive crud can be a major source of contamination in a hot-cell and on all handling gear.

To remove this problem of contamination it was decided to build a special loop, close to the hot-cells, which would decrud the fuel bundles prior to post irradiation examination.

The loop is shown diagrammatically in Figure 2. It is constructed from stainless steel. The section, into which fuel bundles are loaded, is situated within a 300 mm diameter vertical hole in the floor in an area near to the hot-cells. The decontamination fluid (usually Turco 4521) is stored and heated in a shielded tank. The hot fluid can be pumped around the loop at temperatures up to 90°C and at a rate of 3 m per sec past the fuel bundle. There is a by-pass system which enables the fluid to be circulated, and checked, prior to it being employed on the fuel bundle.

For the operation a fuel bundle (4 metres long) is loaded, from a flask, vertically into the hole. Everything is mounted within a spillage tray which could accommodate all the fluid in the system. Different decontaminating fluids may be used in the loop. Because of this there is a test section in which corrosion reactions between the fluid and various materials may be investigated. The progress of the de-crudding operation is measured by monitoring the rise in activity in the circulating fluid. The cleaning is finished when this activity ceases to rise.

The loop has also been used for the decontamination of the inside of large flasks.

Pond examination

The fuel element handling route at the SGHW reactor starts and finishes in the fuel storage pond situated within the secondary containment of the reactor building. New elements are coupled to hangerbars to form fuel stringers (Figure 3) and passed along a fuel transfer tunnel to the refuelling machine. Spent fuel is discharged in the reverse mode, the irradiated elements being decoupled and stored in racks for a minimum period of several months before transit to Windscale. A pond transporter bridge is used for the movement of complete stringers and components throughout the pond.

The dimensions of the fuel pond are 23.8 m length x 4.9 m width x 10.7 m depth and it contains 1240 m^3 of demineralised water when at this depth. In order to provide sufficient water shielding, the irradiated fuel is submerged approximately 5 m below the surface of the pond, and it is therefore essential for underwater viewing purposes, that a high degree of clarity be maintained.

At every annual shutdown of the reactor between 15 and 25 fuel elements are unloaded from the core and viewed in the pond. Individual fuel elements are examined for a variety of reasons. For example, lead burn-up fuel is checked to ascertain if significant spacer grid/fuel channel interaction has occurred during irradiation, other fuel elements are examined to determine their suitability for return to the core for further irradiation. Fuel elements destined for post irradiation examination in the cave lines at Winfrith are given a detailed examination to check on their condition prior to shipment.

Two methods of visual examination are used:-

(a) a portable system employing an underwater mirror (thus allowing viewing and photography from a position above the pond surface);

(b) a dry-tube periscope fixed to one end of the pond.

Mobile Pond Mirror Rig with Integral Lighting (Figure 4)

Originally designed as a general visual inspection tool for fuel elements situated in pond storage racks or suspended from the pond bridge grab. The assembly consists of a front silvered mirror 1000 mm long x 200 mm wide located in a frame and fixed 45° length-wise to the pond surface. 4 KW of halogen lamp lighting are attached to the frame and the assembly suspended by stainless steel cables from a portable winch bracket. The system is normally used clipped to the side of the pond bridge and the image viewed through cave binoculars. A 35 mm camera fitted with an 800 mm telephoto lens is used to obtain colour transparencies of the fuel element, the lens being fitted into a cylinder with a plate glass window at the bottom end. Some typical examples of fuel elements viewed in this manner are shown in Figure 5, eg, crud deposits, interpellet ridging and nodular oxidation on zircaloy cladding adjacent to stainless steel spacer grids. The effectiveness of in-core chemical decontamination is also shown.

The pond mirror technique is found to be most suitable for rapid cursory examinations of large numbers of fuel elements. Since 1968, more than 300 have been examined by this method.

Dry Tube Periscope

The SGHWR pond periscope is telescopic in operation with an open length of 13 m and a closed length of 9 m. The lower section containing the periscope objectives is housed in a 220 m bore aluminium tube; an operational vertical movement of 4 m is imparted to this lower section by a motor driven ballscrew, the tube being designed to telescope over its upper section in order to scan the full fuel element length. An operator situated at a control console can thus view and photograph the fuel element at any position.

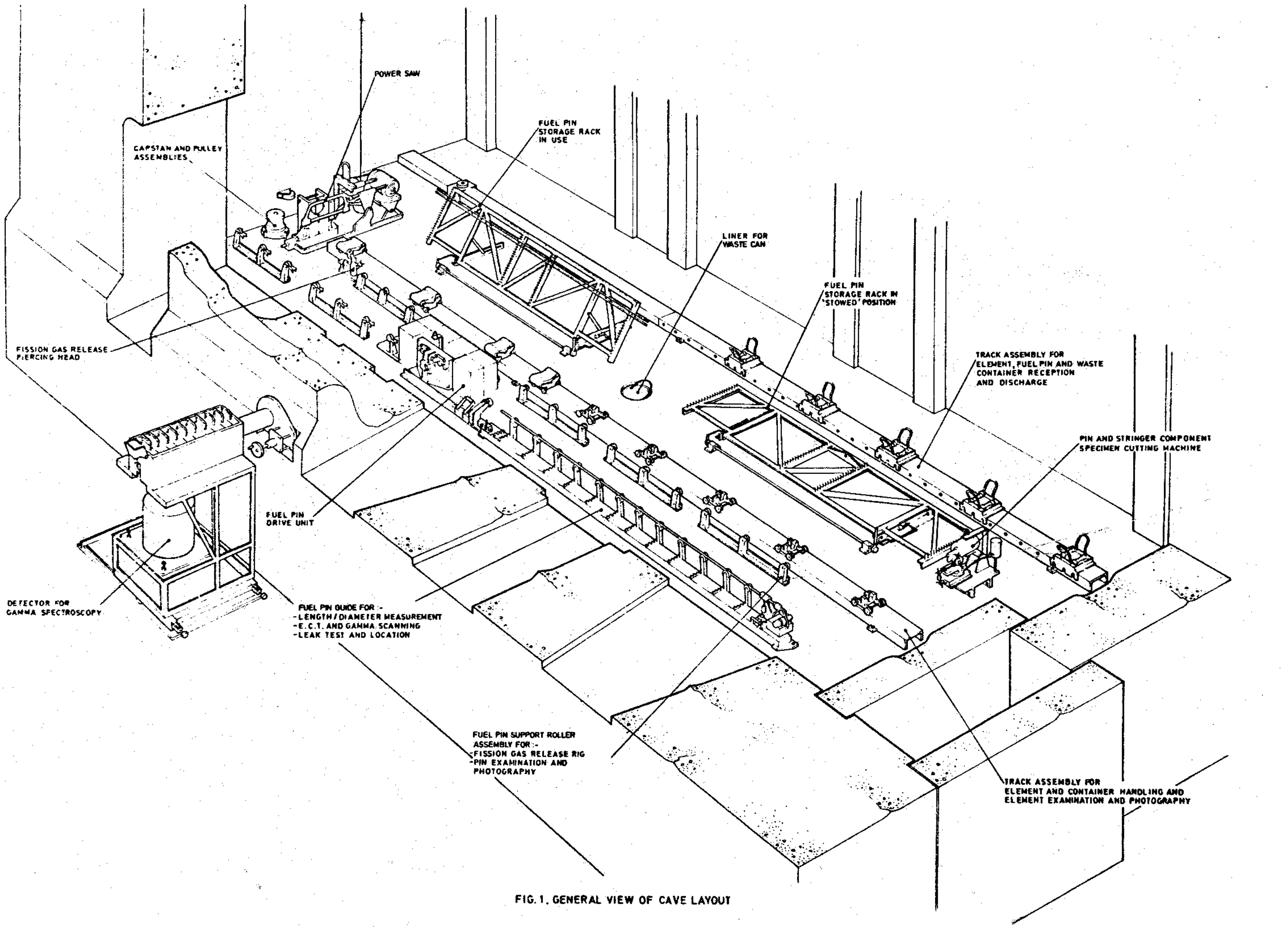

FIG. 1. GENERAL VIEW OF CAVE LAYOUT

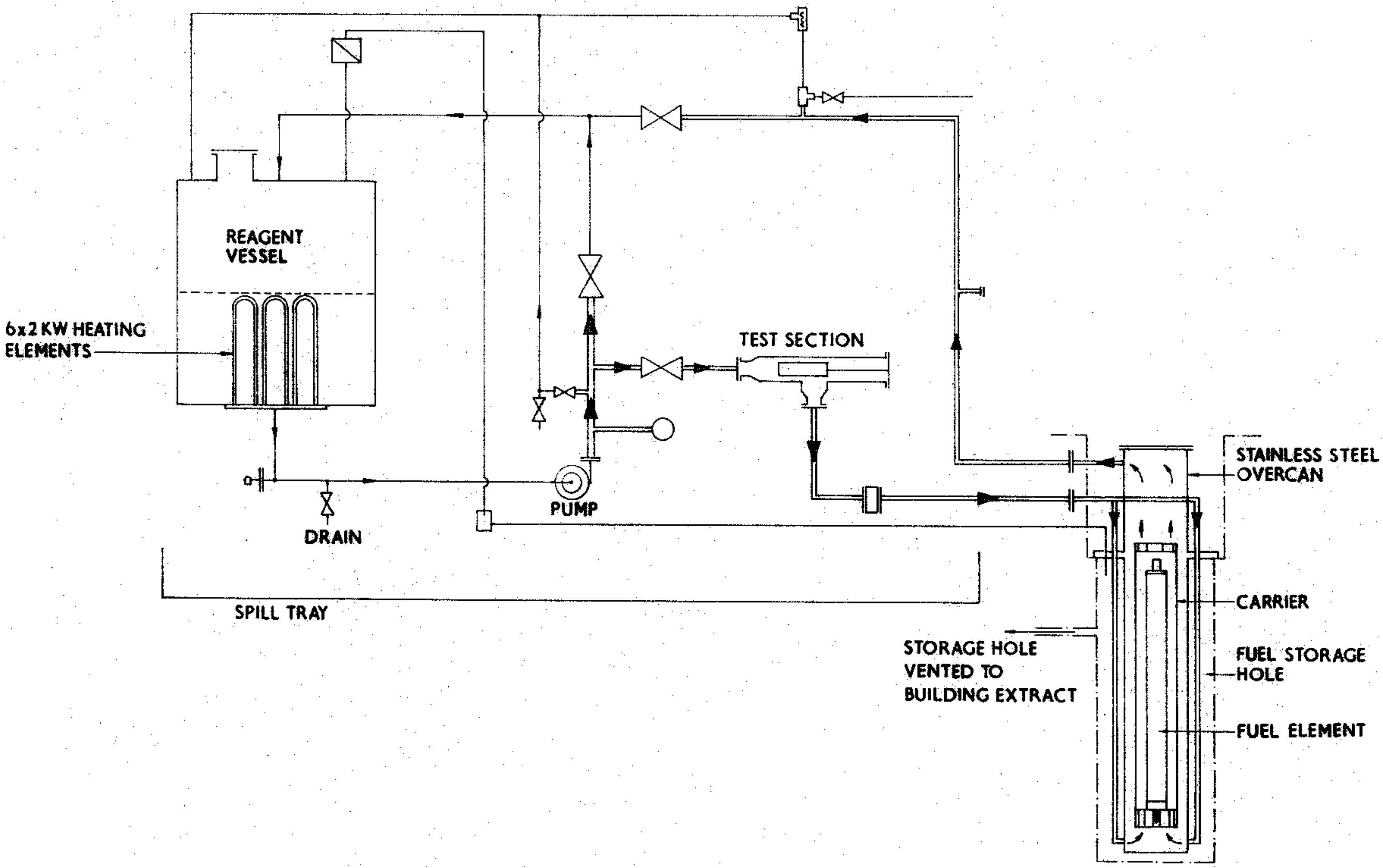

FIG. 2. FUEL ELEMENT DECRUDDING RIG

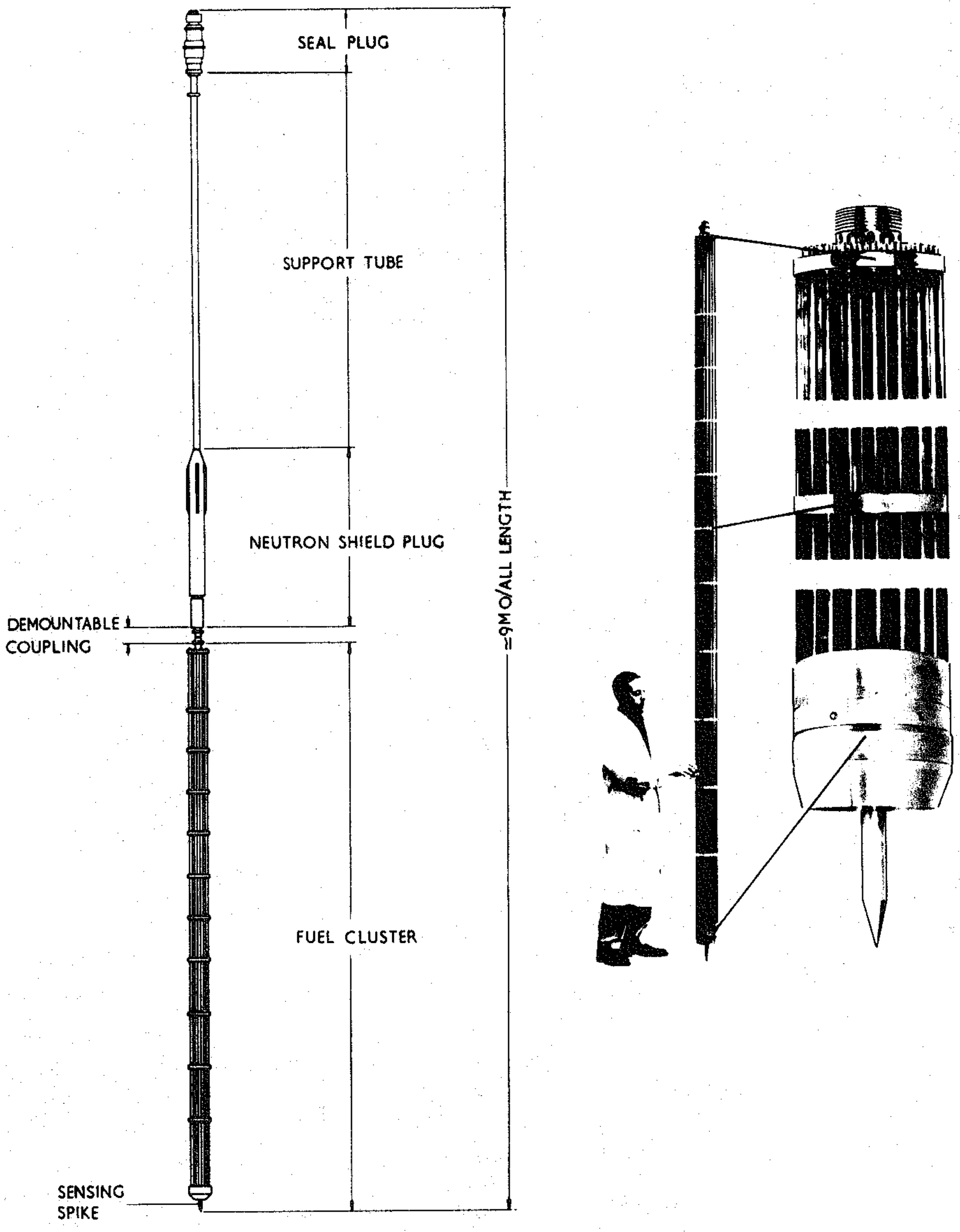

FIG. 3. FUEL PLUG STRINGER

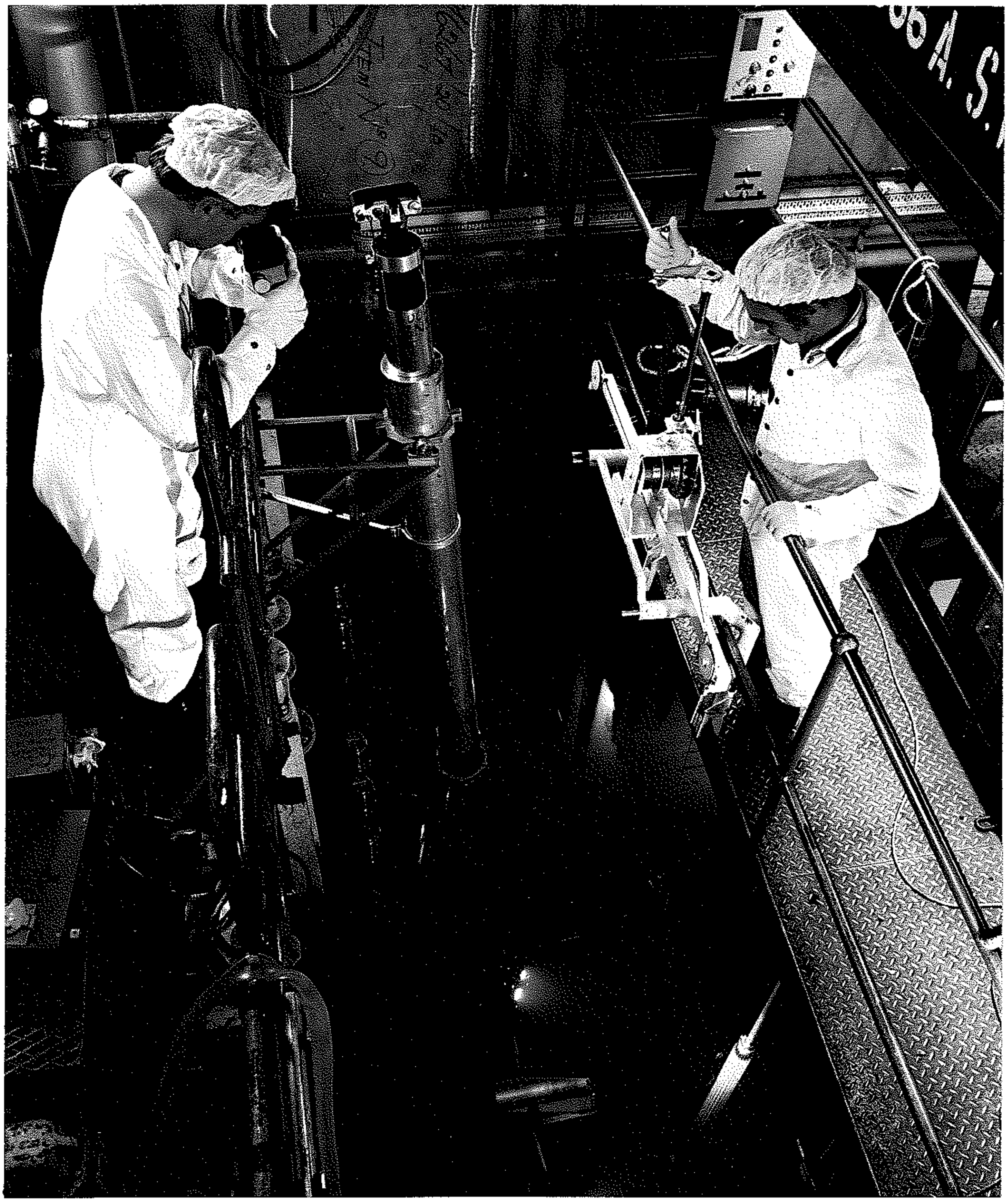

FIG. 4. POND EXAMINATION OF SGHWR FUEL ELEMENTS USING AN UNDERWATER MIRROR RIG

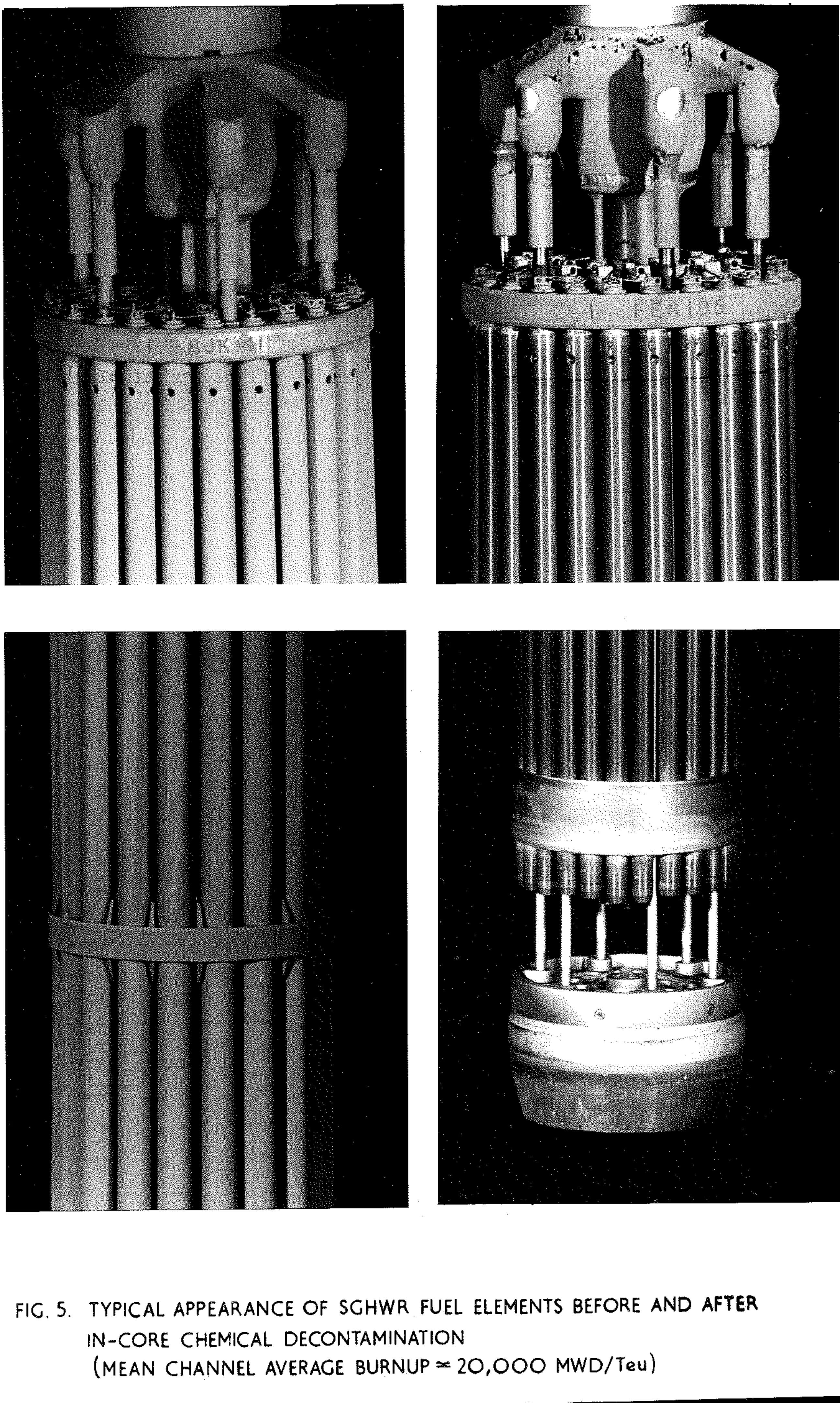

FIG. 5. TYPICAL APPEARANCE OF SGHWR FUEL ELEMENTS BEFORE AND AFTER IN-CORE CHEMICAL DECONTAMINATION (MEAN CHANNEL AVERAGE BURNUP ≃ 20,000 MWD/Teu)

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