DEVELOPMENT OF THE SWEDISH NATIONAL DATABASE FOR QA OF SPENT NUCLEAR FUEL

Henric Lindgren
Swedish Nuclear Fuel and Waste Management Co

Author
Affiliation

Author
Affiliation

Author
Affiliation

Author
Affiliation

ABSTRACT

The Swedish Nuclear Fuel and Waste Management Co (SKB) is responsible for all the back-end issues in the Swedish nuclear industry. SKB operates a central interim storage for spent nuclear fuel (Clab), and is responsible for research, development, construction and operation of a future final repository for spent nuclear fuel (SNF).

Data for all the nuclear fuel assemblies (FA) in Sweden is stored in a national database, administrated by SKB. The national database is used for the administration and quality assurance (QA) of handling, transportation and storage of SNF.

The database is continuously updated and includes data for all FA at the nuclear power plants (NPP), and all FA at the Clab facility. The data includes identification, fuel type, initial and irradiated masses for heavy metals, assembly enrichment and burnup, location (i.e. at NPP or Clab) and date for unloading.

The database is an important tool for QA and administration of SNF for SKB. The QA consists of checking that fuel parameters are in accordance with the requirements in the certificate for the transport casks and the Safety Analysis Report (SAR) for the Clab facility prior to transportation from the NPP:s to Clab.

Internal requirements at SKB regarding more fuel data for the long term safety analysis at a final repository, and the fact that SKB plans to apply burn up credit for the Clab facility and later the final repository, requires a new database in order to meet future QA requirements.

The paper describes the program for developing and replacing the current database in order to meet future requirements regarding more detailed fuel data, and to use the application for QA of burnup credit. The database will ensure that required fuel data follows the FA from the reactor to the closure of the final repository for SNF.

INTRODUCTION

The Swedish Nuclear Fuel and Waste Management Co (SKB) is owned by the Swedish Nuclear Power Plants and is responsible for all the back-end issues in the Swedish nuclear industry. SKB owns an INF-3 ship (m/s Sigyn) and 13 type B containers of which 10 are used to transport irradiated nuclear fuel. SKB also owns and operates a central interim storage for spent nuclear fuel (Clab), where the fuel is unloaded from the transport casks and stored in large underground pools. SKB is also responsible for research, development, construction and operation of a future encapsulation plant and a final repository for spent nuclear fuel (SNF). The Swedish system for management and disposal of SNF and low and intermediate level operational waste is shown in Figure 1. This report will only discuss management of SNF.

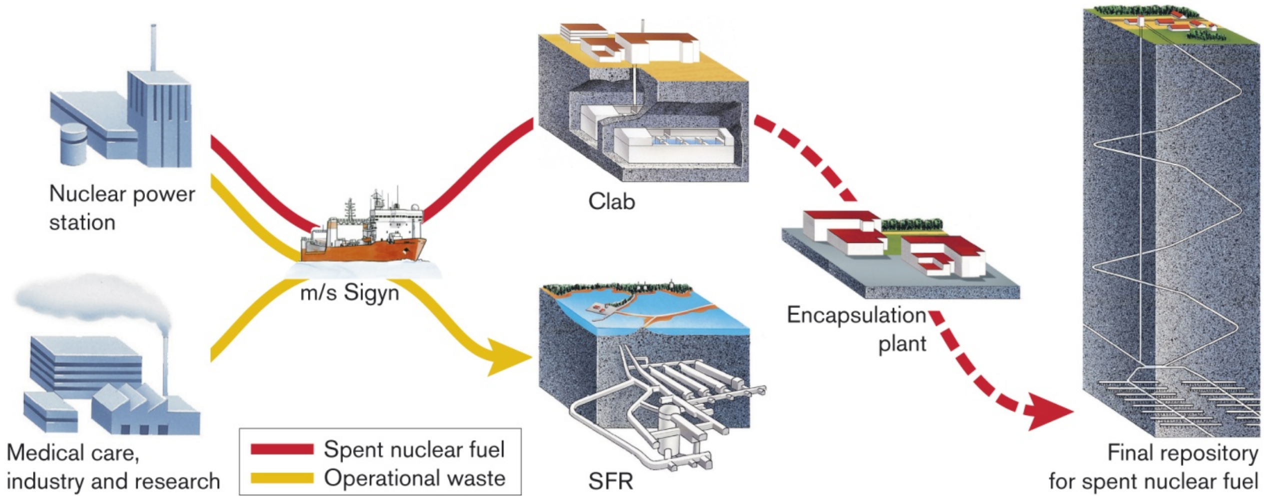

Figure 1. The Swedish system for management and disposal of radioactive operational waste and spent nuclear fuel. The encapsulation plant and the final repository for spent nuclear fuel are not yet constructed. The other plants are already in operation.

One of the most important tools for SKB is a reliable computer system which can keep track of all the fuel assemblies in Sweden and their corresponding mechanical and nuclear properties. The system must be able to handle all the fuel parameters that are used presently to ensure that all transport and intermediate storage regulatory criteria are met. The system must also include all the mechanical and nuclear parameters that will be required for the long term safety analysis report for the final storage. Furthermore the system must be able to make appropriate validations that the criticality criteria are met since SKB plans to apply Burn-up Credit (BUC) for the intermediate and final storage in the future.

<u>Purpose and objective</u>

The purpose of this paper and the forthcoming presentation at the Patram 2010 conference is to present the ongoing project at SKB to replace its current national database for Quality Assurance that the spent nuclear fuel is in accordance with all possible present and future regulations.
The objective is to share experiences and ideas with other users with similar operational needs to increase the common knowledge about how other countries manage the same type of data to make sure that vital information will not be left out.

PRESENT DATABASES FOR SPENT NUCLEAR FUEL

Presently, SKB has two different applications and two different databases for the spent nuclear fuel. One application performs validation of transport and intermediate storage criteria prior to transportation, and generates the necessary transportation documents. The other one is a safeguards application, which also keeps track of some operational restrictions at the Clab facility, and generates working orders for the unloading procedure.

The databases are continuously updated after each irradiation cycle at the NPP:s and include data for all FA at the nuclear power plants, and all FA at the Clab facility. The data includes identification, fuel type, initial and irradiated masses for heavy metals, assembly enrichment and burnup, location (i.e. at NPP or Clab) and date for unloading.

The present system is rather old and is not flexible. New regulatory requirements are difficult to integrate in the present system, why separate built-on applications must be created each time they occur. The present system cannot be updated to include more fuel parameters without making significant changes in the code.

FUTURE DATABASE FOR SPENT NUCLEAR FUEL

SKB has started a project to replace the current databases and applications with a new system with a single database. This will be done in order to meet future requirements of more fuel data for final storage and Burn-up Credit purposes, and have a dynamic system that is easy to update as regulatory requirements tend to change frequently.

Large amounts of data for the nuclear fuel is stored in databases at the nuclear power plants for each fuel assembly that has been in the core. However, this data is not necessarily the same data that SKB needs for its intermediate and final storage, since it is stored for core management purposes.

The future computer system must be more dynamic than the present. This is due not only to that the regulatory requirements will change over time. The existing fuel data will most likely be recalculated in the future when the core simulators and cross section generators are improved and the uncertainties will likely decrease. The database must be able to be updated when fuel data is recalculated.

The data that SKB will require from the nuclear power plants is listed in Appendix 1. This is an extensive amount of data. However, by storing all this data, the intention is to cover all cases to fulfill the regulatory requirements for transportation, intermediate storage, and final encapsulation and storage.

The computer system plans to be structured as follows. The system is illustrated in Figure 2.

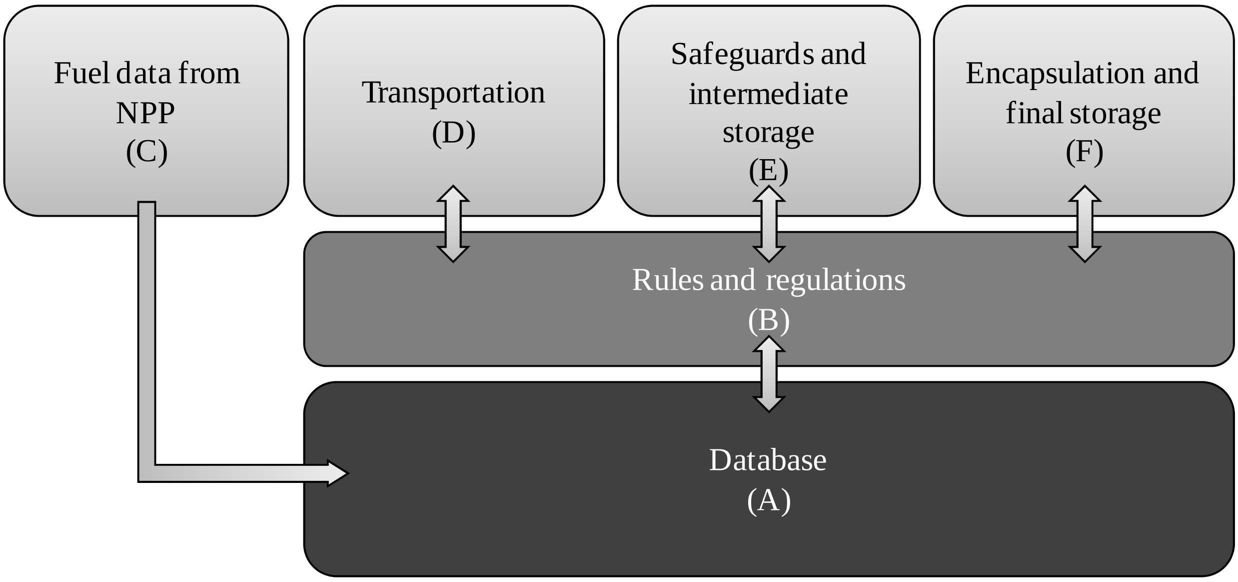

Figure 2. Schematic view of the future Swedish system for QA of spent nuclear fuel

A. The foundation of the system is the database itself, where all the fuel parameters are stored, including the physical location of each fuel assembly. The database must be able to be easily updated with data from (C), so SKB has the best possible data at the time for encapsulation. The updating process will be made simple, so runs for each EOC can be recalculated with e.g. POLCA or SIMULATE and a script will transfer the desired data to the database.
B. On top of the database is a separate application where all the rules and regulations (from the Safety Analysis Report and transport certificate) are stored and checked. Also specific internal SKB requirements will be stored and checked in this application.
C. The nuclear power plants will have a separate application which they will use to store fuel data in the database for all fuel types and fuel assemblies. The NPP:s will be able to create, update, recalculate and store the fuel data in (A), e.g. after each EOC if the data is recalculated with an updated core simulator.
D. The transportation application will be used prior to transportation of spent fuel from the NPP to the Clab facility. The transport cask loading pattern is given in the application, along with a date for transportation. Next it calls for the rules and regulations (B) and the database (A) in order to check that all fuel parameters including cooling time is in accordance with all the transport and intermediate storage regulatory parameters. The application will also call for a check that each specified fuel assembly is of a fuel type that has been approved for encapsulation and final storage.
E. The application for safeguards and intermediate storage will be used when generating the working order for the unloading of the transport cask into the intermediate storage pools. The application is an important tool to make sure that restrictions during the unloading procedure are met.
F. An additional application will be added in the future, when the fuel is going to be encapsulated for final storage. The application will ensure that all fuel parameters are in accordance with the future license for the final repository and that the criticality criterion for each copper canister is met by applying BUC.

SKB plans to have the new system in operation in about a year from now. The project will be divided in a couple of steps, where the database (A), Rules and regulations (B) and the transportation application (D) will be finished first. The other applications will be added on later.

QUALITY ASSURANCE OF THE SPENT NUCLEAR FUEL

In order to meet the criticality criterion for future fuel types and the final storage copper canister, SKB will apply for Burn-up Credit (BUC) in the re-licensing of the intermediate storage facility (Clab) and also in the licensing of the final repository. Applying BUC requires extremely good quality assurance of the spent fuel data. When a fuel assembly is about to be encapsulated in the copper canister, SKB must be certain that the fuel data match the physical properties of each fuel assembly.

The quality assurance of the fuel data are divided in several steps. A short description of the QA follows below:

1. First of all the nuclear power plants verifies that the delivered fresh fuel is manufactured according to the mechanical and nuclear specifications (enrichment and burnable absorber). If deviations between specifications and manufactured fuel occur, the NPP make necessary changes in the database.
2. The NPP keeps track of the fuel parameters during the irradiation cycles in the core. The nuclides are calculated from the burn-up which is in turn calculated based on the thermal power and feed water flow. The main uncertainty in the burn-up calculation is the uncertainty in the feed water flow. The calculated burn up is also verified at each start up of the reactor and during the irradiation cycles by TIP (traveling in-core probe)-measurements.
3. Prior to transportation, the transportation application checks that all the fuel assemblies fulfill the requirements of the transport cask license and the safety analysis report for the Clab facility. An application coupled to the database will generate and verify a loading pattern for each transport cask. During loading and unloading, an extra control is performed in order to verify that the cask is loaded according to the specified loading pattern.
4. When the fuel has been unloaded, the safeguards application keeps track of all the fuel in the Clab facility.
5. In the future, when the encapsulation plant has been built, several more steps are required to ensure that each fuel assembly has its correct corresponding mechanical and nuclear parameters, along with its physical location.

Each FA must have the correct data. This is important for the criticality and radiation safety. If the burn-up is over- or under estimated, it can lead to incorrect criticality and/or radiation assessments. Of course, the event of incorrect data is evaluated in the criticality safety analysis, and radiation protection analysis, and appropriate margins will be built-in in the system.

CONCLUSIONS

QA is essential to the SNF handling process why the project is of great importance to SKB. Sharing experience and knowledge at an early stage with other users could get the system in operation quicker and lead to less problems in the future.

APPENDIX 1 – FUEL PARAMETERS IN THE FUTURE DATABASE

Area	Description	Unit
General	Fuel Type	
	Fuel Vendor	
	Reference Document	
	Reprocessing drawing	
	Overall Assembly Length, nominal	mm
	Assembly Mass, nominal	kg
	Overall Assembly Cross Section Min	mm
	Overall Assembly Cross Section Max	mm
	UO2 Mass, nominal	kg
	Uranium Mass, nominal	kg
	Initial Average Enrichment (in Section with Highest Reactivity)	w/o U235
	Initial Uranium Enrichment (Average in Assembly)	w/o U235
	BA Type	
	Content of BA	%
	Number of BA rods/assembly	
	Active Fuel Length, nominal	mm
Assembly	Rod Array	
	Fuel Rod Pitch minimum	mm
	Fuel Rod Pitch maximum	mm
	No. of sub assemblies	
	Wight of sub assembly	kg
Rods	Number of Rods	
	Number of fuel rod types	
	Normal fuel rod length	mm
	Supporting fuel rod length	mm
	Spacer rod length	mm
	number of part length rods	
	length of part length rods	mm
	Drawing of Fuel Rod without BA	
	Drawing of Fuel Rod with BA	
	Normal Fuel Rod Length, nominal	mm
	Weight (UO2) of Fuel Rod (without BA)	kg
	Weight (UO2) BA Fuel Rod	kg
	Minimal mean cladding tube outer diameter	mm
	Maximal mean cladding tube outer diameter	mm
	Total Mass of Rod Excluding UO2 Pellets	kg
Pellet	UO2 Density Min	g/cm3
	UO2 Density Max	g/cm3
	UO2 Density BA-Pellet (nominal)	g/cm3
	UO2 Pellet Diameter Min	mm
	UO2 Pellet Diameter Max	mm
	Dishing Volume	%

Area	Description	Unit
Cladding	Clad Material / Liner	
	Minimal cladding tube thickness	mm
	Maximal mean cladding tube thickness	mm
	Total Mass of one cladding	kg
PWR Guide tubes (with end fitting)	Number of Guide Tubes	
	Material	
	Wall Thickness (Average in Active Region)	mm
	Outer Diameter Max	mm
	Outer Diameter Min	mm
	Guide tube end fitting material	
	Mass of one Guide Tube, nominal	kg
PWR Instrumentation tube	Material	
	Wall Thickness (Average in Active Region)	mm
	Outer Diameter Max	mm
	Outer Diameter Min	mm
	Mass	kg
Filling gas	Initial filling gas	
	Initial filling gas pressure	bar
	EOL gas pressure	bar
BWR water channel	water channel material	
	water channel thickness	mm
	water channel size max	mm
	water channel size min	mm
water rod	no of water rods	
	water rod wall thickness	mm
	water rod material	
	water rod outside diameter	mm
BWR water cross	water cross thickness max	mm
	water cross thickness min	mm
BWR fuel channel	channel material	
	weight of channel	kg
	Channel inner measures	mm
	channel wall thickness	mm
	channel bottom piece material	
	channel zr weight	kg
	channel stainless steel weight	kg
handle	handle material	
	handle weight	kg
top plate	top plate material	
	top plate weight	kg
spacers	number of spacers in active zone	
	axial partitions of the spacers	mm
	drawing of spacer	
	spacer height	mm
	spacer material	
lower tie plate	Lower tie plate material	
	Lower tie plate weight	kg

Individual data	Description	unit
	Fuel assembly identification	
	Box identification (BWR)	
	Project code	
Initial data	Initial weight Utot	g
	Initial weight U235	g
	Initial weight Pu 238	g
	Initial weight Pu 239	g
	Initial weight Pu 240	g
	Initial weight Pu 241	g
	Initial weight Pu 242	g
	enrichment distribution for each fuel segment	
EOL data	irradiated weight Utot	g
	irradiated weight U235	g
	irradiated weight Putot	g
	irradiated weight Pu 238	g
	irradiated weight Pu 239	g
	irradiated weight Pu 240	g
	irradiated weight Pu 241	g
	irradiated weight Pu 242	g
	Assembly average burnup	MWd/kgU
	Axial burnup distribution	
Other data	Box (BWR)	y/n
	Damaged (leaking)	y/n
	Damaged (mechanically)	y/n
	Repaired/Reconstructed	y/n
	Missing fuel rods	y/n
	contains control cluster (PWR)	y/n
	Other experiences/events	

Irradiation history	Cycle nr	Added burnup	Date BOC	Date EOC
(for each FA)	i	MWD/kgU		
	Cy i+1			
	..			
	..			
	Cy k			