GERMAN APPROACH TO ESTIMATE POTENTIAL RADIOLOGICAL CONSEQUENCES FOLLOWING A SABOTAGE ATTACK AGAINST NUCLEAR INTERIM STORAGES

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ABSTRACT:
The German approach to estimate potential radiological consequences caused by a sabotage attack on shipping and storage casks loaded with spent fuel elements in the near vicinity of interim storage facility at German NPP sites is described. The source term of radioactive releases in to the environment is calculated on the basis of a sabotage scenario including a shaped charge attack and experimental data. The atmospheric dispersion of the released aerosol particles are calculated using a Monte Carlo particle model and parameters of the German Accident Calculation Bases on the one hand in a deterministic way for the diffusion categories A - F and on the other hand in a probabilistic way corresponding to the weather situations and their probability at the storage site as well as the orographic conditions. The radiation exposures is represented by the potential doses for inhalation and for ground-shine of an adult versus distance from the storage facility and their probabilities of occurrence.

1 INTRODUCTION

Potential consequences from conceivable sabotage actions are of increasing public concern, especially in connection with interim storage of spent fuel elements at German Nuclear Power Plant (NPP) sites. For the competent authorities aspects of physical protection at the storage facility have been of concern for a long time. Consequently various kinds of investigations in this area have been performed in Germany as well as in different other countries.

According to the German Atomic Consensus Act transportation of nuclear spent fuel elements is time limited and restricted to spent fuel reprocessing in France and Great Britain. After reprocessing the fissile material will be used to produce MOX fuel elements, the high radioactive vitrified waste will be stored at the German storage facilities Ahaus and Gorleben.

Spent fuel element not foreseen for reprocessing has to be stored in temporary and interim storage facilities at the NPP sites. One aspect of licensing these facilities by the Federal Office for Radiation Protection is the precaution against sabotage attacks. For that reason GRS provides an expertise including potential radiation exposure results.

The present contribution describes the German approach to estimate potential radiological consequences caused by a sabotage attack on shipping and storage casks loaded with spent fuel elements in the near vicinity of an interim storage facility at a German NPP site.

2 INTERIM STORAGE FACILITY

In essence their exist two construction designs for German interim storage buldings, the so called STEAG concept and the WTI concept. The main safety features are

- Safe Confinement of Radioactive Materials,
- Safe Conditions of Non Criticality,
- Sufficient Shielding for Staff and Population,
- Safe Heat Removal and
- Precaution against Remaining Risk.

The main features of both designs regarding the aspects in this paper are very similar. As an example, Fig. 1 shows the cross section of a STEAG storage hall.

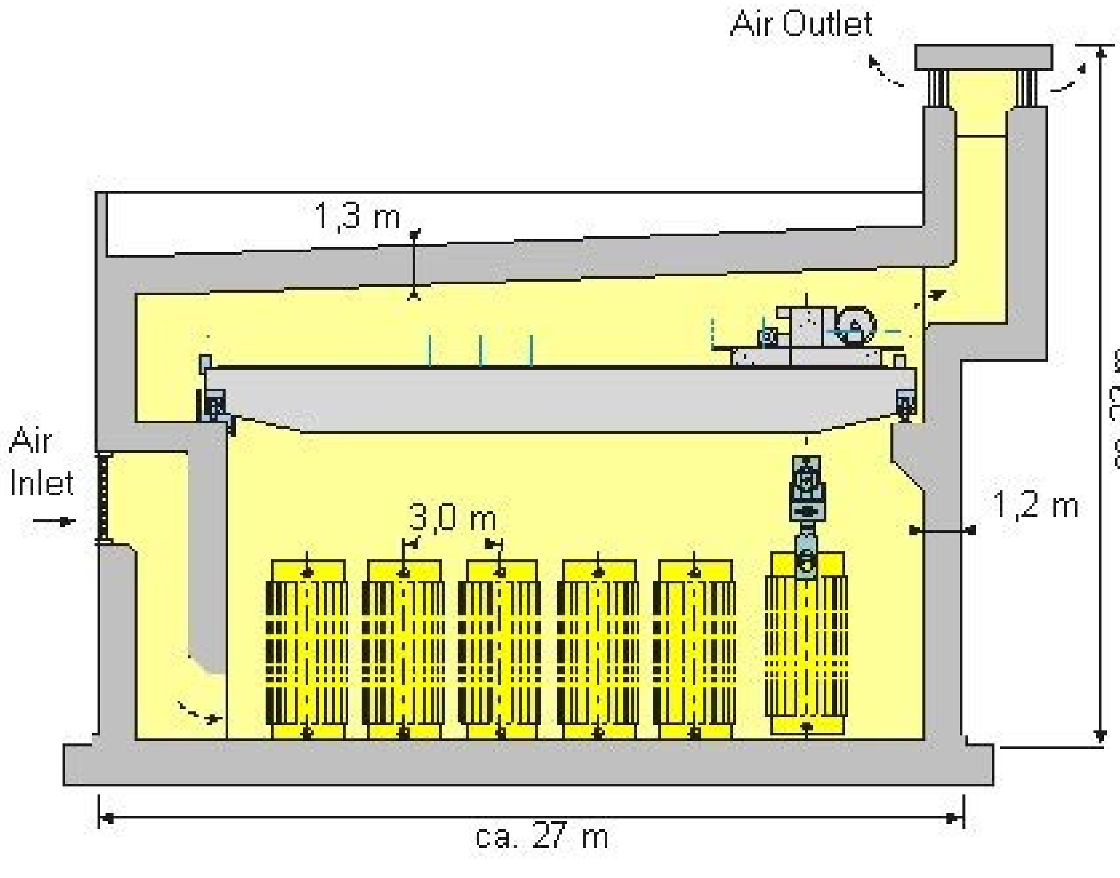


Fig. 1 Cross Section of a STEAG Storage Hall

The storage building in general consists of a reception and operation building at the front as well as the storage hall itself, which are divided by a 0,8 m thick concrete shielding wall. The length of the hall depends upon the planned storage capacity and amounts to several tens of meters. All other dimensions are shown in Fig. 1. The casks are placed in rows with 5 positions each. The distance of two neighbouring casks (middle axis) amounts to about 3 m, a CASTOR type cask has a diameter of 2,44 m.

The bottom and roofing plates as well as the walls are made from steel concrete of 1,2 m thickness, the monolithic roofing plate is 1,3 m thick.

At the one side of the storage hall air inlet openings with Z-shaped channels and at the opposite side air outlet openings are foreseen, both of which can be closed by hand.

In general the air ventilation of the storage area is caused by natural convection. Entering through the air inlet the air will be heated up at the casks surfaces and will leave the hall through the air outlet. Typical air changing values are 20 per hour, i.e. every 180 s the air volume of the hall is completely exchanged.
The storage facility erected at the NPP site is guarded by a protection fence. For radiation exposure calculations the minimum distances to the point beyond the fence where public access is possible as well as to the next settlement are of importance.

3 SCENARIO OF IMPACT

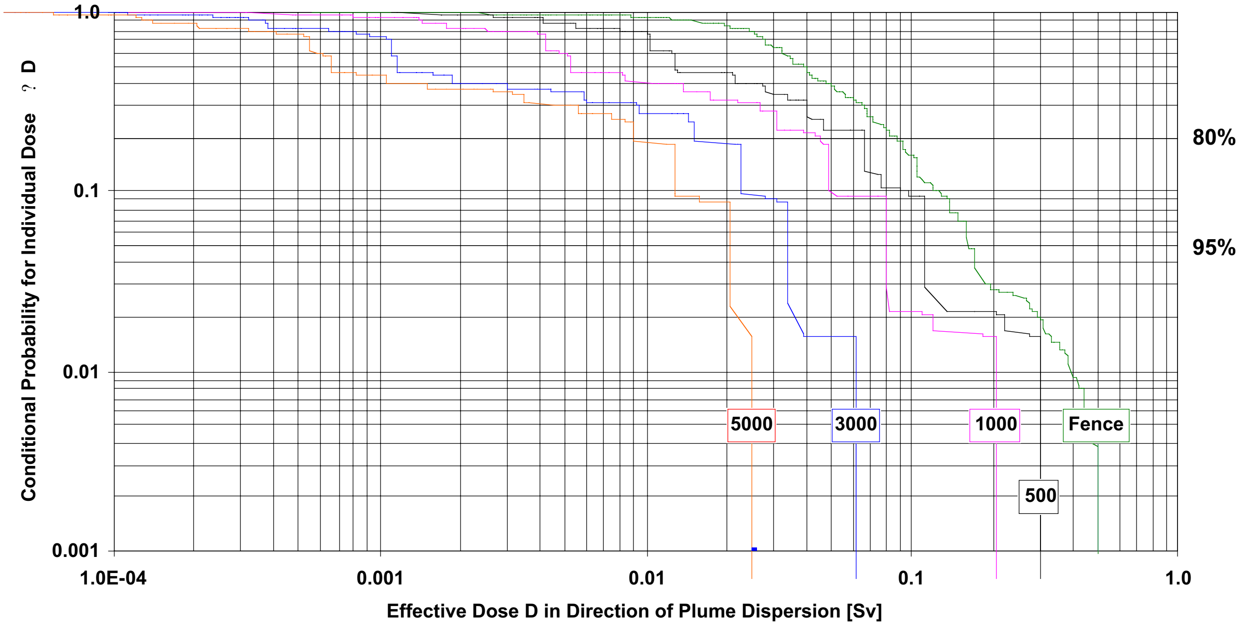
A sabotage scenario was defined by the German Federal Office for Radiation Protection considering a conical shaped charge attack on to a CASTOR type spent fuel cask.
A penetrating shaped charge jet creates a channel through the cask wall and damages fuel elements on its further way inside the cask. Thus, fuel rods and hence fuel pellets are breached and partly pulverized. Due to short term overpressure inside the cask airborne radioactive material will be released through the penetration channel in to the storage hall and subsequently via the air ventilation in to the environment at the NPP site.

4 SOURCE TERM CONSIDERATIONS

The action of the shaped charge jet itself, associated ingression of hot detonation gases and in addition depressurization of damaged fuel rods result in an overpressure inside the cask. This will lead to a short term release of radioactive dust particles and gases through the penetration channel. The source term from the cask will be made up of aerosol particles containing fission products, activation products, uranium and other actinides and of some fission gases.
The mass release after a shaped charge attack was determined by real scale experiments. The cask contained fuel elements filled with depleted Uranium (DUO_2) as a surrogate material of low radioactivity instead of spent fuel /1, 2/. As in Germany a pressure of 0,8 bar inside the cask is an upper limit for conditions during interim storage of spent fuel, this pressure was also maintained for the experiments. The dust materials released through the penetration channel after the shot were collected and deposited on different sampling media for further analysis.
The results showed a released fuel mass fraction of 0,375 g in the respirable range of aerosol particles with Aerodynamic Equivalent Diameter (AED) of < 10 µm and a fraction 0,350 g in the coarse particle range of 10 µm $\leq$ AED < 100 µm.
These values serve as a basis for calculating the source term of real spent fuel elements at interim storages using an appropriate scaling procedure.
Additionally, enhanced release of volatile elements at small aerosol particles known from the Literature was considered by enhancement factors (see /1, 2, 3/). Gaseous Cesium release from the fuel rod gap was also taken into account.
The nuclide inventory of the spent fuel elements considered for the interim storages were calculated using a special GRS version of the ORIGEN burn up code. A selection procedure allowed to neglect all nuclides contributing less than 0,1 % to the radiation exposure compared to the nuclide with maximum contribution.

5 ATMOSPHERIC DISPERSION AND RADIATION EXPOSURE

On the basis of the source term derived from the experiments mentioned above calculations of the atmospheric dispersion of the radioactive materials and of the potential radiation exposures of individuals in the vicinity of an interim storage building containing a breached spent fuel cask have been made.
From the experimental findings it could be concluded that the action of the shaped charge leads to an almost instantaneous release of radioactive material through the penetration channel. The released airborne radioactive material will be entrained in the highly turbulent surrounding air and hot explosion gases of the conical shaped charge.
Following the air stream in the storage hall the radioactive aerosols and gases will subsequently leave the air outlet and be released into the surrounding atmosphere of the storage building.
For further simulating the distribution of the radioactive materials the advanced atmospheric dispersion model LASAT, a Monte-Carlo type particle model using modern turbulence parameters for the calculation of short term dispersion and deposition processes in the atmospheric boundary layer was applied to the radioactive particles with respect to their size distribution. Additionally, parameters of the German Accident Calculation Bases, e.g. describing the influence of buildings as well as the orographic conditions, were also taken into account.
With the resulting coefficients for near ground air concentration and ground deposition the radiation exposures on the one hand was calculated in a deterministic way for the diffusion categories A - F. The resulting radiation exposure is represented by the potential doses for inhalation and for ground-shine of an adult versus distance from the storage facility for the different diffusion categories independent of their probability of occurrence.
On the other hand the results of the particle simulation model LASAT were used to derive cumulative complementary frequency distributions (CCFD) of ground-level air concentrations and deposition levels in downwind direction from the location of release and the resulting doses for inhalation and for ground-shine taking into account the broad spectrum of atmospheric dispersions conditions at the storage site and their respective frequency of occurrence.
As one of the results a cumulative complementary frequency distribution of potential effective dose from inhalation is shown in Fig. 2. The probability, conditional that a release occurred, of certain effective doses of a person residing at a given distance in downwind direction from the location of a release can be read from the curves. For this example a site with weather data typical for the northern parts of Germany and nearly flat terrain has been used, a fuel burn up of 55 GWd/Mg HM was selected.
The results show e.g. that at 500 m distance doses of 65 mSv and less may occur with a probability of 80 %, i.e. with a probability of 20 % higher doses up to the maximum value of 300 mSv may occur.



Te Fig. 2: CCFD of Inhalation Dose - Particles AED < 10 µm

(Adult, ICRP 72 Dose Coefficients)

6 SUMMARY AND CONCLUSIONS

The approach to estimate potential radiation exposures caused by a sabotage attack on shipping and storage casks loaded with spent fuel elements in the vicinity of interim storage facility at German NPP sites was described.

The sabotage scenario includes a shaped charge attack and the source term of radioactive releases is estimated on the basis of experimental data. The atmospheric dispersion of the released aerosols is calculated using an advanced Monte Carlo particle model.

The radiation exposure is represented by the potential doses for inhalation and for ground-shine of an adult versus distance for the diffusion categories A - F as well as and their conditional probabilities of occurrence with respect to the corresponding weather situations and their probabilities at the storage site.

The results show that beside the deterministic potential doses for the diffusion categories A - F, which for some sites result in relatively high values, the conditional probabilities of occurrence for these dose values give a more realistic picture and thus support the decision making in the licensing process.

7 REFERENCES

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