REPACKAGING OF DRAGON REACTOR (HEU) FUEL

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ABSTRACT

The Dragon Reactor was a High Temperature Gas Cooled Experimental Reactor which operated at UKAEA's Winfrith Technology Centre between 1965 and 1976 The all-ceramic fuel for this reactor was produced in the form of 500 to 800 μm diameter microspheres of fissile material coated with layers of pyrocarbon and silicon dioxide. The finished particle size was about 1 mm in diameter. The coated particles were sprayed with graphite resin mixture and hot pressed generally into annular compacts which were then loaded into graphite tubular fuel elements for irradiation. The fuel was highly enriched in U235 (to> 90% in some cases).

Following irradiation the fuel was transferred to an Active Handling Building for breakdown and examination. Selected samples were retained but the bulk was emptied from the tubes into mild steel spent fuel storage containers with nominal dimensions of 229 mm outside diameter and 2.59 metres long. The fuel compacts were stored in mild steel inner tubes inside the container. Most of the containers had 14 inner tubes but some had 18 and a few 6. The numbers of compacts in each container ranged from a few hundred to several thousand.

At the end of the Dragon Project in 1976, nearly all the fuel inventory of the reactor had been packed inside 85 of these mild steel containers and held in underground fuel storage facilities until a disposal route had been identified.

Following a reappraisal of the storage strategy in 1993, it was decided to repack all the spent Dragon fuel into new third-length containers manufactured from AISI type 316L austenitic stainless steel to provide superior long term corrosion resistance The repacked fuel was then returned to underground storage at the Dragon reactor pending a decision on its final disposal.

This paper describes the repacking project which began in March 1996 and will be complete by April 1999.

INTRODUCTION

This paper describes the repacking of Dragon Reactor Fuel, originally stored in mild steel containers into suitable stainless steel containers for long term storage.

The Dragon Reactor was a High Temperature Gas Cooled Experimental Reactor located at the United Kingdom Atomic Energy Authority (UKAEA) site at Winfrith. The fuel consisted of an intimate mix of fissile material (uranium oxide or carbide with a diluent which was either inert (zirconium oxide or graphite) or fertile (thorium oxide or carbide) in the form of 600 μm diameter microspheres. These microspheres were coated with layers of pyrocarbon and, in most cases, a layer of silicon carbide. The coated particles were then mixed with graphite and compressed generally into annular shaped compacts, although other geometries were produced.

Following irradiation the fuel was transferred to the Active Handling Building (A59) for examination. Selected samples were retained but the bulk was emptied into a total of 85 mild steel spent fuel containers each ~ 2.6m in length. These containers were placed in underground storage holes in the Dragon Fuel Store (DFS) between 1966 and 1976.

An Option Study in 1994, conducted by the UKAEA, concluded that the waste should be repacked in a form suitable both for transport off site and for future storage. The contents of each original container would be transferred to 3 third length stainless steel containers using the South Cave Line shielded facility in the Active Handling Building A59.

The fuel repacking programme commenced in March 1996 and is expected to be completed by April 1999. In July 1996 NUKEM Nuclear Limited (NUKEM) won a 4 year contract for work in A59 which included the completion of the Dragon fuel Repacking Programme. NUKEM carry out all operations within the Active Handling Facility and flask operations in the Dragon Fuel Store (DFS) under the direction and control of UKAEA.

STRUCTURE OF ORIGINAL FUEL CONTAINERS

There are at least five different designs of storage containers the majority of which consist of arrays of mild steel tubes 2.6m long inside a mild steel container 220 mm OD. The tubes in most containers are arranged in a regular array comprising either 14 tubes each of 50.8 mm OD or 18 tubes each of 43mm OD. There are 3 containers with a 6 hole configuration and one with no internal tubes. The lid of the container has a central mushroom lifting feature and is secured by either a central bolt or ten peripheral bolts. The outer container was made from rolled mild steel with a seam weld and the overall length achieved by welding sections together.

STORAGE OF CONTAINERS IN THE DRAGON FUEL STORE (DFS)

The DFS comprises two separate stores each occupying a concrete lined pit one of 50 holes and the other 40. The storage channels in the 50-Hole store were provided with a combined cooling and drainage system. The 40 Hole store does not have any cooling or drainage facilities, each channel being a separate entity and a blind hole. The examination of four mild steel storage containers in 1983 concluded that the structural integrity did not seem to have been impaired. A flooding incident involving dilute hydrochloric acid occurred in the fuel store area in 1984 and subsequent inspections of holes in the 40 Hole store revealed the presence of mildly acidic water. A further examination of four containers in 1986 showed one container had been affected by the acid spill to the extent of being coated with corrosion products. It was assessed that the structural integrity had not been seriously damaged and the container was fit for a further period of storage.

A programme to lift and inspect the fuel containers in the Dragon Fuel Store was carried out using the Dragon Transit Flask and a viewing facility. A programme to detect the presence of water in the 40 Hole Store found 7 out of 12 holes tested contained water and a further 22 had condensation on the sealing plug indicative of water being present. Water samples retrieved were slightly acidic (pH between 3 and 4) and had no significant activity. It was recognised that the presence of chloride ions would enhance the mild steel corrosion rates.

SOUTH CAVE LINE SHIELDED FACILITY

The South Cave Line (SCL) facility in A59 consists of a 3 module ventilated cave constructed of 1.52m thick concrete. It has 6 main operating stations each equipped with 2 master slave manipulators (MSM) either side of a zinc bromide window. Additional MSM's are installed at 3 smaller windows. There are two overhead 500Kg in-cave hoists which run the length of the cave and into a transfer chamber at the west end. The concrete door at the west end can be opened hydraulically to allow posting operations between the shielded area and the transfer chamber.

Posting facilities for transfer of the Dragon Fuel are situated on the cave roof at the east end and a gamma gate system on the cell face on the north side. The former is for vertical use with either the Dragon Transit Flask (DTF) or Type 3359 Modular Flask and the latter for horizontal use of the Modular Flask. The whole area inside the cave has a stainless steel bench supported on a mild steel framework.

FLASK HANDLING AND FUEL TRANSPORTATION

The Dragon Transit Flask (DTF) has been used to retrieve and transfer the original containers from the DFS to the South Cave Line in Building A59. This flask is for vertical use and was designed and manufactured by Heraeus of Hanau in Germany in 1964. The same flask is used to return the third length containers (TLC's) to the DFS. The flask is shown in Figure 1.

Figure 1: Dragon Flask in Position on South Cave Line Roof

Additionally, a Modular Flask (Type 3359) was modified to handle the new TLC's in either a horizontal or vertical configuration. This required the development and commissioning of a winch and push rod system that could operate an electro mechanical grab. This allowed the repacked fuel to be horizontally loaded in Building A59 and vertically discharged into the DFS storage holes.

METHODS AND LAYOUT FOR DRAGON FUEL REPACKING IN THE SOUTH CAVE LINE

The proposed methods for repacking the fuel identified the required new equipment, modifications to existing equipment and in cell furniture. It also specified certain restrictions and considerations to be taken into account.

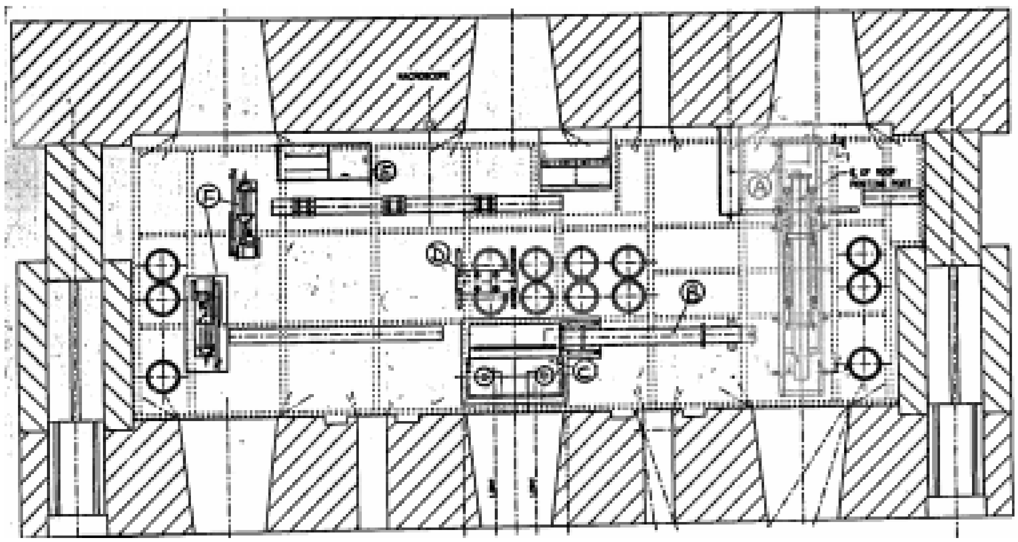
The basic repacking operations are summarised below:

- The Dragon Flask is transferred to the posting port on the roof of the SCL above Station 18. An original container is lowered from the flask into a tilting frame mounted on the cave bench. The container is lowered to the horizontal.
- The lid is removed and replaced with a 'gate' device.
- The original container is transferred from the tilting frame to the emptying frame with the open end of the container connected to the contamination enclosure. Two new third length containers (TLC's) are placed into recessed bench liners.
- The fuel is emptied from the original containers into the contamination enclosure in a controlled manner, one tube at a time using the gate device. The fuel is identified and repacked into the TLC's.
- After filling, the TLC is cleaned and transferred to the tilting frame for loading into either the Dragon Flask or the Modular Flask for transport to the DFS.
- The last TLC remains in place until the empty original container has been inspected for any remaining fuel. This is done by cutting the top and/or bottom off the container in the power saw as necessary, and inspecting all internal cavities for fuel.
- The original container is cleaned and size reduced as necessary and then posted out of cave via the SCL West door for disposal as Low Level Waste. During the same posting operation the next batch of three empty TLC's is posted into cave.

The following parameters had to be taken into account when designing the flow sheet for the re-packing process:-

1) Only the contents from one original container (or part thereof) would be allowed in the SCL at any one time. This provides an obvious means of criticality control.
2) The empty container must be cut open and inspected to ensure that the complete fuel contents have been repacked before the last $^1/_3$ length can be removed from the SCL.

The basic layout of equipment for the repacking process in shown in Figure 2 Prior to installation of the new equipment existing furniture was removed from the bench and provision made for the installation of two recessed bench liners.



A Hydraulic Tilting Frame **B** Emptying Frame **C** Repacking Enclosure **D** TLC Storage Rack
E Shielding Monitoring Enclosure **F** Kasto Power Saw

Figure 2: General Layout of Equipment in South Cave Line

New equipment which required design, manufacture and installation included:

- Hydraulically operated tilting frame for unloading and loading fuel containers via the SCL roof posting facility.
- Emptying frame to discharge the fuel.
- Contamination enclosure with a filtered extract to receive discharged fuel.
- Bench liners to hold new TLC's.
- 2 power saws to cut empty mild steel containers.
- Tilting frame to move TLC's from vertical to horizontal mode.

In addition, a CCTV camera was installed above the repacking station to allow a video record to be made of the repacking process. at a later stage in the programme a modification was made to install a shielded enclosure to facilitate radiation monitoring of the size reduced sections of the original container. The fuel re-packing station is shown in Figure 3.

Figure 3: Fuel Packing Station

FUEL IDENTIFICATION, RECORD AND ACCOUNTANCY REQUIREMENTS

It is of prime importance that the UKAEA system of accounting for and controlling nuclear materials meets national and international obligations. It is necessary to control and maintain accurate records of the location and movement of Nuclear Materials.

In order to comply with regulations adequate steps had to be taken to ensure sufficient information was acquired regarding the fissile material contents of each repacked TLC. This was achieved by physically identifying the fuel and sub-dividing the original fissile material weights accordingly.

Each of the mild steel containers has an original loading sheet which gives information including source fuel element, number of items and fissile material contents. Items from between 3 and 40 different source fuel elements were loaded into the same container. Not only is there a possibility of a variation in fuel enrichment (3.5%-93% U235) but also a variation in the physical characteristics of the fuel. The majority of the fuel is in the form of annular rings (referred to as compacts) which vary in physical size. There were originally individually marked with a unique identification (letter/number) which can still be seen on most of the compacts. For the majority of fuel elements loading information on compact identification was available in archive reports. Fuel is also present in the form of ~ 10mm diameter pins of different lengths known as teledials. Cylindrical boxes ~ 150mm in length also contained fuel in the form of cartridges or loose particulate. Some fuel was thorium doped and therefore after irradiation contains U233.

In order to assign an inventory to each TLC records were made of visible identification markings on each item and matched against archive information on each source fuel element listed on the original loading sheet. When all items of fuel were repacked the original inventory was sub-divided proportionally according to contents of each TLC. The original total inventory for each source element was assumed to be equally divided amongst the number of items listed.

After completion of a fuel container examination in A59, the recorded data is correlated with the number of items actually found. Where differences occur the repacked fuel weights are proportionally adjusted if necessary to give a revised Authority Nuclear Materials Accountancy Project (ANUMAP) value. Any deficiencies and excesses in a container are recorded and these running totals carried forward to subsequent containers. If a net difference still remains at the end of the programme, a single accountancy change will be sought

The fuel items not positively identified are sorted into groups of the same physical size and loaded into the final TLC. Best efforts are made to balance any shortfalls in the number of items against each source element with the unidentified items. Generally the number of items found agrees closely with original records.

FUEL REPACKING OPERATIONS

Following a successful non-active commissioning phase the programme commenced with the repacking of 5 selected containers as an active commissioning phase. A report on this phase was submitted via the UKAEA safety approval procedure to repack a further 15 containers after which point a further report was required. This report was submitted and permission given to repack the remaining containers.

The three TLC’s are engraved with identification of the original container with the addition of a suffix of ‘A’, ‘B’ or ‘C’. Every effort was made to load the ‘A’ and ‘B’ containers with identified fuel to simplify the fuel accountancy process. Compacts with no visible identification markings and all fuel fragments were loaded in the ‘C’ container. In a few instances the fuel was successfully loaded into two TLC’s.

The experience gained repacking the first container, D80 led to improvements and additions to equipment.
These included:

1. manufacture of simple ‘gate’ devices to fit both 14 and 18 hole containers to allow one tube at a time to be unloaded
2. manufacture of basic metrology devices to measure compact dimensions
3. installation of electronic weighing platform to weigh complete compacts and fuel fragments to equate the latter to complete items.

A Euratom inspection of the records declared that the records made for the TLC’s from the first 3 containers repacked were adequate. During the repacking of later containers loose particulate fuel was discovered that had been released from broken boxes. Container D35 in particular had a significant amount of loose particulate fuel. Although it was known that boxes contained fuel in this form it was not appreciated that the fuel was loose. This led to a re-appraisal of the criticality assessment for the DFS to demonstrate that a mixture of fuel in graphite compact and particulate form is safe. This reassessment caused no operational problems.

The outside of most containers from the 40 store have shown varying corrosion typically having 'tide marks' of rust within 45cm of the bottom end. Corrosion was observed on the internal surface of the lids and inner tubes, particularly near the bottom end. The latter had resulted in trapping fuel compacts and boxes in the tubes, particularly near the bottom end. This resulted in the contents not being removed by simply tipping the container. Typical appearance of these jammed compacts is shown in Figure 4.

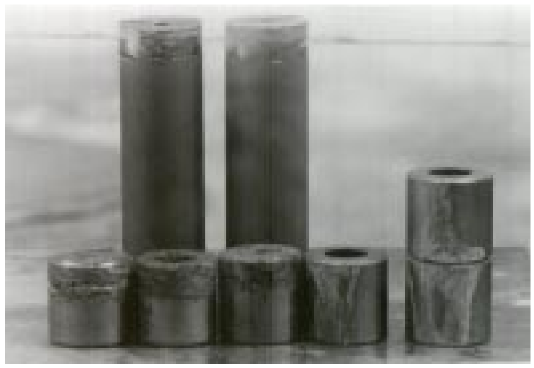


Figure 4: Compacts and Fuel Boxes with Witness Markings Resulting from Corrosion of Mild Steel Tubes

The worst container encountered, D5, had four tubes which initially failed to release any compacts. The container had to be progressively cut and returned to the enclosure to release the fuel from either end. The final four compacts were jammed in a section of tube that had completely corroded through on one side.

The original containers were manufactured to a specified maximum OD and straightness tolerance to ensure no interference with the flask liner. The corrosion of the outer wrapper has caused problems with loading the DTF at the DFS. Several attempts were necessary to load both D20 and D27. It appears that the corrosion band, 25-45cm. from the bottom end, had sufficiently increased the diameter of the container to foul the inside of the flask. Either the container rotated slightly or some material spalled off to allow loading. These containers presented no problems when discharged into the SCL.

WASTE DISPOSAL

The levels of contamination on the mild steel containers were generally low. Using remote cleaning methods and careful radiation monitoring virtually all the containers have been disposed of as Low Level Waste.

The original container is cut into sections using a Kasto power saw adapted for remote use. The internal tubes are cleaned using a carbide tipped honing brush held in an air powered drill. After cleaning the sections are placed in the in-cave shielded enclosure for initial radiation monitoring. The sections are then posted out of cave via the transfer chamber where further monitoring is carried out before loading into 220 litre drums.

CONCLUSIONS

The original mild steel containers had been stored for up to ~30 years in either a nominally dry or wet environment. The majority of those from the former, which were in the ventilated, drained storage holes were in good condition with little evidence of corrosion. Those stored in the unventilated store that had seen wet conditions showed varying degrees of corrosion . There is no evidence to suggest that the outer wrapper had penetrating corrosion but water had entered the containers via the lids either directly during the spillage incident or later by a condensation process. This allowed corrosion of the inner tubes that trapped the compacts near the bottom of the containers. It is possible that a further long period of storage may well have resulted in penetrating corrosion.

The information gathered regarding the contents of each container has improved the records on the physical characteristics of the repacked fuel. The fissile material records for the repacked fuel are comparable to the original records. This project has been completed within time and budgetary constraints to return the Dragon Fuel to a state where its continued secure storage can be guaranteed.

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