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CONSIDERATIONS ON RISK ANALYSIS FOR NUCLEAR SPENT FUEL STORAGE FACILITY OF CERNAVODA NPP

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ABSTRACT
In June 2003, the first capacity of the Intermediate Dry Spent Fuel Storage Facility (DICA) was commissioned at Cernavoda Nuclear Power Plant (Cernavoda NPP). The facility is a dry system type facility. Its designed lifetime is for a minimum of 50 years and capacity for two nuclear power units' lifetime.

The storage structures are monolith reinforced concrete modules offering a very good isolation of the spent fuel from the environment. The spent fuel is confined by a system of double barriers that prevents radioactive emissions and assures protection of the population and environment. The safety functions of the facility are operational through passive means.

In Romania, the National Commission for Nuclear Activities Control (CNCAN) is the authority that licenses the nuclear activities. CNCAN issued the commissioning and operating licenses for DICA following a complex process. The Final Nuclear Safety Report represents the basic documentation for licensing and one of its main chapters presents the risk analysis results. The risk analysis performed for DICA covers normal operational regimes and accident cases considered as design basis events (DBE).

The results of risk analysis for Cernavoda NPP DICA demonstrate that risk for the population and environment is much lower than the licensing limits established by CNCAN. Also, the risk is in agreement with values for proven safe spent fuel storage technologies from European Union and worldwide.

Keywords: DICA, Cernavoda, Spent fuel, Risk analysis

INTRODUCTION

At present, nuclear spent fuel discharged from nuclear power plants is stored either in water pools adjacent to reactors or spent fuel dry storage facilities independent from reactors A more growing fraction of spent fuel is stored in dry storage, worldwide. This option avoids the potential for a spent fuel pool fire. An accident or act of malice that causes loss of water from spent fuel pool could lead to burning of exposed fuel, with severe off site consequences.

Today, dry storage facilities are not designed to resist malicious acts. However, according to US expert's opinion [1], given the present global threat environment and its possible development over coming decades, a determinate and sophisticated attack on spent fuel storage facility cannot be ruled.

Risk analysis for threat spectrum (i.e. a range of potential destructing events) and consequently, identification of options for risk reduction is subject to beyond design accidents. Nuclear industry already has gone to consider beyond design potential events. Risk reduction options against threat will result in harden the dry storage facility.

The licensing process of interim nuclear spent fuel dry storage facilities mandatory ask for the risk analysis. For the Cernavoda NPP Intermediate Dry Spent Fuel Storage Facility (Depozit Intermediar de Combustibil Ars – DICA), the risk analysis results were presented in one of the chapter of the Final Safety Report [2]. FSR represents one of the main support documents for the authorization issued by CNCAN.

1. NUCLEAR SPENT FUEL STORAGE AT CERNAVODA NPP

At Cernavoda NPP, after minimum six years storage in the spent fuel bay of the nuclear reactor, the nuclear spent fuel is transferred to DICA that has a designed lifetime of minimum 50 years. The technology adopted for DICA is based on the dry storage system developed by Atomic Energy of Canada Ltd. (AECL) within last three decades and used by 7 nuclear power plants (6 in Canada and 1 in South Korea).

The site of DICA is inside the exclusion zone of Cernavoda NPP, in front of 5^{th} Unit, about 500m far from Unit 1 that is in operation. This site can accommodate spent fuel generated by the entire lifetime operation of two Units. The spent fuel will be stored in 27 modules. Each module is a monolith reinforced concrete structure that accommodates 20 steel cylinders placed in two rows, each cylinder keeping inside 10 stainless steel baskets with 60 spent fuel bundles each of them.

The total capacity of the module is 12,000 spent fuel bundles. The transfer rate from the reactor's spent fuel bay to DICA is about 500 spent fuel bundles by month (in dry weather conditions) for a unit, thus resulting a construction cadence of following modules from 1 to 2 years. The first module loading started in June, 2003 and it would continue in 2004.

2. RISK ANALYSIS FOR DICA

The risk analysis for DICA [3] addresses normal operation and accidental situations resulting from Design Basic Events (DBE).

The authors considered for this paper information on the evaluation of the risk for population and the class of the addressed DBE was limited to fuel-handling events. The risk analysis for DICA also contained the evaluation of the risk to workers and addressed other DBE, for example those involving human activities or external events but these results are not presented in this paper.

The risk analysis results were used to prove that the facility complies with CNCAN's requirements, as a planning tool to enhance the safe operation of the fuel transfer and to identify possible emergency planning requirements.

2.1 Methodology

In case of risk analysis for DICA [3], the meaning of risk is the expected harmful effects of an activity, where expected is taken in its mathematical sense. In other words, risk is defined as:

$$R = f \times C \qquad \text{(Eq. 1)}$$

Where:

R = risk in units of consequences per unit time

f = frequency of event, in (unit time)$^{-1}$

C= consequence of event, in chosen units (e.g. dose, financial loss, health impact, etc.)

For DICA, the potential consequence of interest is the possible exposure to radiation from normal activities or accidental situations. The relation between dose and probability of health effects helps to translate terms of health consequences.

According to ICRP recommendations [4], the probability of stochastic effects per unit of dose is determined by the *risk factor* and is equal to 0.1 Sv^{-1}. The risk factor includes:

- Fatal cancers

- Severe genetic effects,
- Years of life lost
- Non-fatal cancers

The risk factor is very conservative since it takes into account the non-fatal consequences caused by the exposure.

Consequently, the equation (Eq. 1) can be re-written in specific terms of health effects, as follows:

$$R_{health} = f \times D \times r \qquad \text{(Eq. 2)}$$

where:
R_{health} = risk in units of health effect per year;
f = frequency of event, in year^{-1};
D = dose consequence of event, in Sv;
r = risk factor= 0.1 health effect/ Sv.

Normally, the total risk must be considered, e.g., the sum of the risks for all events analyzed. However, provided that the respective risk associated with each event is low enough, it is possible to make reasonable assessment based on event risk.

The considered consequences can be either the individual risk, e.g. the risk for a single individual (usually the potentially most exposed person from the critical group) or collective risk calculated for an entire segment of population. In the DICA analysis case, only the individual risk was considered.

Risk reduction means to reduce the probability (or frequency) of accidents, or their consequences, or both.

2.2 Criteria for risk acceptance

In Romania, the legal dose limit [5] for a member of public is 1 mSv/an.

Considering those presented before on risk, the limit corresponds to an individual risk limit of 0.1 mSv/year x 0.1 health effect/Sv, or 10^{-5} health effect/year.

Finally, the risk analysis considered the following assumptions:

- The individual risk associated with normal operation must not exceed 10^{-5} health effect/year for the most exposed person at the site fence.
- The individual risk associated with each accidental event must not exceed the risk limit for normal operation, for the most exposed person at the site fence.

3. RISK ANALYSIS RESULTS

The Cernavoda spent fuel dry storage is based on the Point Lepreau spent fuel preparation and transfer system design, and on the storage modules design in use at the Gentilly-2 nuclear generating station, both located in Canada. Experience at these plants has proven the concept to be safe and reliable.

Under normal operating conditions, the transfer of fuel from the pool to the storage area would not have a radiological impact on the surrounding population. Actually, the increase in dose rate would not be measurable.

The analysis of design basis events involving fuel handling activities has shown [3] that in each case, the individual risk is significantly lower than the risk acceptance criterion.

The following Table 1 summaries the individual risk associated with normal activities and fuel-handling design basis events.

Table 1. Summary of results.

Activity or event	**Individual risk (health effect/year)**
Risk acceptance criteria	**$1.0x10^{-5}$**
Normal activity	$6.6x10^{-8}$
Drop of a bundle	$<3.4x10^{-10}$
Drop of a tray	$<8.2x10^{-9}$
Drop of a basket	$<6.1x10^{-8}$
Drop of a transfer flask	$<6.1x10^{-8}$
Loss of a shielding following the drop of a transfer flask	$<6.1x10^{-8}$

4. CONCLUSIONS

In June 2003, an interim spent fuel dry storage facility was commissioned at Cernavoda Nuclear power Plant, with a designed lifetime of 50 years.

The Cernavoda spent fuel dry storage project is based on proven safe technologies for similar Canadian nuclear power plants' facilities.

The risk analysis performed for Cernavoda spent fuel dry storage facility has shown that the risk level both from normal operation and design basis accident scenarios is significantly lower than the risk acceptance criteria.

5. REFERENCES

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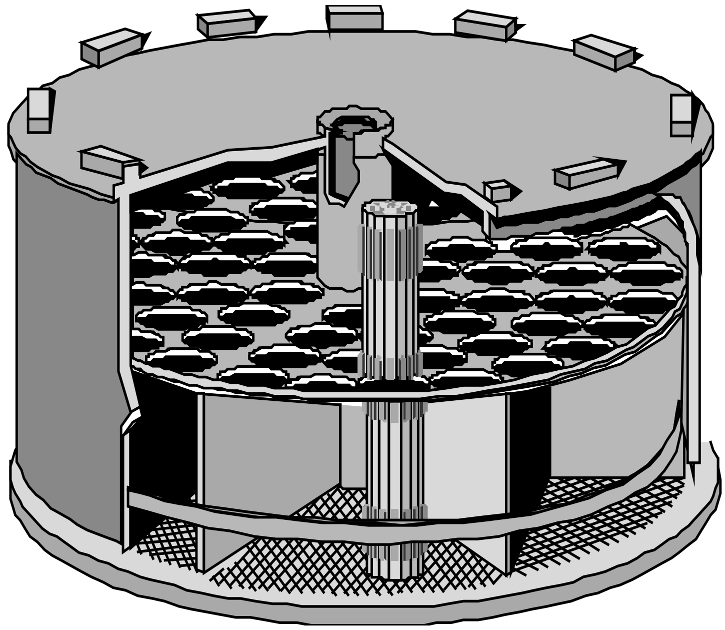

Fig. 1 Spent fuel storage basket

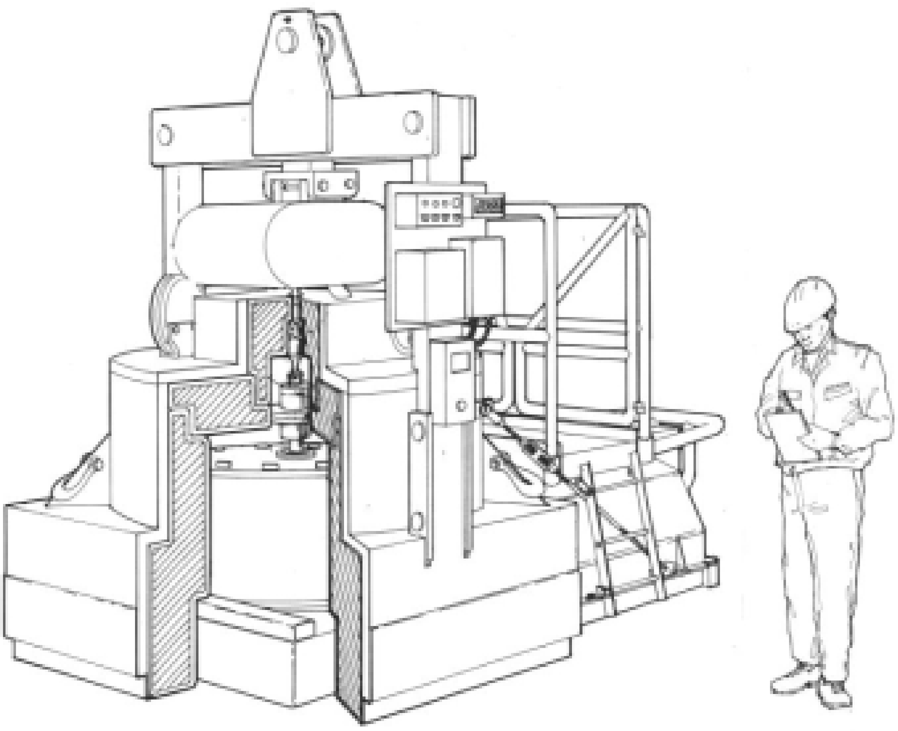

Fig. 2 Fuel transfer flask

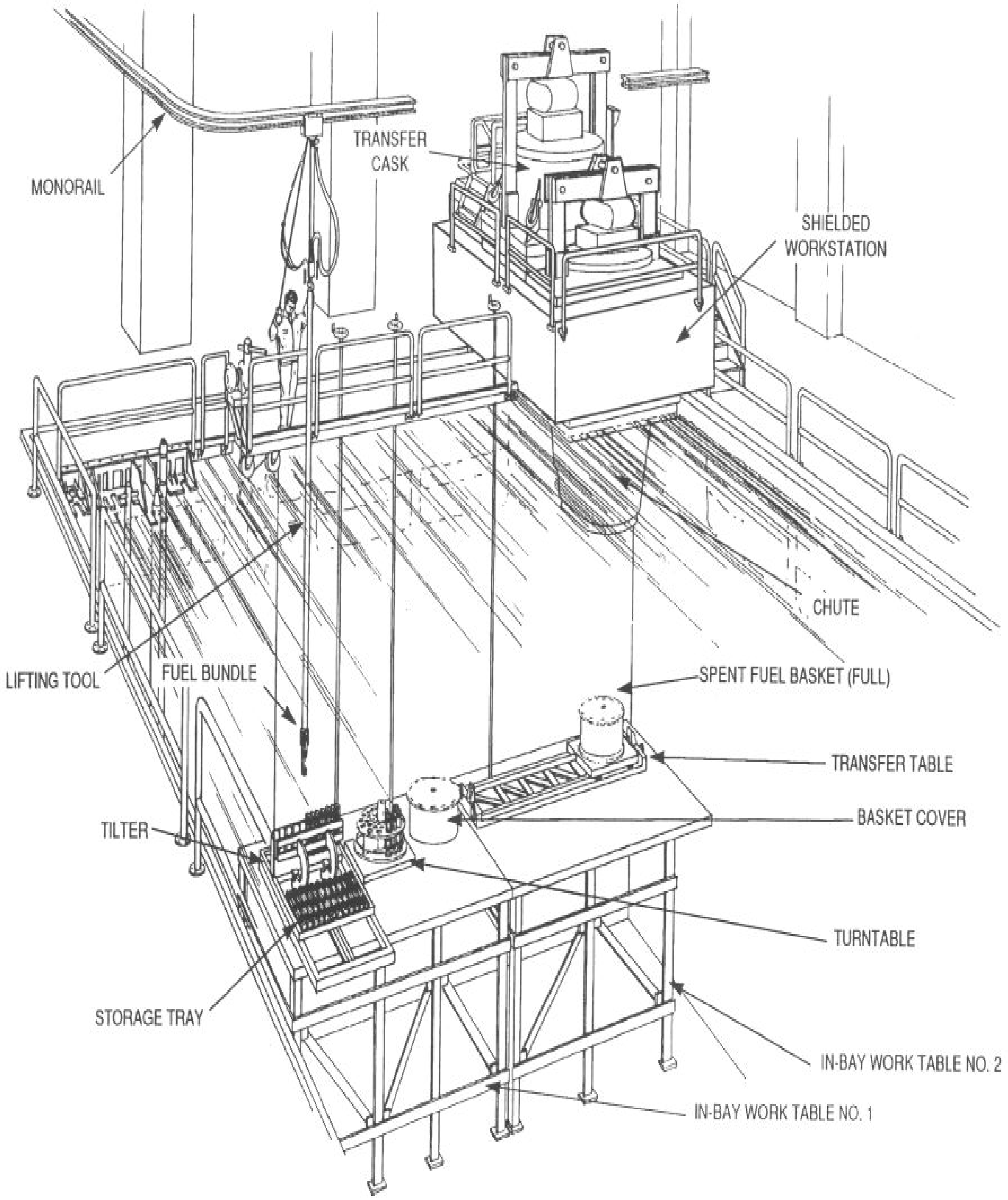

Fig. 3 Spent fuel preparation area

Fig. 4 General view of Cernavoda NPP site

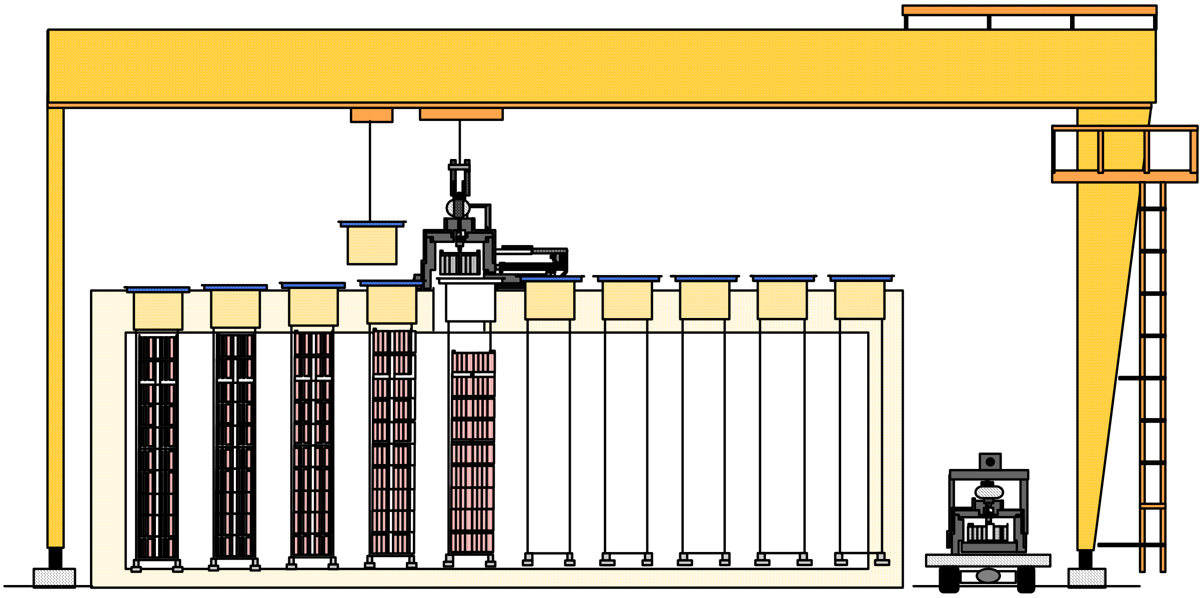

Fig. 5 Storage module loading

Fig. 6 Storage module loading (actual)

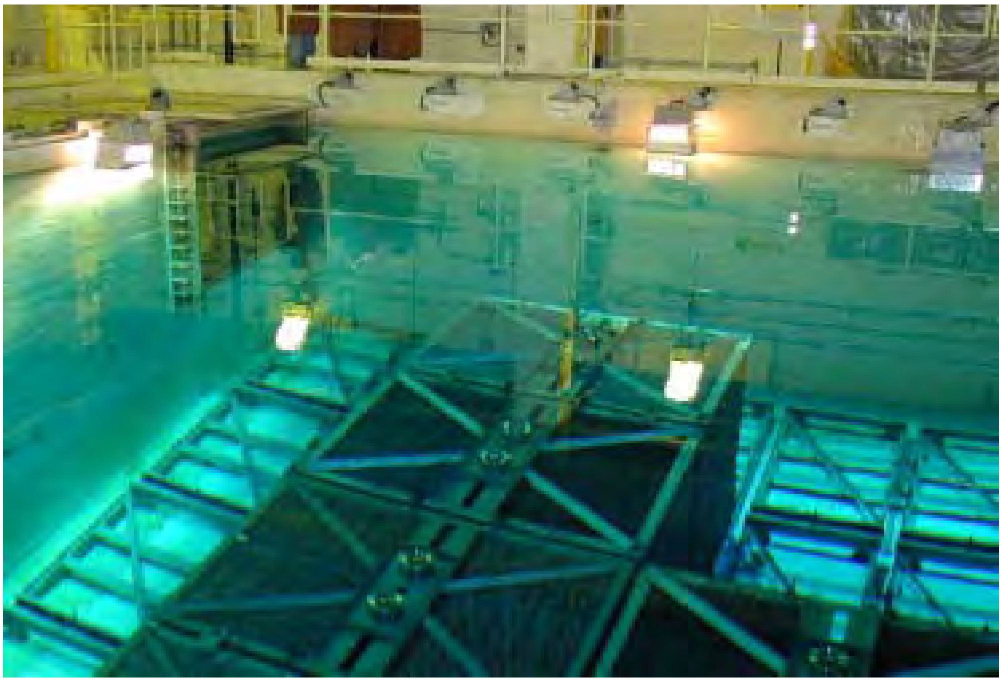

Fig. 7 Storage Trays in Spent Fuel Bay