THE TREATMENT OF ACTIVE WASTE FROM A PIE FACILITY

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The Treatment of Active Waste from a PIE Facility
by
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Introduction

Most cave operators know that one of the most important rules when planning a new programme of work is to ask the question, "How can I dispose of the components and waste after the completion of the PIE?" This rule is a very good one and can be justified on both economic and safety grounds. Caves that are loaded with active waste quickly become choked and work has to cease; a single cave station may cost of the order of £1000 per day to operate, so any loss of throughput is expensive. Furthermore, when stocks of active waste increase and are not cleared away in a planned manner it is inevitable that the radiation dose to operators will be high when steps are finally taken to deal with that waste.

For many reasons the handling of active waste now receives much more attention, in PIE facilities, than it did 10-15 years ago. In addition to the rule quoted above it is essential to have answers to questions concerning the amount and type of waste. It is also important to establish some quantitative measure of performance to ensure that every new step to deal with waste is a genuine improvement.

We must gather more information and treat the whole subject of waste systematically if we are to improve techniques and solve our problems. Information is required on every aspect of cave usage including, operations, cleaning, maintenance, and modifications. This can only be gathered by surveys using method study to establish what is fact rather than relying on opinion. However, opinions can be very useful and much information can be obtained from debriefing sessions with operators who are the only people who observe the process or system at close quarters. Too often valuable experience and information is locked in the memories of a group of operators and not made available to the designers of new plant.

Waste Production and Disposal Routes

The volumes of active waste produced by a typical programme in one of the cave lines in the Winfrith facility are given in Table 1. The quoted volumes are for the collected waste before it is loaded into shielded containers.

The sources which give rise to the waste are -

- Non-fissile surface contamination - (extract filters, equipment, swabs)
- Fissile material residue - (extract filters, equipment, swabs)
- Fuel assembly breakdown - neutron activated components
- Equipment protection prior to decontamination - PVC sheeting.
Table 1  Typical Annual Discharge of Active Waste for throughput of Ten Elements

<table>
<thead>
<tr>
<th>Type</th>
<th>Quantity in litres</th>
<th>Method of Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per element</td>
<td>Annually</td>
</tr>
<tr>
<td>Swabs</td>
<td>Non Fissile</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Fissile</td>
<td>Nil</td>
</tr>
<tr>
<td>Stringer components</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td>Nil</td>
</tr>
<tr>
<td>Filters</td>
<td></td>
<td>Nil</td>
</tr>
<tr>
<td>PVC sheet</td>
<td></td>
<td>Nil</td>
</tr>
<tr>
<td>Fissile material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid effluent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Routes for Disposal

The largest volume of waste is disposed of by the "sea disposal route", and from operational records and by testing with known energy sources approximate shielding factors have been produced for each type of disposal drum.

There are five variations of these drums in common use at the caves, the particular type being chosen to suit core diameter and shielding requirements (See Table 2).

Temporary Storage before Disposal

Immediate disposal is not always possible because the activity of some components is too high. The Winfrith Facility includes a large number of underfloor storage holes and these have been used to store containers of active waste for up to ten years. This cooling period reduces the gamma activity (Cobalt-60) to approximately 25% which may then allow the container to be sent for disposal via the sea route.
### Table 2 Shielding Factors for Sea Disposal Drums

<table>
<thead>
<tr>
<th>Type</th>
<th>Core diameter d cms.</th>
<th>Additional shielding t cms.</th>
<th>Shielding factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete (10 cms)</td>
<td>55</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Concrete (15 cms)</td>
<td>45</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Concrete (25 cms)</td>
<td>25</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Concrete + iron shot (25 cms)</td>
<td>25</td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>Concrete + lead (25 cms)</td>
<td>25</td>
<td>5 cms Pb.</td>
<td>56</td>
</tr>
</tbody>
</table>

**Note** The accuracy of these values is dependant on the accuracy of assessment of dose rate at source (prior to shielding) and the distribution of waste within the drum, and can only therefore be used as a guide when loading waste for disposal.

**Figure 1 Section Through Sea Drums**

![Figure 1 Section Through Sea Drums](image)
Problems

The Winfrith caves are specifically constructed and equipped to handle full-size fuel assemblies and in the past they have received F4R/SWR/SGRW/HR/Candu type/WAGR/CAGR/Magnox and other fuel types.

When undertaking the dismantling and PIE of fuel assemblies, active waste can arise from the irradiated components themselves or from contamination of otherwise clean objects. Let us now consider some of the routes which give rise to active waste.

A significant source of radioactivity and potential contaminant is, of course, the irradiated fuel and there are two ways that fuel particles can be released into a cave area. (a) If the fuel pins are deliberately cut for specimens, or (b) If the reason for PIE is because the fuel assembly contains a failure. Oxide fuel usually has a specific gamma activity of 1-10 curies per gramme and small particles which can become trapped in crevices in equipment, etc, can be the cause of significant waste. Oxide fuel also may contain, or become, a powder and in this dusty state it can easily disperse throughout the cave and perhaps reach the primary filters.

The deposits on the surface of the fuel pins are a further source of contamination. 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; the deposits are usually called crud in water reactors. The layers of corrosion products then become radioactive during their neutron exposure in the reactor core and are a potential source of contamination when the fuel assembly is removed from the reactor. The problem is more serious with the fuel taken from boiling water reactors. The corrosion products from the circuits are more firmly fixed to the fuel rods when they are wet, but if the fuel rods dry out the crud deposits tend to spall-off and are easily dislodged. The material in the crud deposits can be of high specific activity for example, samples taken from high burn-up fuel pins have had activities of up to 10 curies per gramme (Cobalt 60).

The irradiated assembly is usually placed in a specially designed corset for protection and then loaded into a flask for delivery to the PIE cave. The flask containing the fuel cluster is filled with water at the reactor and then is brought to a cave; this water is drained off and the cluster tends to dry itself by fission product heating. Because of the length of water reactor assemblies (4-5 metres) they often have to be introduced into a cave horizontally; this is more difficult to achieve smoothly than vertical loading, and during the operation it is quite easy to dislodge some crud. However, the most serious dislodgement of crud occurs when fuel pins are pulled through the supporting grids during the dismantling process, this operation tends to leave small heaps of crud on the supporting stands and this may become dispersed throughout the cave. Subsequently, everything that touches 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 vast quantities of operational equipment and materials in a cave and lead to large volumes of waste. The amount of waste is magnified considerably when one considers the materials necessary during the complete cleaning of the caves at the later stage.

A further minor form of contamination will occur if small quantities of 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 corset and then drip onto the cave bench or equipment.

Air filters are a good example of how a very small amount of radioactive material can lead to a very large amount of active waste. The primary air
filters used in the Winfrith caves measure 60 cm x 60 cm x 30 cm. If one of these filters is contaminated by one curie of irradiated fuel it will eventually have to be disposed of as active waste. Now one curie of fuel usually weighs less than 1 gramme, an easy amount to use in the example. The volume of 1 g packed as powder (at say, 50% of theoretical density) will be 0.2 ml approximately. The Winfrith disposal route for such a filter is to compress one diagonal so that the 60 cm x 60 cm square becomes a diamond with the minor axis less than 45 cm. This allows the filter to enter a concrete-lined drum which is filled with further concrete. The final volume of this drum is approximately 0.8 cubic metres and it weighs a little over one tonne. Thus, to dispose of 0.2 ml of radioactive waste (which could easily be shielded within a one litre container) we are forced to use a drum of 800,000 ml volume.

The steel fittings on fuel assemblies form another type of active waste. This type of waste is packed separately into containers, loaded into a flask, and taken away for long term storage. The cave processing of this waste is relatively simple the only problem is that transport delays can lead to a local storage problem. However, in the future it is fairly certain that there will be a demand to reduce the volume of the waste by increasing the packing fraction in the container. At present there are only a few items which are crushed, eg grids, to reduce their volume.

Certain wastes are combustible but, as yet, there is no established route to use a burning process to reduce the volume. One of the materials which arises as waste in the Winfrith caves is graphite (See Appendix 1).

Training

The training given to cave operators influences their attitude to operations and, at a later stage, can affect the amount and nature of active waste produced. In a busy active handling complex it is usual to employ relatively unskilled non-scientific labour for many of the jobs. These operators are given training on remote handling, protective clothing, basic health physics, safety, etc. The object of the training is to install an acceptance of rules and procedures. The fully trained man has a set of Operating Instructions which cover all normal situations; for non-standard operations he will be directly instructed by a scientist. Whilst this insistence on strict procedures is excellent in keeping safety standards high it does lead to a rather uncritical approach and a suppression of thoughts of improvements. The operators with 5-10 years of experience will have the attitude - "We have always done it this way". The requirement for maintaining safety standards by stringent procedures needs to be augmented by a regular review of all techniques and materials, etc, used in the programme of work.

Method Study

It is essential to collect detailed information for use at the planning stage if improvements are to be made to future cave operations. In the past improvements, and changes in procedure, have usually been based on experience and opinion. Whilst this approach has often been very successful it tends to be too narrow and has usually had the objective of improving the cave throughput of assemblies undergoing PIE. Without a careful systems analysis it is always possible that any improvement to cave throughput may be gained at the expense of, say, an increase in waste handling. For some years the management of the Winfrith caves have been using method study surveys to gather information and an example taken from one of these is included as Appendix 2. This was not really concerned with active waste but was primarily directed towards general operations inside the cave. However, the survey did reveal that one or two long-held opinions were incorrect. For example, Master Slave Manipulator breakdowns did not cause the loss of much cave time. To-date only a limited amount of surveying has been completed on the subjects of active waste, cave cleaning, and decontamination.
However, we plan to increase our studies of these subjects during the next year. For example, when one considers that the amount of waste generated by one-man entry into a cave is 72 litres (after packing) it is obvious that considerable savings must be possible. There were 405 man entries into the Winfrith caves during the first eight months of 1978.

**Future**

There are several factors which are tending to direct the future programme related to the disposal of active waste.

1. The reduction in the level of gamma dose received by operators has been high on the list of priorities in the Building for many years. (See Appendix 3). The handling of waste and the cleaning of caves is a major contribution to the accumulation of man-rem.

2. There is a growing desire to limit the volume of active waste from any plant or laboratory, both from a safety and cost viewpoint.

3. There is a considerable economic drive to reduce the down-time when caves have to be cleaned (for the modification of equipment) and also to reduce the waste handling time which is very often considerable.

4. As scientists we are constantly striving towards one of the ideals for active waste which are, either, a very high degree of concentration or, a very efficient dilution and then dispersion at an acceptably harmless level.

There are various improvements which have become apparent from the experience gained from the past fourteen years. It has become obvious that we must do something to reduce contamination problems. A first step has been taken in this direction, it is the installation, close to the caves, of a separate plant which can chemically clean a water reactor cluster (see Appendix 4). This rig is capable of completely removing the crud deposits from the cluster and once this has been done the amount of waste that is produced in the PIE caves is reduced dramatically. The next significant stage is to challenge all cutting of fuel inside the caves; before fuel is cut we must ask questions.

(1) Is it really necessary?

(2) Can the information be gained by some other technique?

(3) If the fuel must be cut how can it be locally contained?

(4) Can the number of cuts be reduced?

If fuel is cut, steps must be taken to stop any of the particles from reaching bulky filters. We are putting in hand an investigation of more refined fuel collection methods that can be used close to the cutter, for example, electro-static precipitation, cyclonic separation, magnetic trapping.

The other philosophy which must be more firmly adopted is to challenge everything that is passed into the caves. Again we must ask questions - Is the article really needed? Is there any other method or material that will do? How will the article be disposed of? Could earlier planning have avoided the need for the article in the caves?

Summarising, our approach to active waste (which is very closely linked to other subjects, eg, man-rem doses and economics) is based on -
(a) finding out more detailed information by method study,
(b) reducing input of materials causing contamination,
(c) reducing the input of materials that can be contaminated,
(d) stopping contamination reaching large objects like filters,
(e) looking at each problem more systematically to ensure that any change is a genuine improvement.
Incineration Process for the Disposal of Irradiated Graphite

An incineration process will be used for the disposal of irradiated matrix graphite of HTR fuel and other irradiated graphite components, e.g., graphite sleeves. Inactive trials have demonstrated that kilogram quantities can be burned in a controlled manner suitable for in-cave operations at 950°C in air (100% excess of stoichiometric). A vertical metal lined furnace, 15 cm diameter x 60 cm high fitted with electric heaters was used for the work with inactive graphite; the external wall of the furnace was automatically cooled by compressed air to control the inside furnace temperature.

In order to investigate the behaviour/volatilisation of radionuclides and impurities during the burning process in-cave burning trials were carried out on irradiated HTR fuel and laboratory scale trials on samples of irradiated graphite sleeves. Levels of radionuclides measured on furnace components and metal and absolute filters in the furnace off-gas system confirmed that the majority of the radioactivity remained in the furnace ash. Approximately half of the volatile impurities present (Cd, Pb, Sn) were deposited on the relatively cold pipework of the gas filtration system. The in-cave furnace for the small scale incineration of graphite will be operational in 1979.
Appendix 2

Example of Method Study of a Short Cave Programme

Some of the information gained from the survey has been condensed into diagramatic form. See Figure 2. The survey was concerned with the handling and PIE of a single water reactor assembly and all aspects of the work were monitored in great detail. The programme of work did not include any significant cave cleaning or decontamination; these were completed at a later date after further PIE programmes.

Figure 2. Method Study – Observed Time Breakdown

Total time = 328 man hours

Cave Station operations 71.6%
Flask preparation & use (Element) 9.2%
Flask preparation & use (Specimen & waste) 12.5%
Health Physics 2.5%
Cleaning 2.1%
Equipment posting operations 1.5%
Master Slave Manipulator 0.6%
In-situ repair.
Radiation - Personnel Exposure

In order to achieve a reduction in operator exposure, the available total REM exposure was assessed from the number of operating personnel in the section and the current permitted maximum annual exposure, i.e., for 40 personnel the maximum REM budget is 200. This concept of studying total man-rem for the area was started in 1968/9. During the ensuing eight years the individual maximum exposure has been reduced from 5 to 3 REM and the average exposure from 3.5 to 1.25 REM.

Figure 3 Reduction in REM Exposure Over Eight Years
Background

A feature of boiling water reactor fuel is the build up of deposits of crud on the surface of fuel elements during operation. This crud layer plays an important, if totally unwanted, part in the reactor operation. In the first place if the layer grows too thick it will reduce heat transfer and cause damage to the fuel. However, by control of primary circuit conditions this can be avoided. Secondly, it is this crud layer on the fuel which is responsible for the production of activation nuclides, e.g., Co\(^{60}\), which when subsequently released and transported to cut-of-core parts of the system give rise to radiation fields which cause problems for maintenance and inspection. Finally, the presence of a masking layer of crud on the fuel gives rise to considerable problems when the post irradiation examination of the fuel takes place.

At the present time our knowledge of crud deposits on fuel has been obtained from small samples of material taken from elements either in the fuel handling pond or during in-core examination. Although much valuable information has been obtained in this way it is extremely labour intensive and because of the possibility of large sampling errors the calculated values of total crud which are used in mass balance assessments are subject to uncertainty. In order to overcome the errors associated with discrete samples, and provide accurate data for the total crud and its composition on a fuel element, a rig has been built which can decontaminate full size fuel clusters. In addition to this information the decurred fuel available from the rig will enable post irradiation examination to be carried out more easily. Finally, the rig can be used for testing the effectiveness of alternative decontaminating solutions for removing crud from fuel elements.

Description of DECOR 3

The rig has been called DECOR 3, an acronym for Decrudding Rig, and it is the decontamination rig in use at Winfrith, and is located in the Active Handling Building. The plant consists of a vessel in which the decontaminating reagent can be mixed and heated to temperatures up to 95°C, a fuel cluster containment vessel in which an irradiated fuel cluster (held in a protective carrier) can be placed. These two vessels are connected by 3" diameter pipes and a pump circulates hot decontamination reagent from the heated header tank up through the fuel cluster at flow rates which are similar to those found in the reactor during a decontamination. A flow diagram of the rig is shown in Figure 4. The fuel cluster channel is located down a floor storage hole to provide the necessary shielding and other parts of the plant are shielded by concrete block walls. Access to the cluster channel for loading and unloading irradiated clusters is by use of a transport flask.

The rig is equipped with both physical and chemical instruments which enable the decontamination process to be followed in detail and to measure the total amount and composition of material removed from the element. In operation the degree to which each stage in the process is monitored will depend on the experimental requirements, e.g., is crud inventory measurement or a clean fuel element the prime consideration or, alternatively, is a new decontaminating reagent being tested.
VEM
30 lb/in²
90° C MAX
40 lb/in²
100° C

THE PRESSURISED PART OF THIS CIRCUIT IS THE OVERCAN AND ALL PIPEWORK UP TO AND INCLUDING VALVES: VI, V2, V3, V4 & V5 PUMP DELIVERY FLANGE F.D. AND IS INDICATED BY

FIG. 4 FLOW DIAGRAM OF DECOR 3