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PIE Radwaste - Handling and Transfer Techniques in the UK

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1. INTRODUCTION

The handling and disposal of radwaste produced during the post irradiation examination (PIE) of fuel elements is an important factor to consider when planning programmes of work. The efficient running of expensive cave, or lead cell, lines depends on a carefully organised and planned throughput of work; caves that are full of radwaste quickly become difficult to operate and work has to cease. Failure to clear away radwaste regularly and in a planned manner may force operators to use temporary storage outside the caves and, thus, give rise to other handling problems.

There is considerable pressure to reduce the amount of radwaste produced and of course local storage space for active materials is expensive. Thus, there has been a drive to improve methods to cut down on waste at source by the use of new or novel techniques, and to improve segregation and packing of waste for disposal.

There are currently five establishments in the UK involved in PIE. The UKAEA sites are located at Windscale, Winfrith, Dounreay, and Harwell, and the CEGB conducts its own operations at Berkeley Nuclear Laboratories (BNL).

Two of the UK PIE sites, Windscale and Dounreay, are also places where irradiated fuel is reprocessed. This has advantages and disadvantages. The advantages accrue from the extensive facilities which surround reprocessing plants, eg, active stores, active drains, transport, decontamination plants, active maintenance units, etc. Thus, there are established radwaste routes which the PIE operator can use. The primary disadvantage is that the size and importance of the reprocessing plant often dictates the form and routes of the radwaste and often takes priority with transport and other facilities. When PIE facilities share a site with a power reactor, as at Dounreay, Windscale, Berkeley, and Winfrith, there may also be similar advantages.

There are two extremely useful disposal routes to sea used in the UK:-

1. Liquid effluent pipeline to sea (not available at Harwell);
2. Solid waste packed in drums and dropped by ship in an Atlantic deep.

Both routes are strictly controlled by UK Government and International regulations.

The liquid routes are not used directly but via hold-up tanks where the level of activity can be verified. These routes are mainly used for the disposal of decontamination effluents from caves and for cooling water drained from large transport flasks. The solid routes, in which radwaste is loaded into concrete-lined drums, are used for medium active waste.

The UK sites are involved in many different aspects of work but an important task which produces large quantities of radwaste is the primary dismantling and subsequent detailed examination of irradiated fuel assemblies. These assemblies originate from Magnox, CAGR, PFR and water reactors of various types both UK and overseas. Table I lists the categories of radwaste. All sites, therefore, have to take steps to deal with the relatively large quantities of in-cell waste generated by PIE activities; these are primarily solids.

2. DISMANTLING - SOLID WASTES

A significant radwaste problem is due to the amount of neutron-activated structural material, especially stainless steels of various types. Activated steel is highly radioactive and needs to be transported in a heavily shielded flask. When each fuel bundle is stripped down to its components a considerable amount of this type of waste is produced (Table II). In the case of CAGR fuel bundles it is often possible to reduce the amount of radwaste produced in the cave because the design of the element (Figure 3) permits a limited number of individual fuel pins to be removed from the assembly with only minimal machining. The structural integrity of the bundle is not impaired and it can be returned intact to the storage pond to await reprocessing. The graphite sleeves, from elements which have been completely dismantled, are treated as medium active waste and are loaded into concrete drums for sea disposal. Originally, burning of the graphite had been considered as a disposal route. However, this operation is quite costly and difficult, and also releases Carbon 14.

The in-cave handling and packaging of activated structural material is relatively simple. All sites use steel containers of various sizes (see view of dismantling cave, Figure 1). Some send packaged waste of this type directly for silo disposal in shielded modular flasks, whilst others sort and repack in a separate dedicated cell prior to long term storage. Since many items are relatively massive structural components it is difficult to crush the waste in order to obtain a better packing fraction (currently only about 1/3). Exceptions to this are items such as retaining grids which are easily deformed. Methods of reducing the volume of this type of waste are currently being investigated at Winfrith.

Should transport delays occur because, for example, of other operational priorities for flasks, sites such as Winfrith and Harwell are equipped with large numbers of underfloor storage holes and these have been used as buffer stores for containers of high active waste. Some of this material was retained for 10 years and by then decayed enough to be packed and sent for sea-disposal.

3. SURFACE DEPOSITS ON FUEL PINS

Surface deposits, especially on water reactor fuel pins, are a source of contamination of otherwise clean in-cave equipment.

In most fuel assemblies the heated surfaces of the pins trap corrosion products from the primary circuit coolant and these corrosion products become attached to the can surfaces as a layer, usually less than 50 μm thick; (these deposits are called crud in water reactors). The layers of corrosion products become radioactive during their period in the reactor core and are thus, potential source of contamination when the fuel assembly is removed from the reactor. The problem is most serious with the fuel taken from boiling water reactors. The corrosion products are not easily detached from the fuel rods when they are wet. In the cave atmosphere, drying occurs, and the coatings tend to be powdery and are easily scraped off by handling equipment, thus, producing a major source of contamination. The material in crud deposits can be of high specific activity, for example, samples have had activities of up to 10 curies per gramme (Cobalt-60). The length of water reactor fuel assemblies (4 - 5 metres) means that they have to be introduced into a cave horizontally and during this operation crud deposits are often dislodged. Furthermore, during the dismantling process fuel pins are pulled through the spacer grids and deposit crud onto the surfaces of the dismantling bench; this may subsequently become dispersed throughout the cave. Everything contacting the surface of the fuel pin may also become contaminated with crud and have to be treated as active waste. Thus, a few grammes of crud deposits can contaminate large quantities of operational equipment and materials in a cave and lead to large volumes of waste. The volume of waste is increased considerably when one includes the materials necessary for the complete cleaning of the caves at a later stage.

A further minor form of contamination will occur if small quantities of pond water are transferred with the fuel cluster into the cave. This happens when small pockets of water are trapped on the fittings of the cluster or its supporting carrier and then drip onto the cave bench or equipment.

4. FUEL PIN SECTIONING

A major source of in-cell activity and contamination comes from direct work on fuel pins. There are generally two ways in which fuel debris can be released:

1. If the intact fuel pins are deliberately sectioned to provide specimens (usually for metallography)

2. If the fuel assembly contains defective pins.

During PIE UO_2 fuel typically has a specific gamma activity of ∿ 1 - 10 curies per gramme, and so even very small particles when trapped in crevices in tools or equipment can be the cause of significant waste. Oxide fuel may be fragmented, or become a powder, especially during in-cave cutting operations. In this dusty state it can readily disperse as particulate throughout the cave and perhaps reach the primary filters. In order to prevent this happening, enclosed in-cave slitting machines have been developed, and are being improved, to collect dust very close to the cutting blade. In this way virtually no fuel is lost during cutting operations; all fuel dust and debris being returned for repacking with the cut fuel off-cuts. Special stainless steel transport containers are used for fuel debris which are sealed by welding and returned to pond storage prior to eventual reprocessing.

In addition to oxide fuel sectioning, whole uranium-metal (Magnox) elements are routinely sectioned at Berkeley, and Windscale, using 10" diameter tungsten carbide tipped cutting wheels running slowly at 60 rpm. A proprietary oil is used as a lubricant and a coolant, and is recirculated. The swarf produced is collected in wire baskets, spin-dried and then embedded in concrete blocks.

5. METALLOGRAPHIC SAMPLE PREPARATION

The preparation of sections for metallographic examination requires grinding away of the face of the specimen, using discs of waterproof silicon carbide papers stuck back-to-back and held on a grinding machine plate by the surface tension of lubricating water and the pressure of the specimen. Both sides of the pair are used, typically becoming exhausted after grinding two specimens. A weekly discharge from a busy metallography line could be 70 - 80 discs, all to be treated as high active waste. Final preparation of specimens includes mechanical polishing with diamond pastes on proprietary cloths backed with self-adhesive card discs for uranium metal, oxide fuel and magnox sections. Attack-polishing is routinely employed for oxide fuel and uranium sections using a thin slurry of gamma alumina in 100 volume H_2O_2. For zirconium, an electrolytic attack-polish is used with chromic oxide lubricated by very dilute aqueous HF. When exhausted, these slurries are allowed to dry out and are discarded (usually once per week) as solid high active waste. Some establishments, example Windscale, profit by having cave and lead cell lines connected to the BNFL active effluent system. At other sites the waste liquids from metallographic preparation are drained from the cells to a local removable liquid container fitted with a level indicator. Approximately a litre of liquid can be produced each day, with an activity level per container (after 10 days) of roughly 200 mR/hr. This is treated as low level waste and taken to the laboratory effluent plant for settling-out prior to disposal as low level liquid waste.

Solid waste from metallography lines includes:

(a) Discarded grinding and polishing discs, tong heads, gaiters, plastic containers, glassware, swarf and cleaning materials.

(b) Defective machines or machine parts.

(c) Unwanted mounted microspecimens and surplus samples of irradiated materials.

Items in category (a) are normally loaded into tin-plated steel containers (200 mm O/D x 250 mm high) sealed and sent for silo disposal. Items in (b) are decontaminated and repaired if possible, otherwise they are sent for disposal. In category (c) fuel sections which are free from epoxy resins are returned for reprocessing. However, fuel which is mixed with, or impregnated with, epoxy resin, including mounted metallographic specimens is debonded by a process developed at WNL, Windscale. This involves removing as much as possible of the resin by cracking off the molds followed by the use of a proprietary solvent. Finally, the specimens are heated to 500°C under vacuum in a small furnace. The debonded fuel can then be returned for reprocessing.

6. FAST REACTOR PROBLEMS

Essentially most problems stem from the presence of significant quantities of plutonium and from the use of high rated fuel. Thus, there is an even greater incentive at Dounreay to minimise active waste and to contain it very thoroughly. For example, Dounreay have looked at the widespread use of plastics in contaminated areas and, in an attempt to reduce the amount of this type of waste, they have introduced engineered posting routes (eg, La Calhène, Padirac, etc) extensively. If plastic must be used and then becomes contaminated waste, it is washed, shredded, and compacted (Ref 1).

Another very important problem with fast reactor waste is due to its relatively high fissile content. Because of this there has always been a bigger trend towards recovery of fuel from radwaste at Dounreay. The problems of checking radwaste which may contain fuel is also very important and various interrogation techniques have been used at Dounreay (Ref 1).

Finally, because of these problems there is considerably more emphasis at Dounreay on the sorting and separation of different types of radwaste to avoid filling expensive storage space.

7. FUTURE DEVELOPMENTS

Many of the current developments are concentrated on reducing the production of radwaste in the caves, or not taking the potential radwaste into the caves, rather than treating the wastes by some process. It is likely that future developments will follow this trend.

For reactor fuel bundles at least three approaches are possible:-

1. The prior chemical decontamination of whole fuel bundles is possible in purpose-built rigs situated close to the cave lines. A plant, (DECOR III), is already operational at AEE Winfrith (Ref 2). Several fuel elements destined for PIE have been successfully cleaned of crud deposits and this led to improvements in subsequent cave clean-down times. A limitation of this rig is the inability to decontaminate failed fuel elements.

2. Fuel bundles can be dismantled in a pond to extract and ship those pins selected for detailed examination. This would also save handling large quantities of activated structural material in the caves.

3. Similarly, the necessity of cutting fuel inside the caves should be constantly challenged and reduced to a minimum consistent with the information sought. Any cutting must be locally contained in order to prevent contamination of large areas and/or prevent particulate reaching bulky filters.

The amount of waste produced by metallographic preparation especially at the grinding stage has been identified as an important area for waste reduction appraisal. Work is proceeding on suitable alternative methods such as grinding slurry mediums. A promising line of development currently under test at WNL, Windscale, is the use of commercially available diamond impregnated laps which it is hoped will elminate silicon carbide papers altogether.

Finally, improvements are needed in the packing density of waste sent for disposal. The metallographic lines at Windscale have developed an in-cell hydraulic waste compactor which can successfully reduce the volume of 'soft' contaminated waste to 10% of its previous value. Larger machines for more massive activated structural parts of fuel elements are under consideration.

ACKNOWLEDGEMENTS

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Table I

Categories of Waste Arising from PIE

Categories	Typical Waste Source	Current Disposal Route
High Active	Fuel element hardware. Mainly activated stainless steels.	Engineered storage then silo disposal.
High Active	Cutting swarf, crud deposits, spalled oxide. General bench sweepings.	" "
High Active	Contaminated equipment (redundant)	" "
High Active	Fuel debris from pin cutting.	Segregated and returned with pin offcuts for reprocessing.
High Active	Metallographic prep arisings and mounted specimens.	'Soft' waste segregated for silo disposal. Specimens incinerated and residues returned for reprocessing.
Intermediate	Structural graphite, swabs, filters.	Sea disposal drums (various)
Low	Gaiters, plastic containers, glassware, PVC, housekeeping tong heads etc.	Land burial.

Table II

Projected Annual Discharge of Active Waste for a Five Element Water Reactor and Eighty Element CAGR PIE Campaign

Material	Activity	Water Reactor		CAGR	
		Per Element*	Annually**	Per Element	Annually†
Structural components, eg activated stainless steel.	High	10 Kg	50 Kg	1.15 Kg	23 Kg
Fuel pin sectioning for metallography	High	18 specimens	90 specimens	25 specimens	2000 specimens
Contaminated Equipment	High	NIL	180 litres	NIL	450 litres
Graphite	Intermediate			≃ 28 Kg	≃ 1120 Kg
Filters, swabs, PVC, housekeeping etc	Low	NIL	1000 litres	NIL	4000 litres

*Water Reactor fuel elements generally 4 metres long with up to 60 pins per element.

**CAGR elements 1 metre long with 36 pins per element.

†Approximately 25% of elements completely dismantled, remainder only partially stripped.

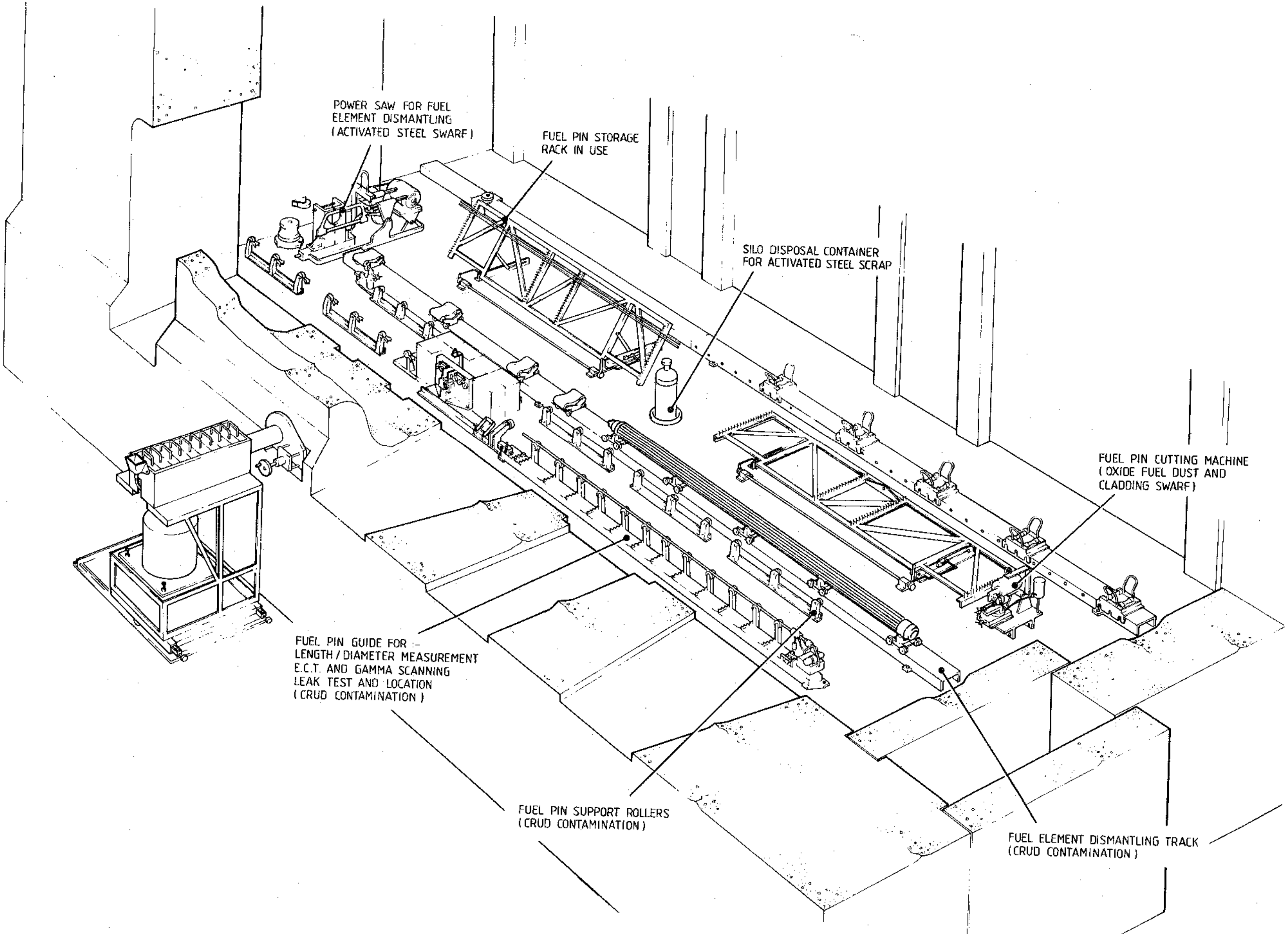

FIG. 1 BREAKDOWN CAVE FOR WATER REACTOR FUEL ASSEMBLIES

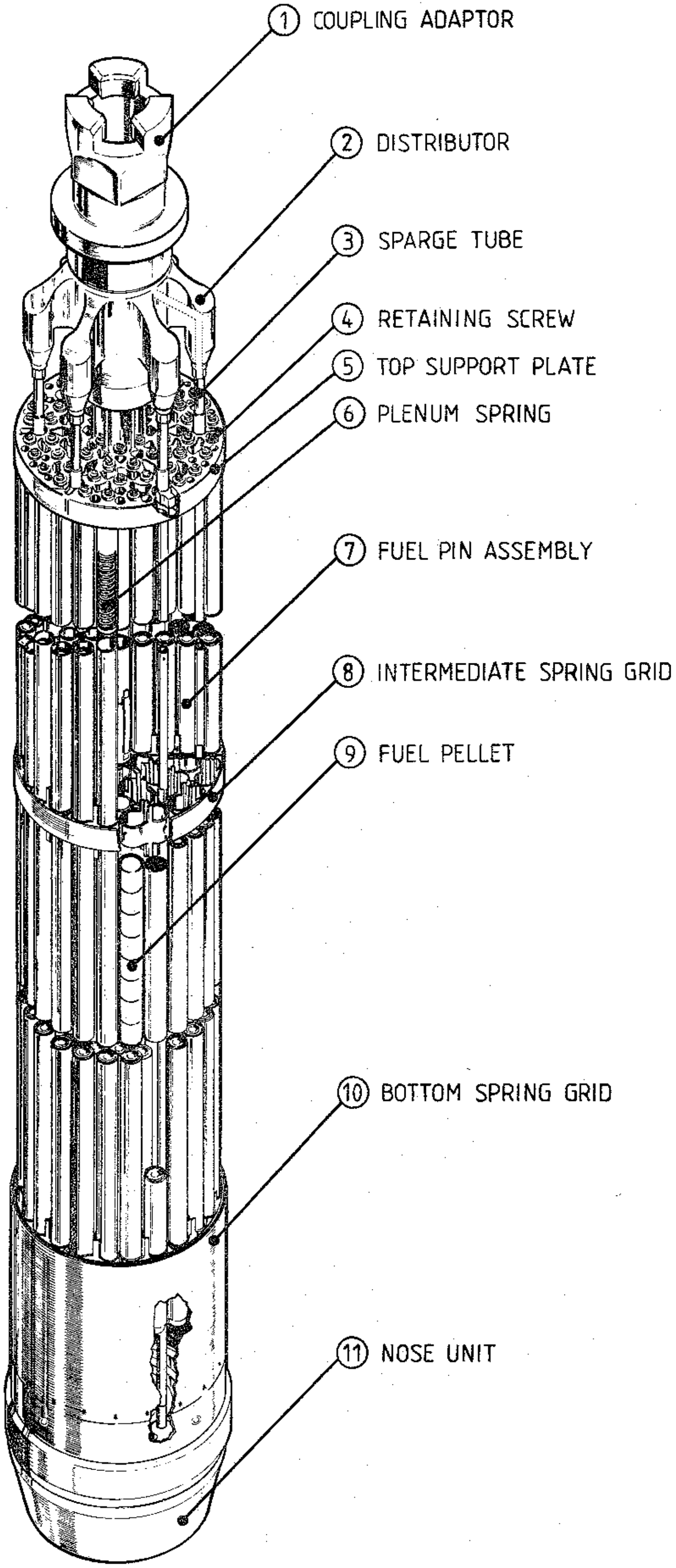

FIG. 2 60 PIN SPRING GRID SGHWR FUEL ELEMENT

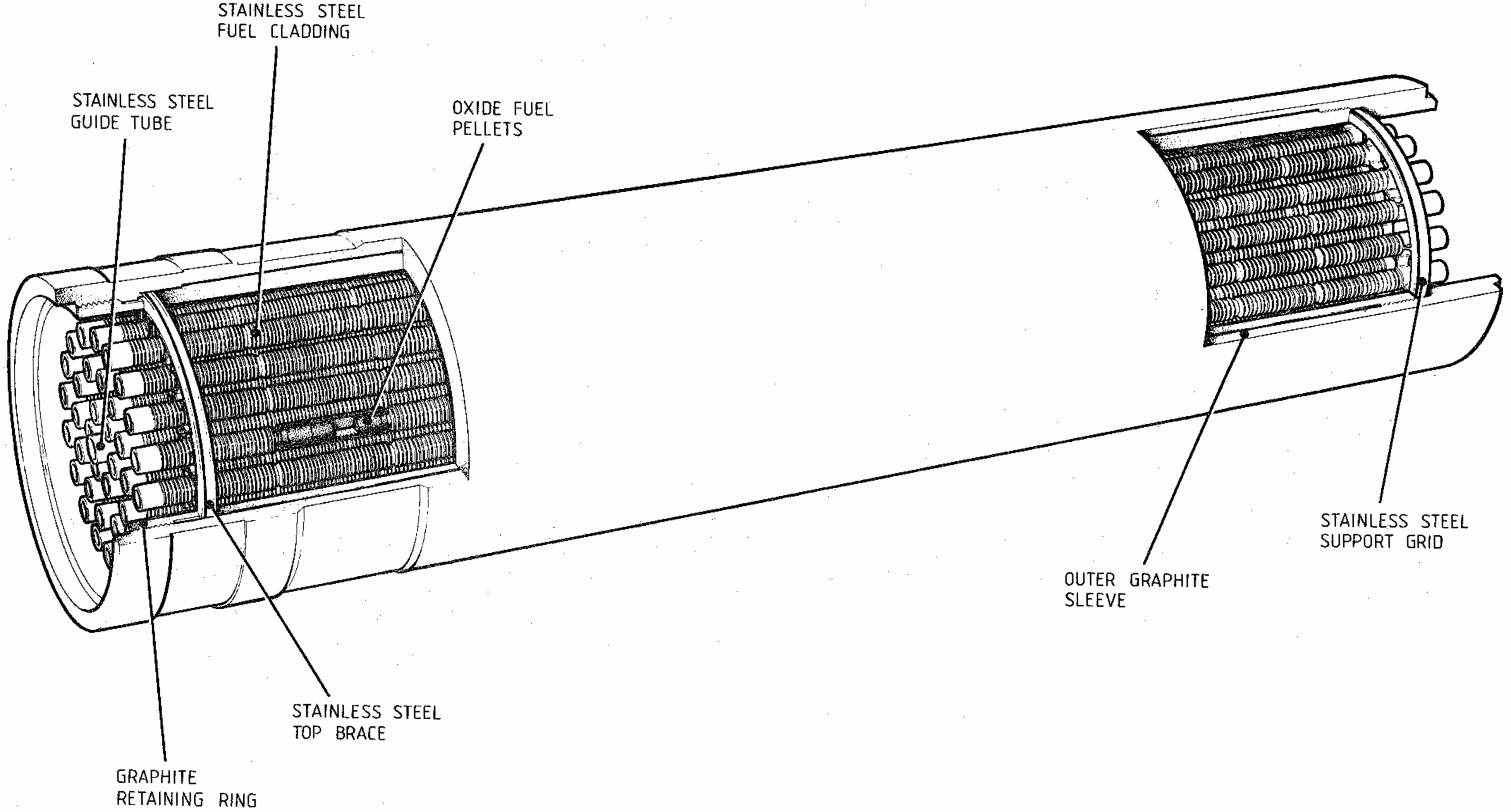

FIG.3 CAGR FUEL ELEMENT

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