PROBABILISTIC SAFETY ANALYSIS FOR A SHAFT HOISTING INSTALLATION*

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ABSTRACT

Subject of the present probabilistic safety analysis (PSA) are transport processes during the direct disposal of POLLUX-casks in a repository. Direct disposal includes surface caging, shaft hoisting and uncaging in the mine.

This analysis is aimed at finding the frequencies of events which lead to an increased radiologic exposure of the personnel or the environment. Such events are directly or indirectly due to technical failure or human malactions. This paper is dealing with technical failures only.

The fault tree method was used for this analysis. The events under consideration are the events on top of the respective fault tree. After determination and allocation of the necessary reliability data the fault trees have been evaluated with respect to quantity.

The result is that frequency of events with a value of $< 10^{-9}$ for 10.000 disposal processes which could lead to a release of radioactive material can be considered as acceptable risk. But several times per operating year operational occurrences could make it necessary to carry out activities which result in an increased radiation exposure of the personnel. Because of the limited surface dose rate of radioactive containers and possible additional shielding measures this additional radiation exposure can be kept below the applicable limits.

INTRODUCTION

In addition to the waste management concept of the German federal government to emplace radioactive waste in a salt dome, investigations are carried out to study the feasibility of emplacing spent fuel directly in POLLUX-casks in the drifts of the mine. For this purpose a probabilistic safety analysis (PSA) considering transport processes during the direct disposal of POLLUX-casks in repository mines has been established. This PSA is used to evaluate the safety of a planned shaft hoisting installation with a payload of 85 t and shall determine the frequency of occurrence of safety-relevant events for selected transport or handling processes during shaft hoisting.

Transport processes under investigation are:

- horizontal charging of the hoisting cage on the surface;
- the directly following vertical shaft hoisting transport into the mine as well as
- decharging of the hoisting cage

Most essential technical components and parts of the plant being used for the described handling processes are: shaft safety gates, air lock or lift gates (with interlockings), loading and unloading devices, weigh bridges, cage rests, car catches (above and underground) and the hoisting cage.

The location of these components in surface and underground areas is represented in Figs. 1 and 2.

Safety relevant events which are due to failure of technical components (only those will be considered) and may result in increased radiologic exposure of the personnel or the environment can be classified in two categories:

1. Increased radiation exposure for the operating personnel during elimination of operational stoppages.
2. Release of radioactive materials into the environment.

SELECTION OF SAFETY-RELEVANT SCENARIOS

A forced longer stay within the radius of appr. 5 m from a POLLUX-cask is defined to be a precondition for an increased radiation exposure of persons (category 1). This condition is given when the loaded platform car is blocked during the horizontal rail-bound transport on the surface or in the mine or during the shaft transport into the mine and workers have to repair parts of the equipment or defect components in the vicinity of the POLLUX-cask.

During the loading process on the surface and the unloading process in the mine generally situations exist which could lead to a blocking of the platform car independently or dependently upon its respective position.

One example for the first mentioned case is failure of the loading device which does not open when it is actuated after the uncoupling process. One example for the second case (independently upon the position on the surface and in the underground) is the blockage of the loaded platform car by the downfalling air lock gate (lift gate) or the unintentional closure of the air lock gate (lift gate).

Serious damage of a POLLUX-cask (rupture of the inner container or the primary lid in connection with partial loss of its sealing function) is assumed to be one precondition for a release of radioactive material (category 2).

The necessary kinetic energy can result only from the free fall of a POLLUX-cask over long distances (> 9 m) or from the crash of a load with a high weight from an appropriate

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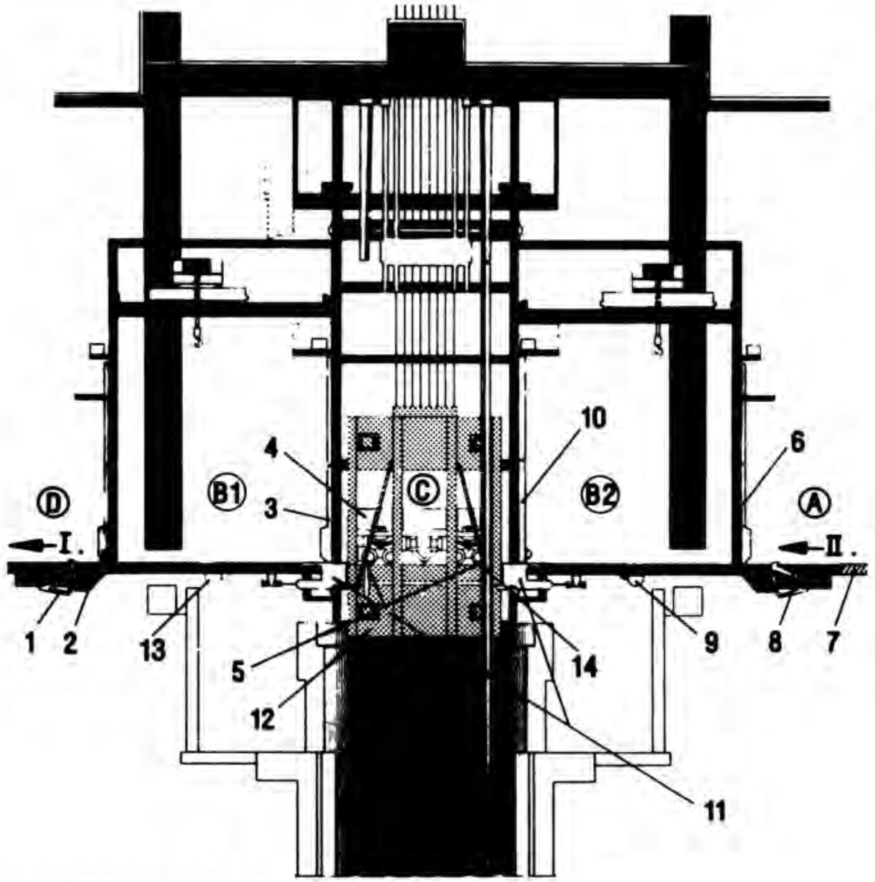


A Position of platform car before shaft safety gate (weigh bridge)
B Position of the platform car in the shaft air lock
C Position of platform car in the hoisting cage
D Position of the empty platform car behind the shaft safety gate (after unloading)

Pos.	Description	Pos.	Description
1	shaft safety gate 1	8	shaft safety gate 2
2	air lock gate 1	9	loading device 1
3	lift gate 1	10	lift gate 2
4	platform car	11	cage rests 1 - 4
5	car catch 1	12	hoisting cage
6	air lock gate 2	13	unloading device 1
7	weigh bridge 1	14	car catch 2

I. unloading direction
II. loading direction

Fig. 1. Positions of components and positions of platform car in the surface shaft charging equipment.

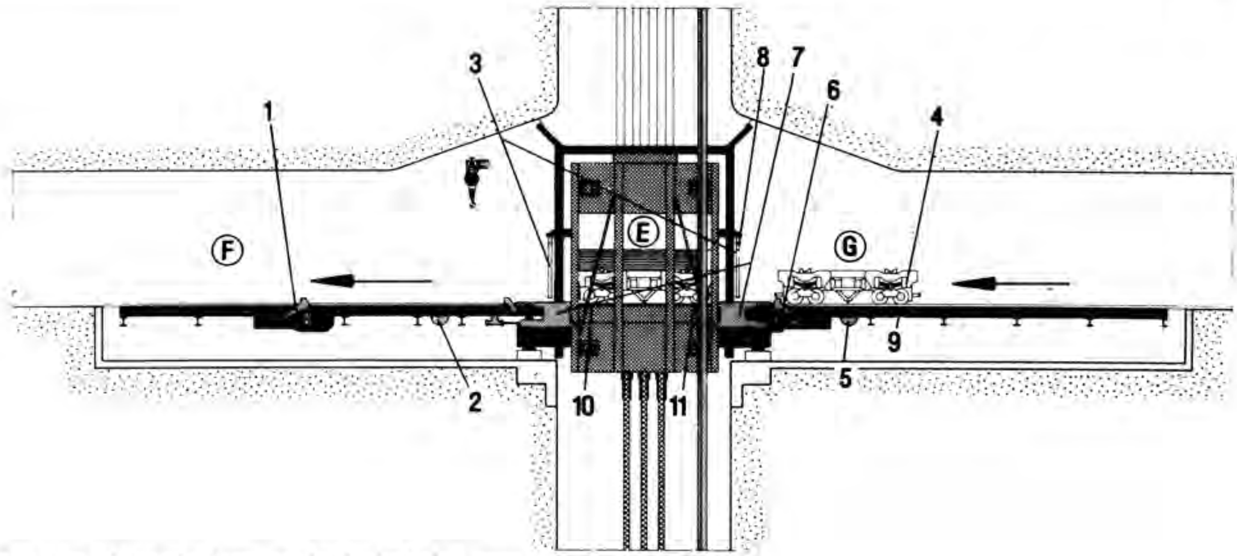
height onto the POLLUX-surface. Accordingly we consider the crash of a loaded hoisting cage after failure of several headropes or after friction wheel rupture in a first scenario.

The second scenario comprehends the crash of a heavy load (deflecting wheel, counter balance) onto a POLLUX-cask.

Finally we consider the crash of a platform car loaded with a POLLUX-cask onto the loaded or empty hoisting cage in the hoisting shaft in a third scenario. This scenario assumes failure of several safety-technological interlockings and improper handling of the platform car.

METHODOLOGY

The frequency of occurrence of events (1) and (2) with respect to quality and quantity is investigated with a fault tree. Reliability data which are necessary to calculate the frequencies of occurrence of component failures which are considered to be basis results have to be taken from comparable fields or have to be estimated. Uncertainties in applying these data resulted in the introduction of failure categories to classify the different components. This way it is possible to describe the failure behaviour by 11 groups using failure ratios which differ in half an order of magnitude from each other.



E Position of the platform car in the hoisting cage
F Position of platform car behind the shaft safety gate
G Position of the empty platform car before the shaft safety gate

Pos.	Description	Pos.	Description
1	shaft safety gate 3	7	rests 5 - 8
2	unloading device 2	8	lift gate 4 incl. lift gate interlocking
3	lift gate 3 incl. lift gate interlocking	9	weigh bridge 2
4	platform car	10	car catch 3
5	loading device 2	11	car catch 4
6	shaft safety gate		

Fig. 2. Position of components and positions of platform car in filling station of disposal level.

RESULTS

Frequency of occurence for 10.000 emplacement processes and a medium handling time of 30 min. delivered by PSA result in an expectation value

- of 14 events (or 0.03 events, in case the hydraulic supply remains unconsidered) in category (1) (increased radiation exposure)
- of $< 10^{-9}$ in category (2) (release of radioactive material).

It is necessary to state that all investigations which have been carried out so far do not permit conclusions about the respective radiation exposure, its duration and resulting dose rates. This depends upon the specific component which failed and upon alternative possibilities which may essentially reduce duration of repair in the very vicinity of the loaded platform car.

The low frequency of occurrence of $< 10^{-9}$ for category (2) results from the fact that several different interlocking conditions must be given at the same time and hence are included in the fault tree with "AND"-gates.

These results are also valid for the disposal of other waste containers which have to be emplaced in addition to the POLLUX-casks.

Generally, events with an annual frequency of occurrence of $< 10^{-6}$ - 10^{-7} belong to the acceptable risk. Therefore the occurrence frequency of events which may lead to a release of radioactive material can be allocated to the acceptable risk. Because of the limited surface dose rate of radioactive containers and possible additional shielding measures the additional radiation exposure of the personnel can be kept below the applicable limits.

In summary it can be stated that no essential risk points are recognizable for the technical realization of the investigated disposal sub-system with respect to the selected safety-relevant events.