HANDLING AND TRANSPORT SYSTEM USED FOR SPENT FUEL FROM THE THTR 300 MW NUCLEAR POWER STATION

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Abstract

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After reaching the reference burnup, the spherical spent fuel elements of the thorium high temperature reactor are put into cans using a special filling device and then temporarily stored in the reactor building, with 2100 spent fuel elements per can. The cans are sealed with a press-fitted lid and have a leaktightness of approximately 10^{-4} mbar·L/s. These cans are then lowered by means of a crane equipped with a can grapple through an opening in the ceiling into the loading station. Here the shipping and storage cask is ready for loading. The cask hangs in a special trolley on rails. Under observation through a shielding window, and with camera monitoring, the cans are lowered into the cask. Still at the loading station, the primary lid is placed on the cask by remote control. After this, further handling is carried out at a second station outside of the loading station, where the secondary lid is assembled. These procedures are also either fully or partially automated. At the third station in this handling chain, the trolley drives to the shipping carriage, where the transfer of the cask takes place by means of a remote-controlled hoisting crane. The process of finally readying the cask for shipment is similarly automated. The handling procedure is designed to be able to smoothly perform approximately 100 cask loadings per year. Transport units consisting of two shipping carriages, with a total of six casks in each case, have been constructed. The transfer to an external facility will be performed by the national railway system of the Federal Republic of Germany. Particular emphasis was placed in the design on minimizing the collective radiation dose of the service personnel. The design of the cask itself and its peripheries on the shipping carriage meets the regulations for the shipping of Type B(U) packagings.

1. INTRODUCTION

The 300 MW thorium high temperature reactor (THTR) nuclear power station is the first large scale, high temperature reactor with a pebble bed core, containing a mixture of some 670 000 individual and spherical fuel, moderator and absorber elements, each with a diameter of 6 cm, for carrying out zero energy tests. This is also the number of elements used in the core for power production. The top, side and bottom reflector structure material is graphite. The highly enriched uranium fuel in the fuel elements is embedded in coated particles of a spherical graphite matrix that acts as structure and moderator material. The heat transfer from the core to the steam generators is accomplished using helium as the coolant gas.

The fuel elements which are to be discharged from the inner fuel circuit of the plant will have reached an average burnup of about 11.4% fission per initial material. The handling of these spent fuel elements, e.g. the gastight sealing of the loaded THTR cans (each containing 2100 elements) and their positioning in the shipping and storage casks, is carried out under normal air conditions at the particular part of the THTR plant, as compared with the 'under water' loading of shipping and storage casks for LWR spent fuel elements which, after loading, have to be dried using evacuation and gas-exchange techniques.

2. DISCHARGING SPENT FUEL ELEMENTS FROM THE THTR-300 PLANT: A SUMMARY

Having achieved the above-mentioned burnup, the spent fuel elements are loaded into cans and stored at the THTR spent fuel element storage facility (part of the reactor building) for at least a year. After this cooling time, the cans are placed into a shipping and storage cask which meets international and national regulations for the shipment of Type B(U) packagings.

A transport arrangement, consisting of two wagons, each loaded with three casks, is used to transfer the casks, by the national railway of the Federal Republic of Germany (FRG), to a temporary storage facility for 10 to 20 years before further handling.

3. MAIN COMPONENTS OF THE THTR HANDLING AND TRANSPORT SYSTEM

Important components of the pneumatically operating internal fuel charge and discharge system are three discharge pipes which facilitate the filling of spent fuel elements in the THTR cans.

After being filled with 2100 spent fuel elements, each can is sealed by means of a press-fitted lid with a leaktightness of approximately 10^{-4} mbar·L/s. These cans are then stored at the internal THTR spent fuel storage facility for at least one year. After this cooling time, the cans are hoisted by means of a crane with a grapple and lowered via an opening in the ceiling down into a shielding cell, the 'loading station'.

In this shielding cell, a shipping and storage cask is prepared which hangs in a special remote-controlled trolley (see Fig. 1). The trolley itself is guided by rails.

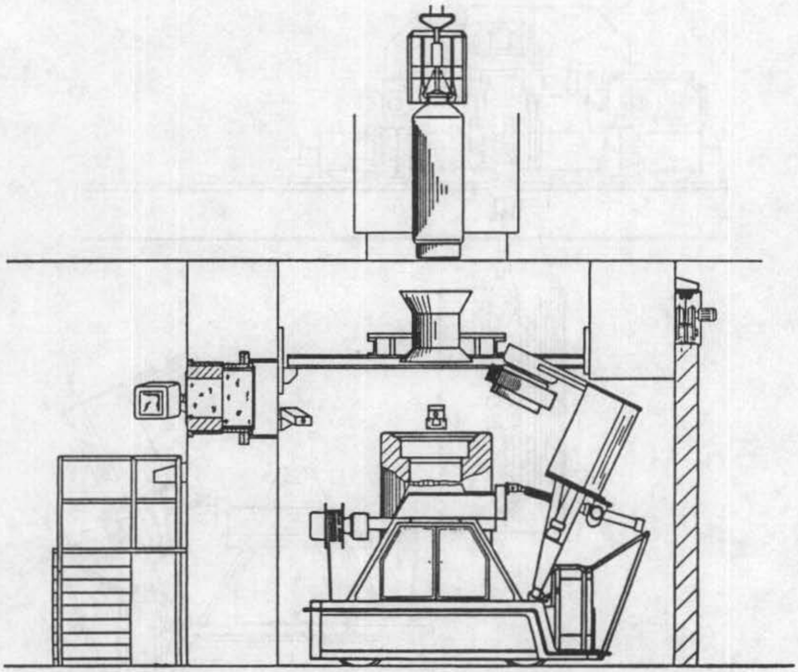

FIG. 1. Position of the trolley at the loading station.

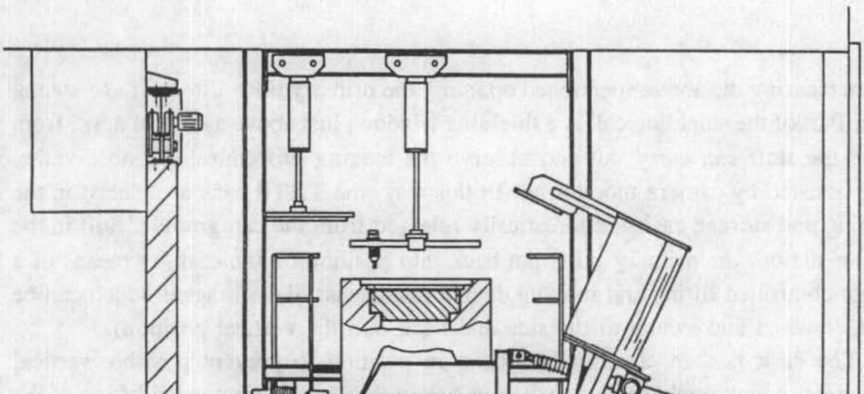

FIG. 2. Cask being readied for transport.

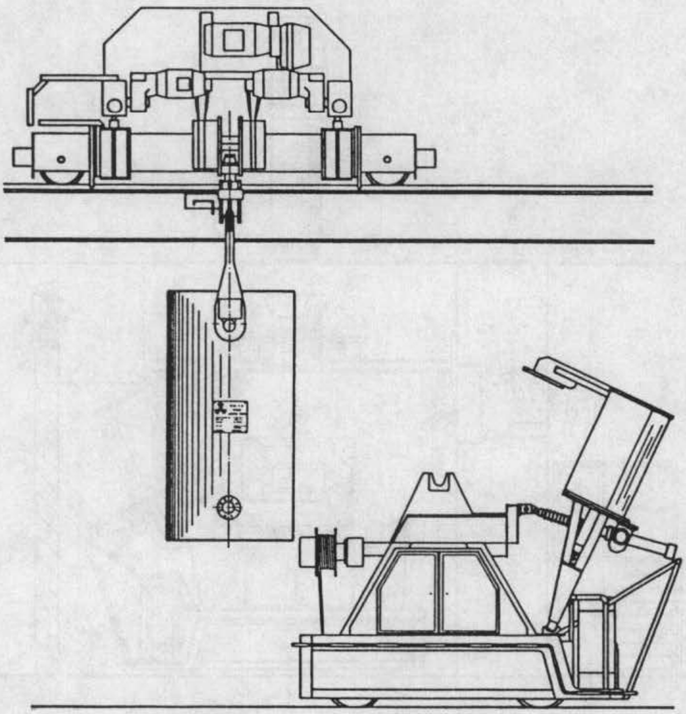

FIG. 3. Trolley and hoisting crane.

Before clearing the above-mentioned opening, the primary lid is lifted off and swung aside. Part of the shielding cell is a shielding window, just above a control desk, from where the staff can carry out and observe the loading procedure, the observation being assisted by camera monitoring. In this way, the THTR cans are placed in the shipping and storage casks, automatically released from the can grapple. Still in the loading station, the primary lid is put back into position on the cask by means of a remote-controlled lifting and moving device (somewhat like a bracket which can be lifted, lowered and swung to the side and back into the vertical position).

The cask is then electrically locked in position to prevent possible vertical movement, which might cause a radiation risk in the case of unintended lifting of the primary lid. The trolley is then ready to leave the loading station, after its movable shielding door has been opened.

The trolley is then moved to another service station, where further handling is carried out, such as bolting of the primary lid. A leaktightness test, to ensure a tightness of 10^{-4} mbar·L/s of the lid, is carried out just before the initiation of transport and before assembly of the secondary lid. These procedures are also either fully or partially automated. At this station, the shipping and storage cask is further prepared so that it meets all requirements and conditions for transport on the national railway and for storage in a licensed storage facility (Fig. 2).

The shipping and storage cask is made of ductile nodular cast iron. The cylindrical shielding walls of the cask have a thickness of about 37 cm, permitting the handling of spent fuel elements after a cooling time of 200 d. The main construction feature of the casks, besides the shielding, is that they have a twin-lid tightness system that acts as an activity barrier which, in the external storage facility, is connected to a control system.

The rail trolley then leaves the reactor building, reaching a position from where a remote-controlled hoisting crane brings the casks to their transport position on one of the two carriages (Figs 3 and 4). After the shock absorbers have been fitted, the casks are ready for shipment to the external storage facility. As mentioned above, shipping units of six casks loaded on two carriages are formed. The latter are modified railway carriages which originally served as carriages for sheet steel coils. The construction of these modified carriages, including shock absorbers and cask supports, meets the relevant international and national regulations for the transport of dangerous goods.

The external storage facility will be licensed for the dry storage of spent fuel elements within the above-mentioned casks. Cooling is performed by natural air convection at the surfaces of the casks.

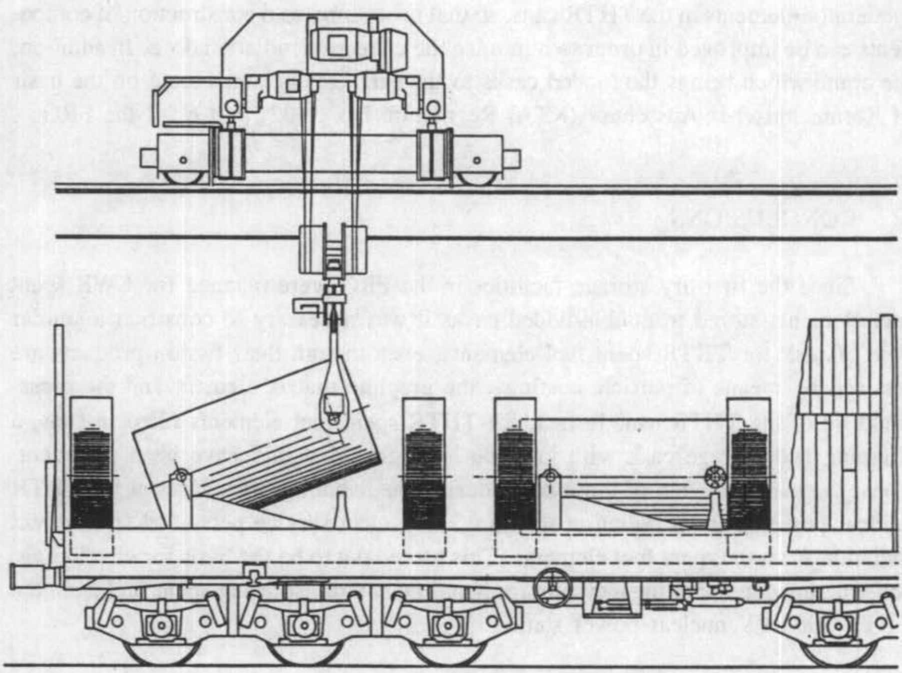

FIG. 4. Carriage and hoisting crane.

4. SAFETY AND HEALTH PHYSICS ASPECTS

The mass of fissionable spent fuel within each cask, or the mass of fissionable spent fuel within the planned pattern of a number of casks in the storage facility, will not be able to become critical under any circumstances. The release of radioactive material from each cask, and therefore out of the storage facility, is virtually nil, thus complying with the stringent health physics regulations of the FRG.

The choice of construction of all of the components used during the handling procedure for the spent fuel elements as well as the planned level of training of the staff operating these components results in a minimum collective radiation dose to the service personnel. Other relevant factors are the following:

(1) The design of each cask allows loading with spent fuel elements cooled for 200 d.
(2) Actual discharge of THTR cans into casks begins after at least one year of cooling.
(3) Significant distances are allowed from the radiation source by the use of remote-controlled handling and special tools.
(4) The time of operation within the relevant radiation limits is kept as short as possible by using automation and optimizing procedures.

Further experience can be gained, during cold and 'hot' handling procedures, by first using fresh, empty THTR cans and then handling discharged (irradiated) graphite moderator elements in the THTR cans, so that procedures and construction of components can be improved in order to minimize the collective radiation dose. In addition, the crane which brings the loaded casks to the carriages is constructed on the basis of Kerntechnischer Ausschuss (KTA) Regulation No. 3902, part 6, of the FRG.

5. CONCLUSIONS

Since the first dry storage facilities in the FRG were planned for LWR spent fuel elements stored in double-lidded casks it was necessary to construct a similar type of cask for THTR spent fuel elements, even though their fission products are retained by means of particle coatings, the graphite matrix element and the press-fitted lid of the THTR can. In fact, for THTR spent fuel elements filled in cans, a shipping and storage cask with just one leaktight lid would have been sufficient. Thus, the main function of these casks during the handling procedures at the THTR nuclear power plant is radiation shielding, to protect service personnel from direct radiation from the spent fuel elements. This turned out to be the basis for developing, constructing and operating a system for handling and transporting spent fuel from the THTR 300 MW nuclear power station.