Results of the Visual In-Pile Inspection of the Inner Graphite Reflector of the AVR

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Introduction

Consideration is being given to reconstruct the high temperature gas-cooled pebble-bed reactor AVR for the application as a source of nuclear process heat. The reactor started in 1967 with a maximum gas outlet temperature of 750°C. Initially it was planned to operate the reactor for 10 years. After 8 years, it was decided to increase the maximum gas outlet temperature to 950°C to prove the possibility of generating gas temperatures which are relevant for nuclear process heat. Except for an interruption of about 1 year, the reactor was successfully operated until now with a maximum temperature of 950°C.

It is a basic requirement for a continuation of the research and development work with the AVR, that after about 16 years of operation, the main components of the reactor are in good condition so that they could be used for a further operation. One of the very important components is the inner graphite reflector. In the AVR, the upper side and the top reflectors were most exposed to fast neutrons and to the highest temperatures. By the end of 1984, the maximum fluences in the upper side reflector was 5×10^{21} cm^{-2} EDN at about 650°C and 1.2×10^{21} cm^{-2} EDN at temperatures at about 1000°C. (1)

To prove the integrity of the graphite reflector, it was decided to carry out a visual inspection of the upper reactor core.

Description of the equipment for visual inspection

The principle of the proceeding was as follows (fig. 1): A camera, especially developed for this purpose, was led through the central charge tube. Because of the small diameter (61 mm) and the small radius of the tube curvature (200 mm), the size of the camera had to be decreased to 155 mm in length and 35 mm in diameter. The full length of the way, on which the camera had to be moved through the tube into the core, was about 30 m (fig. 1). At the periphery of the reactor core, there are 4 more charge tubes which were used for the introduction of 4 spot-lights (fig. 2). The movements of the camera and of the spot-lights were remotely controlled. During inspection, the spherical fuel elements had not to be removed from the core. By shutdown, the temperature was decreased to 50°C; the dose rate, which the equipment had to withstand, was 1.7×10^5 rad · h^{-1}. (2)

Reflector graphite

For the inner side and top reflector of the AVR, the needle coke graphite ARS/AMT produced by the Sigri Elektrographit Company was used. Parts of the side reflector and the graphite tubes for the control rods were extruded. The segments for the

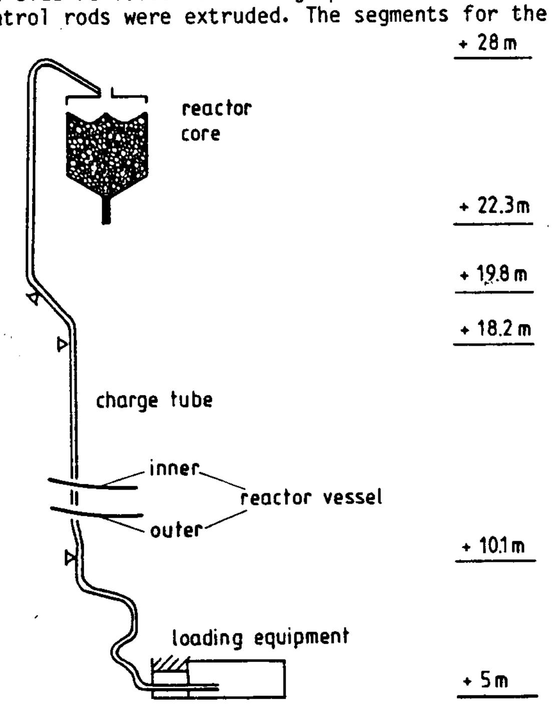

Fig. 1. Schematic illustration of the central charge tube (2)

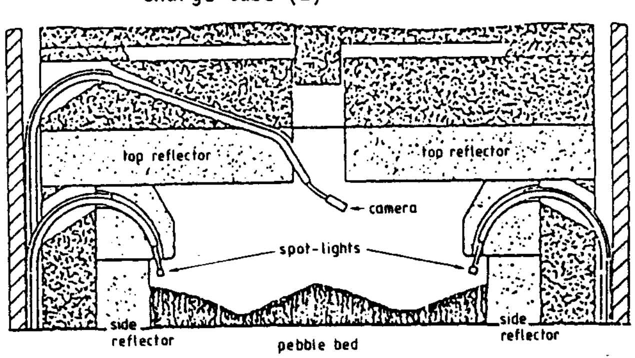

Fig. 2. Schematic illustration of the visual inspection (2)

top reflector (fig. 3) were stamped. The properties of the ARS/AMT are comparable to those of the British PGA graphite which was manufactured by using the same raw materials (shell coke and pitch binder). A few samples of ARS/AMT were irradiated in the DRAGON reactor, in the High Flux Reactor in Petten and in the Dounreay Fast Reactor in the frame of the THTR Association during the sixties. Pre-production material was examined before and after irradiation in the General Electric Test Reactor in Vallecitos/Cal. (3)
The irradiation induced d i m e n s i o n a l c h a n g e s are in a range where the graphite is densified due to the decrease in the dimensions. In spite of a relative high anisotropy ($\alpha\perp/\alpha\parallel\approx2$), the dimensional changes take an comparatively isotropic course in the fluence and irradiation temperature range investigated. The densification was accompanied by an increase of Y o u n g ' s m o d u l u s and s t r e n g t h.
In the fluence region which the reflector has seen during the operation of the reactor, the c o e f f i c i e n t o f l i n e a r t h e r m a l e x p a n s i o n , C T E , increased at low fluence and then significantly decreased with dose, a well-known behaviour of polycrystalline graphite under fast neutron irradiation. Also t h e r m a l c o n d u c t i v i t y measured at room temperature decreased in the way known.

Results of visual inspection

The inner reflector of the AVR was photographically documented by the Hochtemperatur-Reaktorbau Company (HRB) before the reactor operation started. By means of the camera, every block and segment were intensively considered several times. Special features, for example fracture of an edge or peculiar macro pore size distributions, which had been photographed before reactor operation could be identified again and shapes as well as sizes were compared with the pre-irradiation values. The top and upper side reflectors appeared unchanged. Only the spaces between the segments of the top reflector which had a width of 2 mm in the original state appeared closed immediately at the core side. The inspection revealed that the closures had a very small depth so that is can be assumed that the disappearance of the spaces were due to filling with graphite powder. A further possibility is the movement of the segments due to thermal expansion and their changes under reactor operation. The segments were not fixed, but they were put on the side reflector (see fig. 2) so that a very small movement in the radial direction was possible.
The essential results of the visual inspection are that in spite of several shutdowns during 16 years of operation, no cracks or fractures were observed to have occurred. This is in agreement with the results obtained from the irradiation of small samples (fig. 4) as well as of stress calculations performed by HRB (4) and KFA (5).

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Acknowledgement

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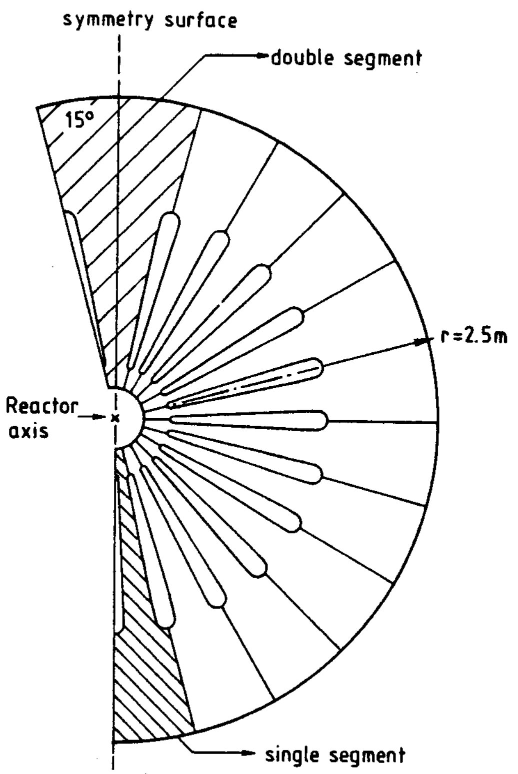

Fig. 3. Horizontal sectional view of the graphite top reflector (4)

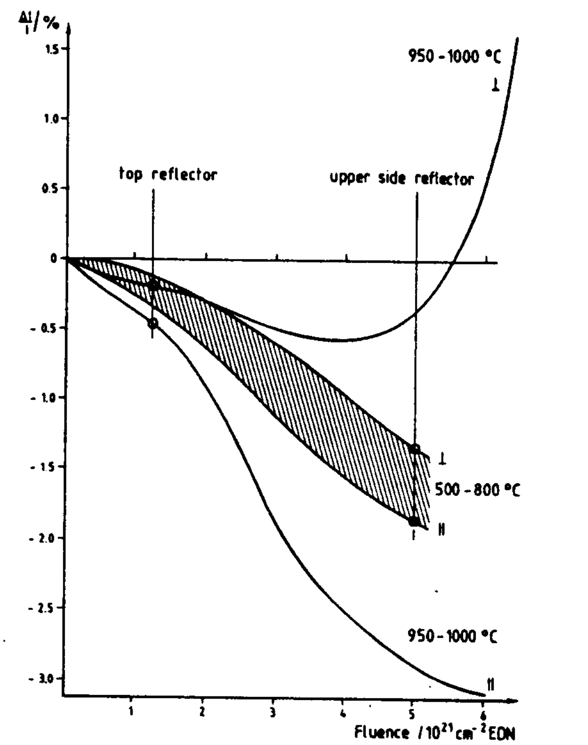

Fig. 4. Dimensional changes of ARS/AMT needle coke graphite with AVR conditions by the end of 1984