OPTIMISED CONDITIONING OF ACTIVATED REACTOR GRAPHITE

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ABSTRACT

The research reactor DIORIT at the Paul Scherrer Institute was decommissioned in 1993 and is now being dismantled. One of the materials to be conditioned is activated reactor graphite, approximately 45 tons. A cost effective conditioning method has been developed. The graphite is crushed to less than 6 mm and added to concrete and grout. This graphite concrete is used as matrix for embedding dismantling waste in containers. The waste containers that would have been needed for separate conditioning and disposal of activated reactor graphite are thus saved. Applying the new method, the cost can be reduced from about 55 SFr/kg to about 17 SFr/kg graphite.

INTRODUCTION

The Paul Scherrer Institute (PSI) is the largest national research laboratory in Switzerland. Its multidisciplinary research is dedicated to natural sciences and technology. The emphasis of the research has shifted during the last decade from nuclear energy research and particle physics towards materials science, general energy research, life sciences and environmental sciences. A consequence of this shift is that two of the three research reactors at PSI have been decommissioned. The dismantling of these reactors generates large volumes of solid waste. In accordance with Swiss legislation, the waste has to be solidified and conditioned to await final disposal. Because of the high conditioning and disposal costs, the development of cost efficient methods is mandatory.

STATEMENT OF THE PROBLEM

The DIORIT reactor (1), named after the igneous rock diorite, is one of the two research reactors decommissioned at PSI. It was a D_2O moderated uranium (up to 2.2% U-235) reactor with a graphite reflector and a thermal power of 30 MW developed entirely by Swiss industry. It was constructed from 1956 to 1960 and operated from 1960 to 1977. The reactor is currently being dismantled. There are approximately 45 tons of chemically inert reflector graphite with segments weighing up to 50 kg. The graphite was provided by Union Carbide. This material poses no significant problem with respect to the induced Wigner energy. The main radionuclides present are H-3, C-14, Eu-152 and Eu-154 with activities of $4.3x10^5$, $1.0x10^4$, $5.7x10^3$ and $1x10^3$ Bq/g respectively.
Several options were discussed concerning the conditioning of this graphite.

In principle, graphite can be incinerated with the release of the volatile nuclides to the atmosphere. The new plasma furnace at the nearby ZWILAG (Zwischenlager Würenlingen AG, the central interim storage facility) would be a future option for this purpose, once it has become operational. However, besides the uncertainty of the commissioning date and the unacceptable release of volatile nuclides, the major technical hindrance is the "feed system" which requires 200 L steel drums. One segment of approximately 50 kg could be loaded into each drum for plasma incineration. For environmental reasons, and because of the unknown cost and unsatisfactory weight reduction, this procedure was not deemed to be appropriate. A possible alternative was the volume-optimised embedding of the untreated graphite segments in cement mortar in standardised PSI concrete containers. About 13 containers with an overall volume 58.5 m^3 would have been necessary. The estimated cost of this option was about 2.5 Mio SFr, based on conditioning, interim storage and final disposal charges of about 42'000 SFr./m^3.

SOLUTION

Steel, cast iron and barite/colemanite concrete, derived from the dismantling of DIORIT, are conditioned at PSI by loading them into standardised concrete containers with an internal volume of 2.75 m^3 and an overall volume of 4.5m^3. Loading the containers in the most efficient manner utilises about 50% of the internal volume. The remaining 50% is filled with inactive mortar.

The newly developed approach uses the void volume normally filled with inactive mortar to condition the activated reactor graphite. The graphite is crushed to a particle size below ~ 6 mm and added to the concrete and grout during manufacture.

Fig. 1. Hammer Crusher.

Dismantling of the research reactor DIORIT

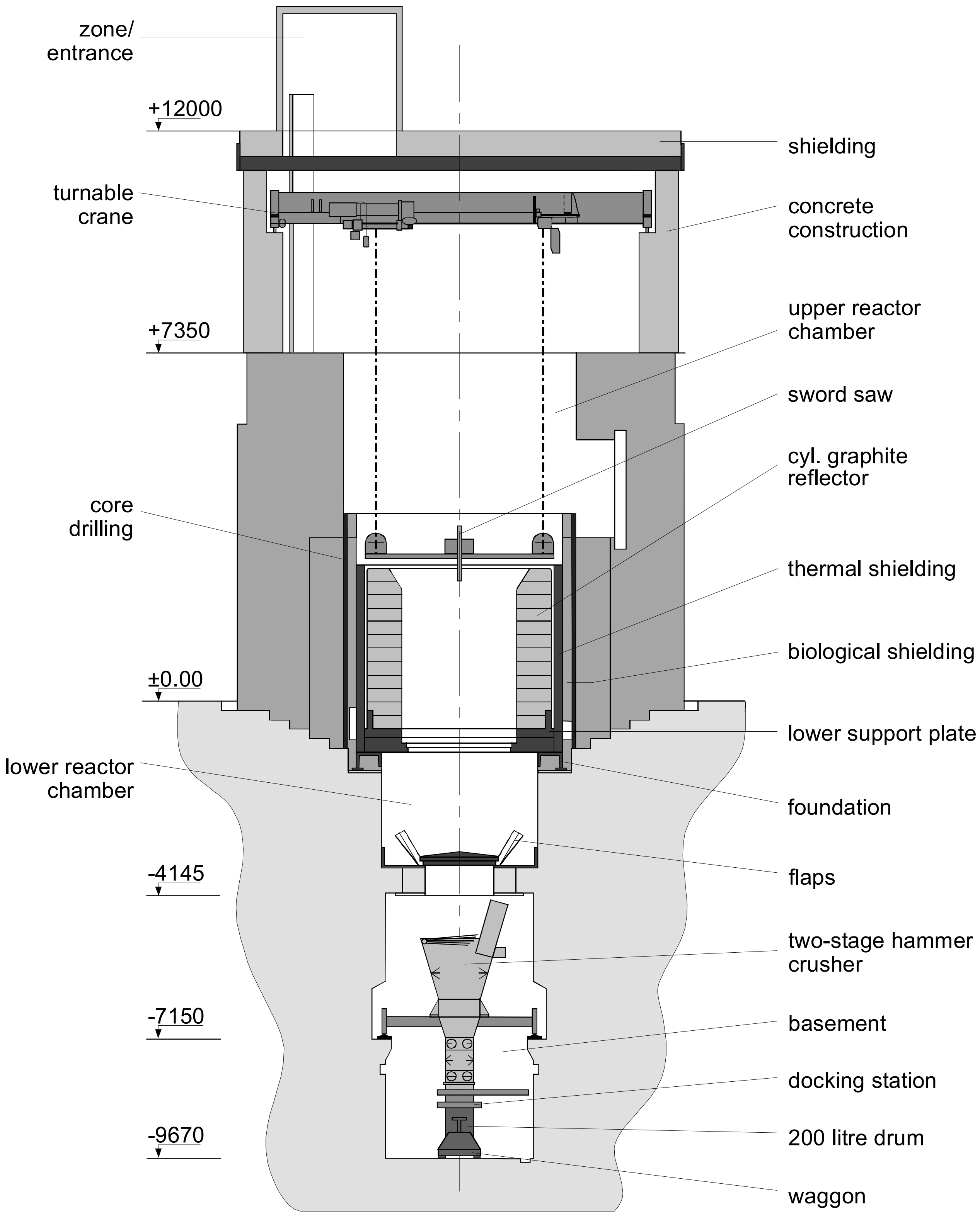

Fig. 2. Cross section through the reactor DIORIT including the hammer crusher.

PROCESS DESCRIPTION

A two-step hammer crusher (Fig. 1) is placed in basement of the reactor building directly below the reactor. The situation is shown in Fig. 2. The 50 kg graphite segments are taken by means of a crane equipped with rubber vacuum holders, and loaded through the interior of the reactor into a funnel mounted on top of the crusher. Subsequently the graphite is crushed to a particle size below 6 mm (Fig. 3). During the crushing the graphite is wetted by adding 3

Fig. 3 Crushed graphite, maximum particle size 6 mm

to 5 weight% of water containing a surfactant to avoid dust formation. The crushed graphite is filled into 200 L drums to await further processing. Up to 50 weight% of graphite is mixed with the grout during the conditioning of waste in 4.5 m^3 standard PSI containers. In the case of concrete, up to 75 weight% graphite content can be achieved by adding larger pieces of up to 60 mm. Containers pre-filled with the above mentioned wastes are finally filled with this graphite cement mortar matrix. This method allows the conditioning of up to 600 kg graphite per container in addition to the normal waste content. The waste containers that would have been needed for the separate conditioning and disposal of the activated reactor graphite are thus saved.

RESULTS

Samples of the hardened graphite grout (Fig. 4) were investigated with respect to its pressure strength and leachability according to the demands of the Swiss regulators published in (2).

The results are described in (3). The minimal pressure resistance of the hardened graphite cement demanded by the Swiss regulators (Swiss Nuclear Safety Inspectorate) of 10 N/mm^2 is exceeded by a factor of about 5. The average of the measured pressure strength after 28 days of hardening is 49.8 N/mm^2 (9 samples). The leachability is about 4 times lower than the demanded maximum of $5x10^{-6}$ m/d. The measured values (average of 4) with demineralised water for Co-60 are $1.27x10^{-6}$ and for Cs-137 $1,17x10^{-6}$ m/d.

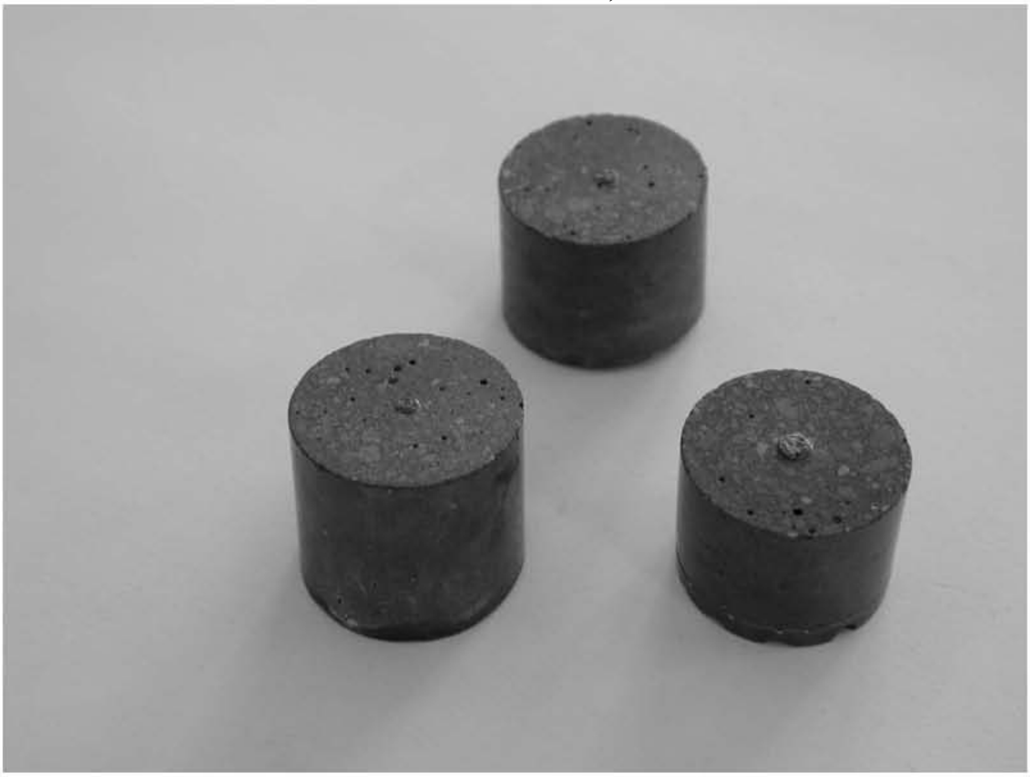

Fig.4 Graphite concrete samples, diameter 21 mm

ECONOMIC ASPECTS

The costs of the disposal of activated reactor graphite are of the order of 55 SFr/kg. Applying the new method, the costs can be reduced to about 17 SFr/kg. The disposal costs for 45 tons of activated graphite at PSI are then about 765'000 SFr. Savings of the order of 1.7 million SFr. are expected.

CONCLUSION

A cost effective conditioning method has been developed at PSI for the disposal of activated reactor graphite. This method fulfils the demands of the Swiss authorities (Swiss Nuclear Safety Inspectorate) and avoids the release of volatile nuclides into the atmosphere. The procedures have been approved by the Swiss authorities and the disposal implementors (NAGRA). Taking into account the huge amount of activated reactor graphite stored world wide awaiting treatment, this cost-saving method is widely applicable. A patent has therefore been filed (4).

LITERARURE

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(4) Disposal of Radioactive Materials“, PCT WO 00/77793, June 14th 1999