Loads imposed on dual purpose casks in German on-site-storage facilities for long term intermediate storage of spent nuclear fuel

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Introduction

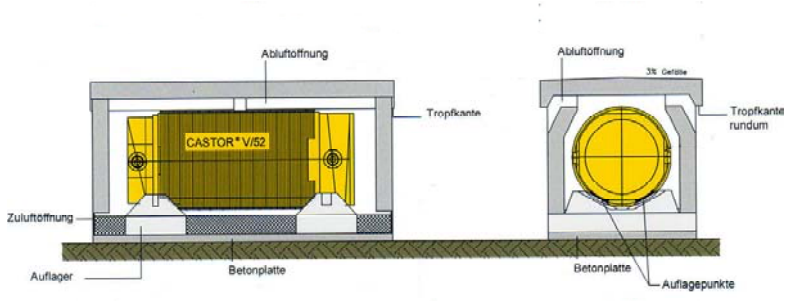
In accordance with recent changes of the atomic energy act and in order to secure reliable removal of spent fuel from the nuclear power plants' fuel storage ponds the German utilities filed license applications for a total of 12 on-site-storage facilities for spent fuel assemblies. By the end of 2003 the last of these storage facilities were licensed and are currently under construction. The first on-site-storage facility of that line became operational in late 2002.

There are several design lines of storage facilities with different handling procedures or possible accident conditions. Short term interim storage facilities for a few casks are characterized by individual concrete hoods shielding the casks in horizontal position whereas long term intermediate storage facilities currently erected for large numbers of casks typically feature a condensed pattern of casks stored in upright position and massive structures of reinforced concrete.

TÜV Hannover/Sachsen-Anhalt e. V. (now TÜV NORD EnSys Hannover GmbH & Co. KG) has been contracted as a body of independent experts for the assessment of all related safety requirements on behalf of the national licensing authority, the federal office for radiation protection (BfS).

Short term interim storage facilities

Short term interim storage facilities can easily and quickly be set up on a sufficiently founded surface. They consist of modular concrete hoods protecting the casks from the various weather conditions and are designed to ensure the necessary heat removal in order to maintain permissible temperatures of the cask and the enclosure of its radioactive inventory. Inside the hoods casks are stored on special supports in horizontal position.



Picture 1: Cask in a short term interim storage facility

In this kind of storage facility up to 28 casks are stored pending the completion and commissioning of a long term interim storage facility at the same location. The hoods and the casks are transported by a mobile crane. Possible accidents such as drop of a cask from a maxium height of 3,5 m on top of the storage area are included in the spectrum of design basis accidents considered for this kind of facility.

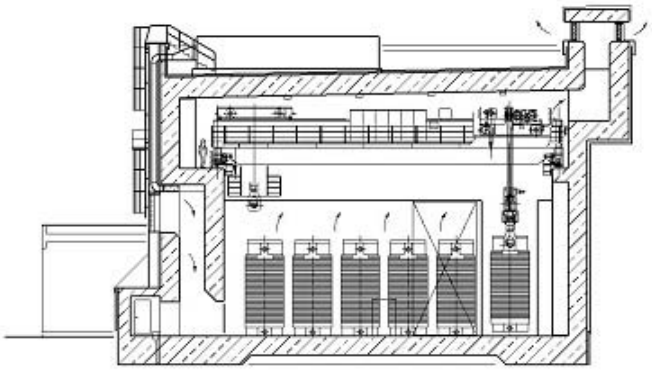
Long term interim storage facilities

Basicly here are two different design lines of long term interim storage facilities, each one with a capacity of up to 192 casks, respectively.

The STEAG design:

Storage facilities according to the STEAG concept (STEAG encotec GmbH) feature a monolithic design with no prefabricated concrete elements and outer wall thickness of 1,2 m. The thickness of the roof is 1,3 m. The building consists of one single nave storage hall with an attached service and maintainance section including a reception area where all necessary checks and preparations can be performed on incoming casks. There is a high capacity crane for loads up to 1400 kN covering the entire reception area and storage area. This crane is supplemented by an auxiliary hoist for up to 200 kN. The maintenance room is additionally equipped with a separate 50 kN crane. Any handling and transport of casks is conducted by means of the 1400 kN crane whereas the smaller cranes are intended for use in maintenance operations such as mounting additional protection plates or replacements for the secondary lids in case there is a need for reparing casks with reduced tightness.

Heat removal is achieved by natural convection of external air that is introduced through openings and ducts in one side wall, directed through the rows of casks, and discharged through elevated outlets in the ceiling on the opposite side of the storage area.

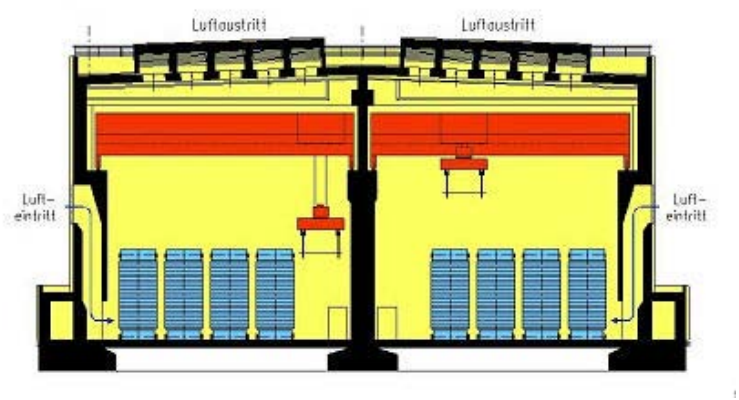


Picture 2: Long term interim storage facility according to the STEAG concept

The WTI design:

The other type of storage facility is designed by WTI (Wissenschaftlich-technische Ingenieurberatung GmbH). It is a pillar/beam design with two storage halls consisting of separate floor structures and some prefabricated concrete elements with a wall thickness of up to 0,85 m. The thickness of the roof is 0,55 m. Apart from the two storage halls the building also features an attached service and maintainance section including the reception area where all necessary steps for checking and preparing incoming casks can be performed. For transportation of the casks a separate crane for a maximum load of 1400 kN is provided in each hall. These cranes are also equipped with small 200 kN hoists for service purposes like mounting additional protection plates and exchanging repairing secondary lids inside the service place.

Again, heat removal is facilitated through natural convection. Air intake is ensured through openings in either of the side walls with outlet openings evenly distributed in the ceiling of the storage areas.



Picture 3: Long term interim storage facility according to the WTI concept

Dual purpose casks

Casks designated for use in the described storage facilities are designed and qualified for both, long term storage as well as transportation. So the specific requirements of both modes of operation must be met. Basically such cask consists of a body of cast iron, a cavity with a basket for holding the spent fuel assemblies and a twin lid sealing system. They are equipped with shock absorbers for transport use only. Cooling fins are attached to or incorporated into the outer surface for sufficient heat transfer to the surrounding air. Polymer rods and slabs are either integrated in the walls or monted on the outside of the casks to enhance the shielding of neutron radiation.

Casks are commonly equipped with two pairs of trunnions due to the requirements of transport in horizontal position. Only the top trunnions are used for handling the casks in the storage facilities in upright position.

Technical rules and guidelines require that casks employed for the dry storage of spent fuel assemblies in Germany must be qualified as type B(U) packaging thus withstanding the set of loads connected to this category.

Especially mechanical loads of the 9 m-drop on an unyielding surface and the 800 °C/30 min fire are of interest when considering possible loads encountered in storage facilities.

Picture 4: Cask for transport and storage shown with mounted shock absorbers

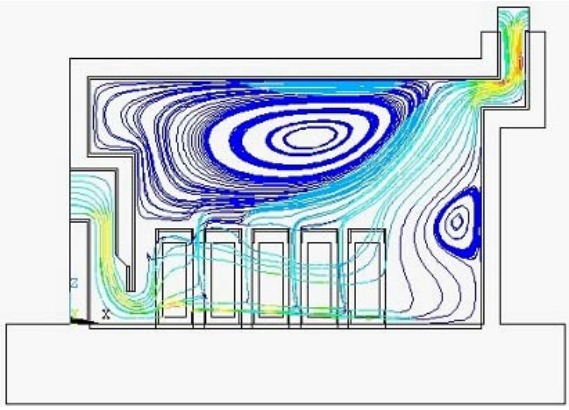
Normal operating conditions

Casks are loaded with spent fuel assemblies inside the fuel pond of the nuclear power plant. After checking the fulfillment of all necessary requirements such as sufficient removal of residual water or leakage rates of the double barrier sealing system they are transported to the storage facility on a special transport vehicle in horizontal position. Shock absorbers necessary for transport on public roads are not mounted in view of the particular conditions of the transfer between the plant and the storage facility. Inside the storage facility the cask is picked up by its top trunnions with the crane of the storage facility. It is then moved into a vertical position and lifted off the transport vehicle. Maximum lifting heights of 3 m above the floor are encountered when the cask is lifted from the support of the bottom trunnions on the transport vehicle prior to lowering it to the internal transport height of 0.25 m. The programmable control unit of the crane used for internal cask transport is designed to exclude lifting heights in excess of the permissible values of 3 m in the limited area at the unloading position with shock absorbers or 0.25 m in the rest of the facility.

Picture 5: Lifting of a cask from the horizontal position on a transport vehicle into a vertical position

With respect to an environment of equally loaded casks surrounding a cask in the storage area it is necessary to ensure safe heat removal under the given storage conditions. Apart from the flow characteristics of cooling air directed through the storage area the thermal situation of the casks is significantly influenced by heat exchange through radiation between adjacent casks. Depending on the actual pattern of casks in the storage area this effect may account for a rise of surface temperatures of the order of 17 K and above compared to a single cask in a stand alone situation. The complexities of more condensed storage patterns are best analyzed by a numerical approach via comprehensive computational fluid dynamics calculations of three dimensional models yielding not only air flow patterns but also temperatures of building structures and casks.

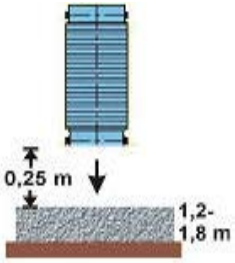
Limitations of the heat generating inventory of the casks are induced by the maximum permissible temperatures of fuel rod cladding due to a requirement to maintain cladding integrity in spite of circumferential elongation. Further restrictions are posed by the maximum permissible temperatures of the polymeric moderator materials.



Picture 6: Calculated airflow inside a storage facility to ensure the necessary heat removal

Design basis accidents

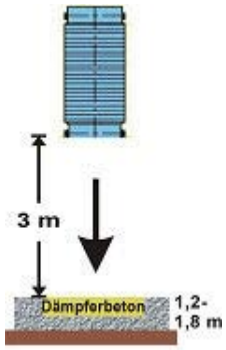
For the transport of casks inside the storage facilities various lifting heights have to be considered for possible drops. Resulting forces must be considered with respect to the cask as well as the design of the building.



Picture 7: Lifting height of 0.25 m for transport of casks

In any case it must be ensured that even after such an accident the cask will maintain its integrity and tightness to avoid any significant release of radioactive material through mass flow of aerosols. This means that the tightness of the double lid sealing system as well as the shielding and the retention properties of the cask itself must be

unaffected by the event. For some handling procedures the casks have to be lifted up to 3 meters above the ground. At those places the floor is either equipped with damping elements of shock absorbing concrete or mobile shock absorbers with a core of soft wood can be used.



Picture 8: Maximal lifting height of 3.0 m necessary for taking a cask of the transport vehicle

The building itself is also designed to withstand earthquakes without collapsing. The maximum mass of debris affecting the casks in the event of an earthquake is limited. This also applies to heavy components like cranes or massive shielding gates that are designed to withstand earthquakes.

Further design basis accidents include blast waves as from chemical explosions that must not cause the building to collapse and do not have any effect on the casks beyond that.

Finally, the circumstances of a possible fire in the reception area may lead to thermal loads in excess of those covered by the type B(U) qualification of the casks. Therefore, precautionary measures are taken to minimize the risk of a fire in that position and to ensure that possible fires are rapidly detected and extinguished during delivery of casks with vehicles carrying fuel or other fire loads.

Events exceeding design basis accidents

The effect of damage resulting from the possible crash of an airplane was assessed for both, a standardized military jet fighter as well as a large civil aircraft. Technical guidelines require that the protection against the damage of a military plane crash can either be archieved by the cask or by a combination of the cask and the design of the building. According to our assessment both of the above described design lines of storage facilities provide sufficient protection to prevent significant release of radioactive materials. The scenario considered with respect to the casks will be governed by thermal loads resulting from the fuel fire and by the mechanical loads caused by massive structural elements of the aircraft and the building.

Considerations for the crash of a large civil airplane included the same factors with special emphasis on the larger amount of fuel and the larger scale of possible structural damage of the building. Inspite of increased leackage

rates of the casks for the later scenario our findings confirm that activity releases would be far below values necessitating severe accident management measures (e.g. evacuation).

Conclusions

On site storage facilities for the long term intermediate storage of spent nuclear fuel are being erected at all operating nuclear power plants in Germany. Casks employed for the dry storage of fuel assemblies in these facilities are required to be qualified as type B(U) packaging. Additional requirements to be considered for the particular circumstances of the storage facilities arise from the condensed storage pattern with respect to the safe removal of decay heat, from different mechanical loads in the case of drops of casks that are handled without shock absorbers and from a combination of mechanical and thermal loads in the wake of events exceeding design basis accidents. The safety assessment conducted by TÜV Nord EnSys Hannover on behalf of the German licensing authority of storage facilities confirmed that all design basis accidents caused no significant release of radioactive materials from the casks and that events exceeding design basis accidents like the crash of military jet fighter airplane or a fully loaded civil airplane did not cause a need for severe accident management measures with respect to the radioactive contents of the casks.