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Dry Interim Storage in Switzerland for 30 Years

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ABSTRACT

Since Patram2010 long-term interim dry storage was introduced as a major issue to the international community. At the IAEA level several working groups have been found for short term, long term and extended dry storage. Raised issues as material degradation or transportability after the storage period are linked to dual purpose casks. Switzerland has started to store the first dual purpose cask 30 years ago.

The paper addresses the history of this 30 year stored cask, the monitoring of leak tightness, temperature and dose as well as the performed transports during the last 30 years. The performance of this cask will be presented and discussed with respect to the development of cask design, contents and requirements. This analysis provides results, which can be helpful for decisions to be taken for casks stored later and faced with this situation during and after their long term storage period.

The paper will also give a regulator’s perspective of the interim dry storage option considering current developments in the spent fuel domain using Switzerland as an example. Subjects as high burn-up, increased enrichment, MOX disposal, material degradation, fuel degradation or transportability after short and long term storage are discussed. Consequences for safety margins of dual purpose cask designs are highlighted.

INTRODUCTION

30 years ago, the first loading of a dual purpose cask in Switzerland was performed at Paul Scherrer Institute. Spent fuel of the research reactor DIORIT was loaded into a CASTOR Ic-Diorit cask designed and manufactured by GNS, Germany. At the beginning, the cask was stored near the research reactor in the same building.

This paper gives a historical review of CASTOR Ic-Diorit including movements, tests, measurements and current state of the cask. In addition, the problems and possible solutions during long term storage and in particular the transport after storage will be discussed. For this discussion current designs are considered also.

CASTOR IC-DIORIT

In 1983, Switzerland realised the first loading of a spent fuel cask at Paul Scherrer Institute in Würenlingen, Switzerland. They used the cask CASTOR Ic-Diorit designed and manufactured by GNS, Germany (figure 1). The loaded fuel originated from the research reactor DIORIT at Paul Scherrer Institute. The research reactor DIORIT was a heavy water moderated and cooled reactor developed in Switzerland. It was operated for a period of 17 years using natural and enriched uranium. In total the 350 loaded fuel assemblies had the following characteristics at the time of loading.

- Activity: 27.9 PBq
- Heat Load: 2.6 kW
- Pu-239 : 4.829 kg
- Pu-241 : 189 g

The CASTOR Ic-Diorit cask design is based on a thick-walled cast iron body. Within the body, there are long holes to introduce polyethylene rods for improved neutron shielding. The cask is closed by a double-lid system. The double-lid system is designed with an inner metallic seal to ensure leak tightness and an outer elastomeric seal to facilitate leak testing. The basket design is based on stainless steel to maintain the arrangement of the 350 fuel assemblies.

Figure 1. CASTOR Ic-Diorit

The safety demonstrations are mainly based on physical testing (figure 2). For the CASTOR Ic-family, several drop tests were performed including a drop test at -40°C [1]. In addition, a pool fire test demonstrates the leak tightness during fire [1]. An aircraft crash test was also carried out to demonstrate the resistance to storage accidents.

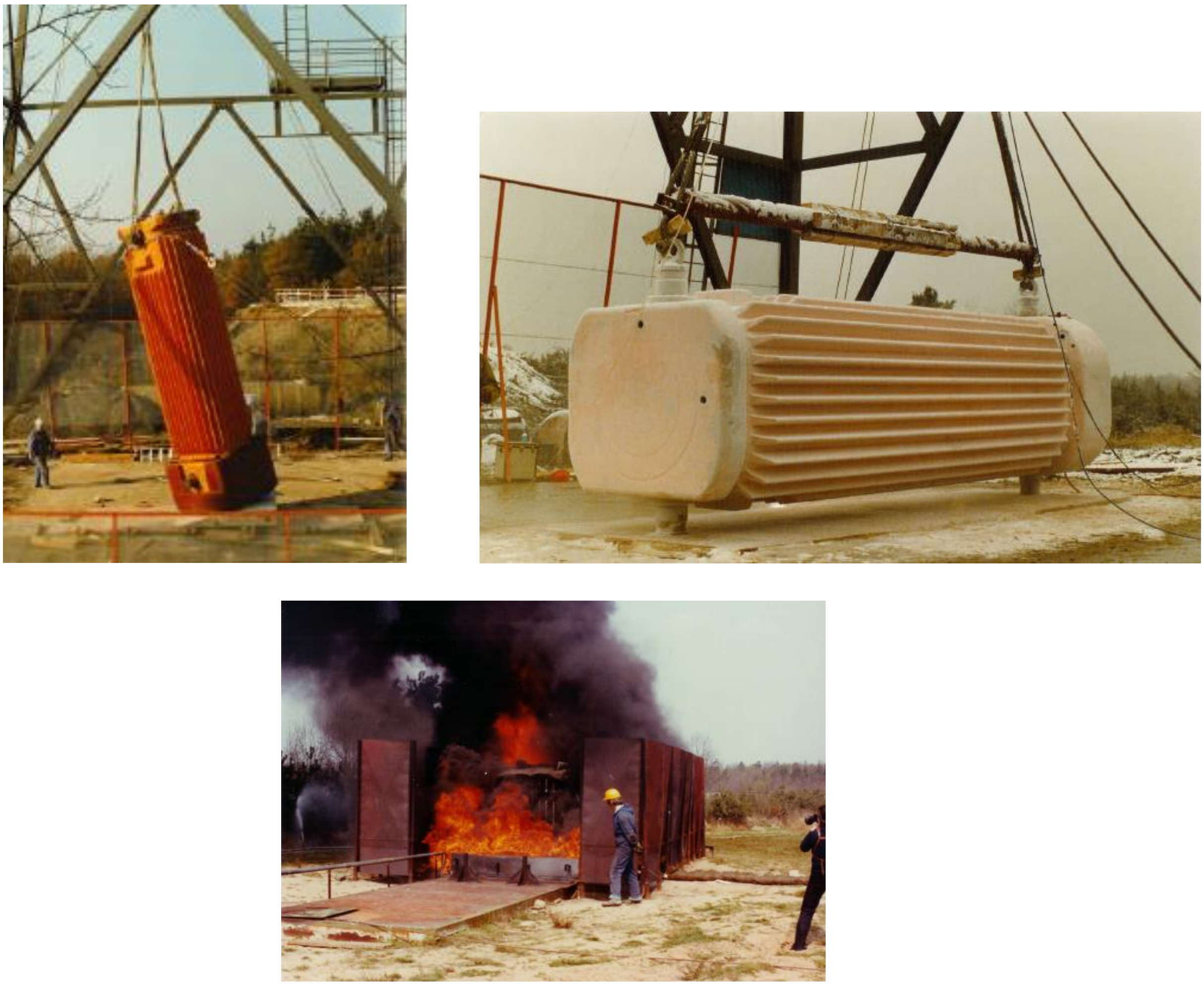

Figure 2. Physical tests for CASTOR Ic (oblique drop, drop at -40°C, pool fire) [1]

The original package approval for CASTOR Ic-Diorit was issued by the Physikalisch Technische Bundesanstalt, Braunschweig, Germany (PTB) in 1983 [2]. Nowadays, German transport package approvals are issued by the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS). Swiss authorities accepted the first storage at Paul Scherrer Institute, Würenlingen, Switzerland. In 2004, the Swiss Federal Nuclear Safety Inspectorate (Hauptabteilung für die Sicherheit der Kernanlagen, HSK) issued the approval for storage at ZWILAG [3], which is the central interim storage facility for Switzerland. The storage approval was based on a detailed safety evaluation [4]. The Swiss Federal Nuclear Safety Inspectorate has been reorganised to yield ENSI in 2009.

Today, the licensing situation is as follows: The transport package approval was not continuously renewed. So, at the moment, there is no transport package approval for Switzerland available. Similar cask designs of the CASTOR Ic-family are still licensed in Germany. The Swiss storage approval has not any time limit because of the requirement for periodical safety reviews for Swiss nuclear installations which include safety reviews of cask designs.

Finally, the CASTOR Ic-Diorit is a singular package. One single cask has fulfilled all the needs of PSI to dispose of the lifetime spent fuel of the DIORIT research reactor. The loading of CASTOR Ic-Diorit was part of the decommissioning project of the DIORIT research reactor. So, there will not be another specimen manufactured for Switzerland.

INTERIM STORAGE PERIOD

After loading in 1983, CASTOR Ic-Diorit was at first stored in the DIORIT research reactor building (figure 3). After two years, in 1985, the CASTOR Ic-Diorit was transferred to another site on the PSI area. This building hosted the cask for nearly twenty years and was used for storage of radioactive waste in general. The CASTOR Ic-Diorit was stored in a separated part of this building. PSI had realised a permanent monitoring of leak tightness and also periodical visual inspections and measurements with respect to dose and temperature.

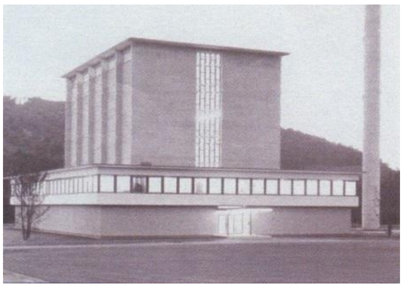

Figure 3. Reactor DIORIT [5]

In 2000, the central interim storage for Switzerland facility called ZWILAG started operating. Because of the modern technical infrastructure of ZWILAG, the Swiss Federal Nuclear Safety Inspectorate favoured the transfer of CASTOR Ic-Diorit to ZWILAG. In 2004, after more than 20 years of dry storage at PSI, the transport of CASTOR Ic-Diorit to ZWILAG was realised (figure 4) [5].

Figure 4. Transport of CASTOR Ic-Diorit [5]

Despite the fact that PSI and ZWILAG are close neighbours and the transport route was just a few hundred metres long, a road transport was organised under the regime of the IAEA and ADR regulations [6] [7] as special arrangement [8]. The special arrangement was needed because the package approval for the CASTOR Ic-Diorit had run out and was not renewed. The special arrangement was mainly based on the original package design demonstrations and the fact that similar designs of the CASTOR Ic-family still had updated licenses at that time. Operational and administrative measures were taken for additional compensation as reduction of velocity and closing of roads for the public along the transport route [9].

Due to Swiss nuclear law, PSI and ZWILAG applied for the shipment approval, which was assessed by the Swiss Federal Nuclear Safety Inspectorate (HSK). Finally, the Swiss Federal Office of Energy (BfE) issued the approval [10]. The transport was performed using a mobile crane and a special truck of ZWILAG (figure 4) August 30, 2004.

After the transport in 2004 leak tightness was measured again and the required leakage rate of 10^{-8} Pa•m^3/s could be confirmed as after manufacturing in 1982, after loading in 1983 and after the first transfer in 1985.

INTERIM STORAGE TODAY

There are two cask interim storage facilities operating in Switzerland: called ZWILAG and ZWIBEZ. ZWILAG is the central interim storage facility in Würenlingen near PSI, which supports the predisposed operations of Swiss nuclear power plants (NPP). The tasks include storage of spent fuel, high active, small and medium active waste as well as the conditioning of different waste types. Figure 5 gives a view to the storage hall containing high active waste and spent fuel casks. The red coloured arrow points to the CASTOR Ic-Diorit.

In addition to the central interim storage facility, there is an interim storage facility of the site of the NPP Beznau called ZWIBEZ. ZWIBEZ is also ready for the storage of spent fuel and small and medium active waste. Another plant in Switzerland operates a wet storage facility for spent fuel.

Figure 5. ZWILAG

There is a monitoring and inspection concept implemented for Swiss interim storage facilities. The concept includes a permanent leak tightness monitoring system for each cask. If there is an alert, the concerned cask could be clearly identified and repair actions can take place. ZWILAG operates a hot cell area, which could be used for such repairs also. In addition to the permanent leak tightness monitoring, temperature and dose measurements are performed periodically for single casks including visual controls. A monitoring of temperature and dose is implemented for the whole storage hall. During operation of interim storage of spent fuel and high active waste in Switzerland, there have not been any findings or abnormalities. Only some of the pressure switches have been exchanged due to malfunction.

To complete the regulatory framework based on the nuclear act and ordinance, ENSI has issued two guidelines for storage of radioactive waste and for transport and storage casks. The guideline ENSI-G04 for design and operation of storage facilities for radioactive waste and spent fuel summarises the following issues [11]:

- Design requirements for
  - Storage building
  - Technical equipment
  - Wet storage facilities
- Operational requirements
- Accident management
- Criticality control

The requirements incorporate among others acceptance criteria for waste, large components, spent fuel, pool type facilities, inspection, maintenance, accounting, reporting and safety evaluation. The original edition was issued on September 2010 and updated at March 1, 2012 (revision 1).

The guideline ENSI-G05 for transport and storage casks (dual purpose casks) used for interim storage facilities contains the following issues and requirements [12]:

- Mechanical analyses
- Lid system and weld joints
- Subcriticality and dose limits
- Temperature limits for cask and building
- Consideration of kerosine fire and covering of cask
- Transportability and retrievability
- Fabrication monitoring and documentation
- Ageing
- Aircraft crash and earthquake event

The guideline ENSI-G05 was issued in 2008 and has replaced the guideline HSK-R-52 issued in 2003 [13]. There were only minor changes for the requirements but the responsibility of the licensee was clarified and emphasised.

DESIGN CHALLENGES AND SAFETY DEMONSTRATIONS

The number of spent fuel casks in interim storage will increase significantly in the next years. Reasons for that is the political stop for reprocessing of Swiss spent fuel and the scheduled availability of the final repository. In addition to the increasing number of stored casks, the characteristic of the fuel will change significantly, too. Table 1 gives the spent fuel characteristics exemplary for CASTOR Ic-Diorit (loaded 30 years ago), TN24BH-L07 (loaded in 2012) and the potential maximum load due to the license of TN24BH.

The values in table 1 provide a significant increase of activity, heat load, enrichment and burn-up for current loadings (TN24BH-L07) in comparison to the loading of CASTOR Ic-Diorit in 1983. But even the current loadings (TN24BH-L07) do not fully exhaust the potential loadings allowed by the license (TN24BH). TN24BH is a design for boiling water reactor fuel, but the increase of activity, heat load, enrichment and burn-up can also be observed for pressure water reactor fuel.

Table 1. Spent fuel characteristics

	CASTOR Ic-Diorit	TN24BH-L07	TN24BH
Spent Fuel Assemblies	350 heavy water reactor	69 light water reactor	69 light water reactor
Activity	27.9 PBq	301.4 PBq	2909 PBq
Heat load	2.6 kW	27.8 kW	35.1 kW
Enrichment	0.7 % and 2.2 %	≈ 3.8 %	up to 5 %
Burn-up	1.5 .. 14 GWd/tU	≈ 50 GWd/tU	up to 80 GWd/tU for specific SFAs
Cooling time	0.5 years	7 .. 10 years	0.5 years for specific SFAs

As a consequence of this development, current cask loadings approach the design limits and make use of the safety margins. Operators and designers are implementing mixed loadings instead of homogeneous ones and burn-up credit has been introduced for criticality demonstrations. In addition, applications to license new designs are evaluated.

Mixed loadings, changes of fuel characteristics and the introduction of burn-up credit lead to new safety demonstrations and thus, to an increased assessment effort. Finally, there is a need for revisions of safety analysis reports of already used cask designs.

Concerning the application of new designs, current safety demonstrations rely to a great extent on numerical analysis. The CASTOR Ic-Diorit safety demonstrations were dominated by physical tests as drop tests, fire tests and impact tests with respect to storage accident conditions (figure 2). Physical tests were dominating despite there were sufficient safety margins for CASTOR Ic-Diorit in comparison with current and new designs.

Despite a significant development of numerical methods during the last decades, it is still a challenge to evaluate a design under normal and in particular accident conditions of storage and transport. High dynamic and transient events have to be thoroughly examined. According to experiences recently made, it is definitely necessary to validate numerical models with experimental results. Therefore, there is a clear tendency in Switzerland to improve the experimental basis of safety demonstrations. The physical testing includes the aircraft crash event with impact tests. In addition, material and component qualifications with emphasis on long term behaviour are required.

FUTURE PERSPECTIVES FOR DUAL PURPOSE CASKS

As a reaction to the increased number of stored spent fuel casks and the expected long storage periods in many countries, there are ongoing international discussions concerning the safety demonstrations for dual purpose casks (DPC) considering long term dry storage up to 100 years and even longer. Casks used for transport and storage are classified as DPC. In addition to long term storage, the transport after storage was identified as a major issue requiring additional safety demonstrations.

Presently, we are confronted on the storage side with long term licenses already considering ageing issues. On the transport side, there are transport package approvals usually renewed after 5 years. But only a few transport package approvals cover transport after long term storage: Ageing issues are usually not part of the safety demonstrations. So, the idea was born to combine the safety demonstrations for transport and storage in a single, coherent safety case to cover the whole life and all user options of a DPC. Therefore, IAEA has initiated a joint working group including WASSC and TRANSSC representatives to develop requirements for a corresponding DPC safety case. The working group has finished its work in 2013 and has provided a TECDOC [14] to support the designer in preparingthe DPC safety case as well as recommendations for the safety committees WASSC and TRANSSC to make adjustments in safety requirements and guidance material.

Due to the regulatory framework, the Swiss situation concerning the licensing situation of DPCs is different: There are unlimited storage licenses issued for DPCs. According to the guideline ENSI-G04, however, the operator has to perform a periodical safety review of a stored cask any ten years. The periodical safety review has to be accepted by the competent authority. Potential measures to keep the safety level have to be agreed. With respect to transport package approvals, Switzerland usually validates approvals of foreign authorities. But despite running storage licenses, some transport licenses were not renewed. In particular, old DPC designs with only a few specimens manufactured are similarly addressed as the CASTOR Ic-Diorit. In addition, technical changes in some renewals of transport package approvals may not be fully applicable for already stored DPCs.

Swiss competent authority tends to opt for an extended licensing regime based on the output of the IAEA joint working group. Based on a first transport package approval in the country of origin and additional ageing demonstrations for transport after storage, ENSI would issue a license for transport and storage, valid for the same period of time. The necessary periodical review would contain transport and storage issues in extension to the demonstrations already required by the guideline ENSI-G04. ENSI has introduced this approach to the SSR-6 review process.

CONCLUSIONS

The 30 year experience with CASTOR Ic-Diorit gives a positive feed-back for DPC operation including loading, 30 year storage, relocation and transport after more than 20 years of storage. In addition, the results of permanent monitoring and periodical inspections and measurements provided during the operation of Swiss interim storage facilities support this conclusion.

This experience is not completely transferable to current and future designs due to the reduction of safety margins resulting mainly from changes of spent fuel characteristics such as increased activity, heat load, enrichment, burn-up. As a consequence, mixed loadings and the introduction of burn-up credit provide the need to update and revise safety demonstrations for current designs.

New safety demonstrations, in particular found in applications for new designs, are mainly based on numerical analysis. But recent experiences provide the need for the validation of numerical models by physical tests.

To cover the whole life and use of a DPC as transport, storage and transport after storage, an adoption of licensing regimes could be useful. This could give the opportunity to evaluate the ageing issues for storage as well as for transport after storage and this could contribute to a clarification of the licensing situation.

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