The SKB Criticality Safety Program

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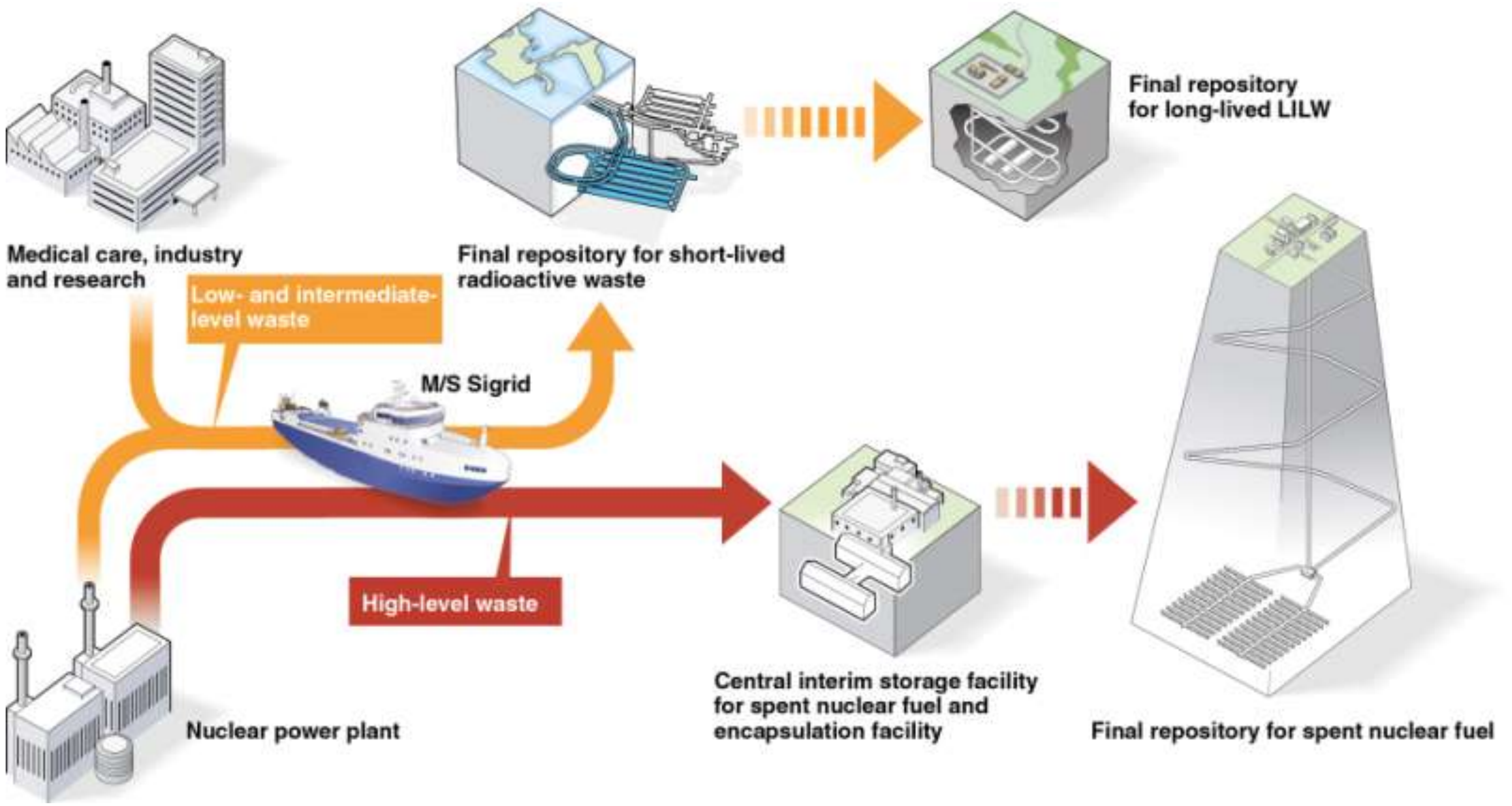
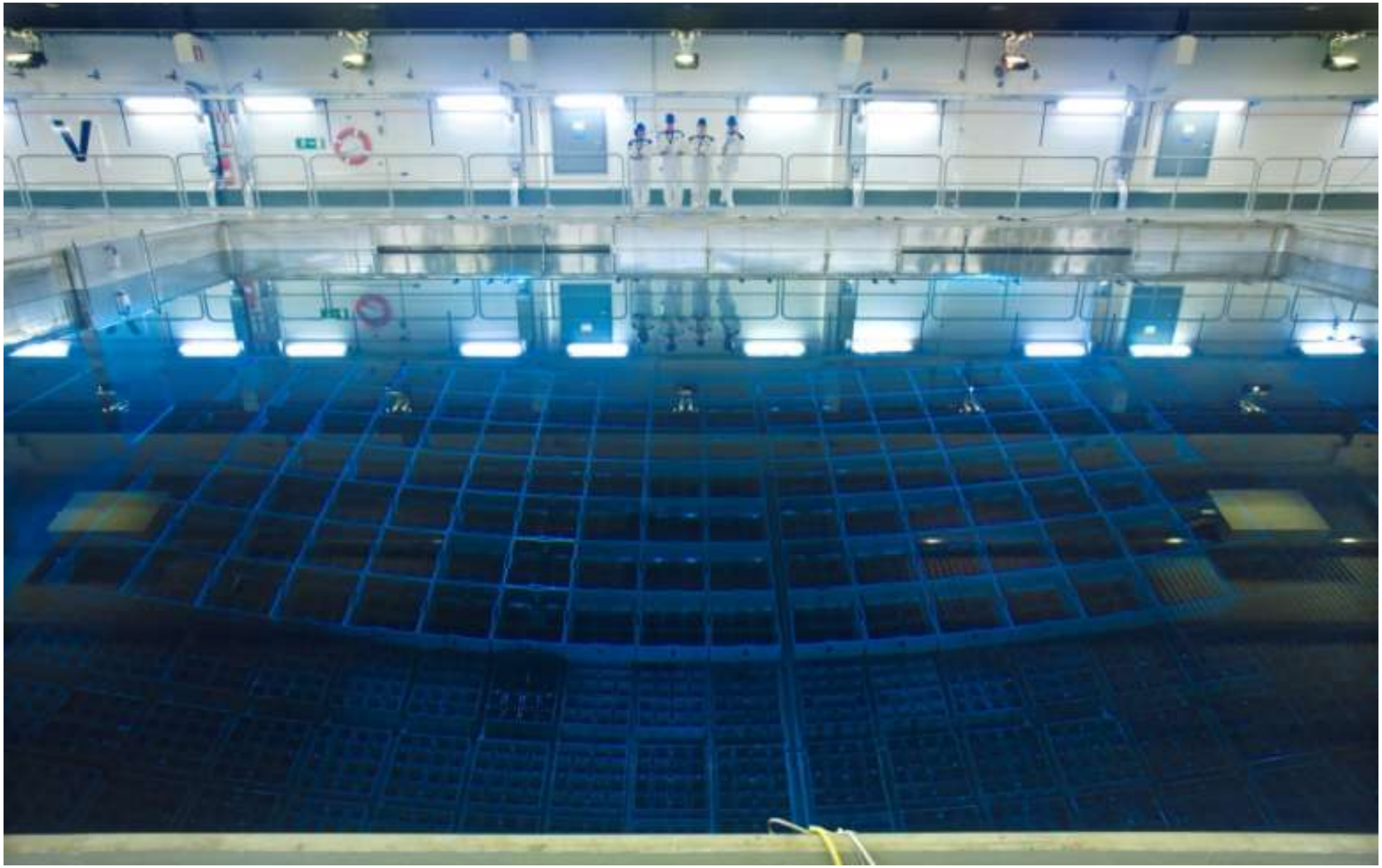
Outline

- The role of SKB in the Swedish system
- The history of Clab
- The boiling frog
- SKB criticality safety program
- Conclusion
- Future work

The Swedish system of Nuclear waste and spent nuclear fuel



The intermediate Storage - Clab



The history of Clab

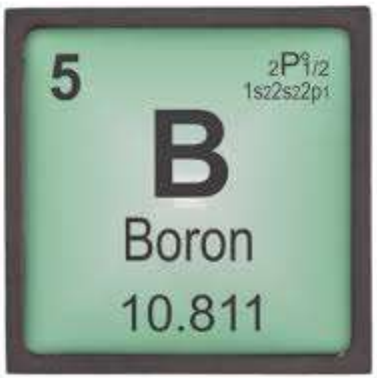
- Clab was built 30 years ago
- In the original safety analysis there were good margins to the criticality acceptance criteria (k_{eff}=0.95) for all events, fresh fuel assumed.
- The highest allowed enrichment was 3.3% U-235.
- The canisters were of one single type and geometrical safe. No boron or other neutron poisons were used.
- All fuel types were treated the same way.
- In regard to criticality safety the facility was literally “fool proof”.

Development during 30 years

- Enrichment levels were raised several times.
- New and more reactive fuel types were introduced.
- The storage capacity was extended by introduction of Compact Canisters made of borated steel.
- Burnable Absorber credit was introduced .
- Introduction of blocked positions in the canisters for the most reactive BWR fuel types and enrichments above 4.2 % for PWR.
- The use of normal canisters for PWR was restricted.

Administrative barriers

- The old “fool proof” facility is no more. Criticality safety is now ensured by different types of neutron absorbers, blocking plugs and administrative routines.



The boiling frog

"*The **boiling frog** story is a widespread anecdote describing a frog slowly being boiled alive. The premise is that if a frog is placed in boiling water, it will jump out, but if it is placed in cold water that is slowly heated, it will not perceive the danger and will be cooked to death. The story is often used as a metaphor for the inability or unwillingness of people to react to significant changes that occur gradually*."
From Wikipedia, the free encyclopedia

Example of the the boiling frog syndrome

- SKB relied heavily on consultants to do the criticality safety work.
- Procedures and instructions specifically mentioning criticality safety were few.
- The criticality analysis in the Clab SAR consisted of several different analysis from different decades made with different calculation tools based on different methodologies.
- Low awareness of criticality safety in the organisation.

James LeeFormerIP at en.wikipedia

Wake up call

- In March 2011 SKB applied to the Swedish Radiation Authority (SSM) for permit to build a final repository for spent Fuel and an encapsulations plant (Clink). The application contained a criticality safety analysis for all the canisters to be used in Clink and the copper canister to be used in the final repository for spent fuel.
- The review report from SSM was rather critical and required SKB to take into account the latest development in the Criticality Safety area as well in Sweden as internationally.
- Even though this didn’t lead to formal regulation it forced SKB to put new attention to the Criticality Safety Area

Development of a criticality safety program

- Development of criticality safety methodology
- New criticality safety analysis reports for all facilities.
- Development of criticality safety training program
- Update of steering documents

Development –New analysis

- Development of a new methodology for criticality safety analysis.
- New validation of criticality codes (Scale 6.1) based on ANSI/ANS-8.24 and ANSI/ANS-8.27. Selection of experiments using the Tsunami tool.
- Writing of new criticality safety analysis report for Clink and the final repository. Using BUC for PWR and BA-credit for BWR.
- Writing of criticality safety analysis report for Clab based on a complete new event inventory using Hazid-methodology.
- Writing of new Burnable Absorber credit analysis reports for all facilities, taking into consideration the new enrichment, fuel types and Burnable Absorber levels (Gd).

Development - organisation and administration

- Gap analyse against IAEA SSG-27 “Criticality Safety in the handling of fissile material”. Update of procedures and instructions to match this guideline.
- More personnel dedicated for fuel projects in general and criticality in particular. Focus on competence development and increased knowledge in criticality codes and criticality analysis.
- Development of criticality safety course targeted for operational personal. Requirements to attend this course for certain personnel categories.
- Update of several administrative procedures and guidelines to secure that criticality safety is considered in all activities that affects the nuclear fuel or related systems.

SSM recent reviews

- SSM has reviewed all new criticality analysis.
  - Satisfied with the criticality safety analysis, including BU-credit, BA-credit and validation of codes.
  - Still work to do defining and describing the administrative barriers.

Lessons learned - Conclusion

- In a world with aging nuclear facilities there is a evident risk of the boiling frog sydrome.
- The ANS and IAEA standards is a great help when creating a criticality safety program.
- Writing a good quality criticality safety analysis report is the easy part.

Future work

- Take care of SSMs remarks and proposals.
- Risk of criticality in the very long time frames
- Scale 6.2 validation

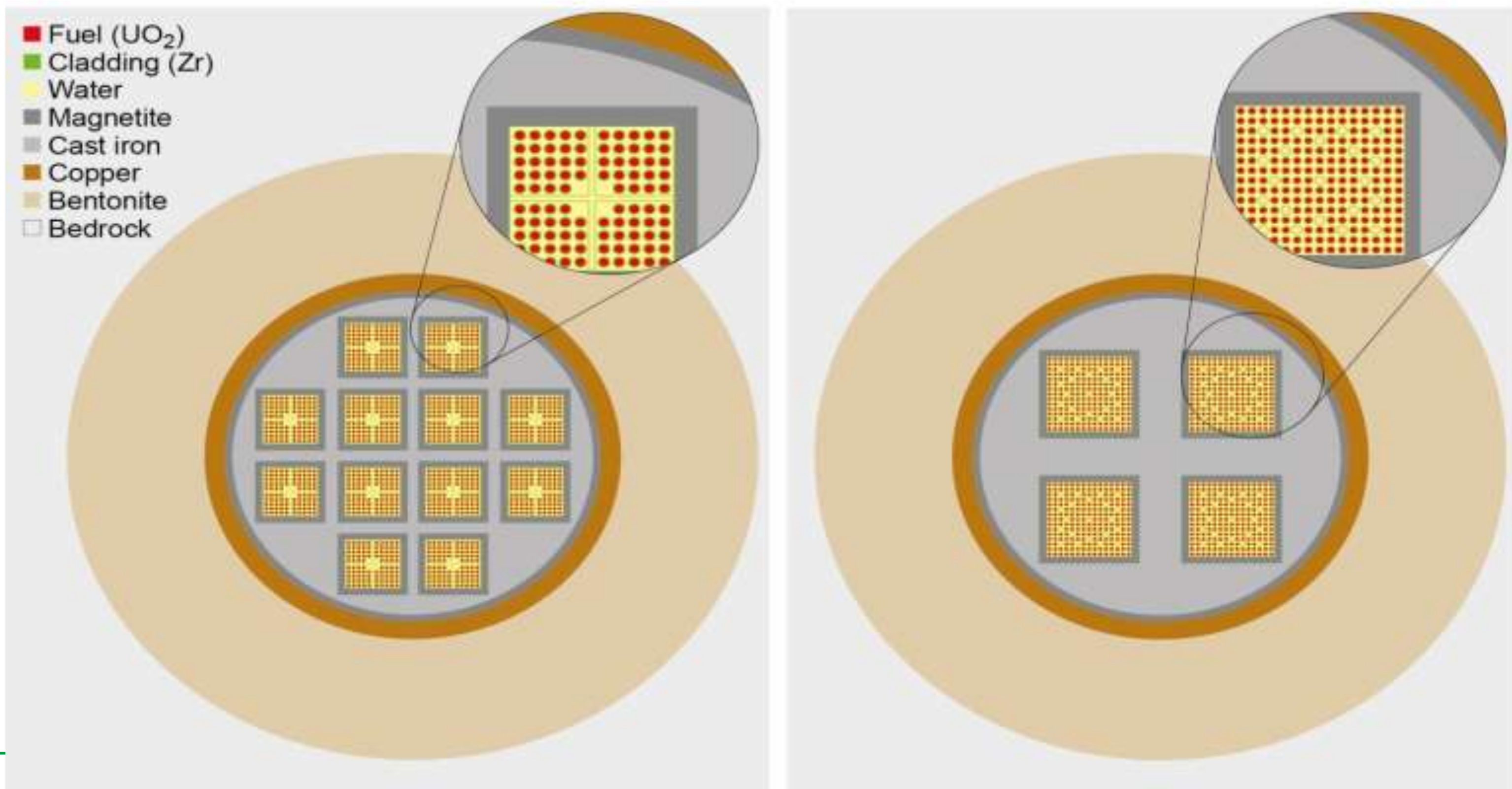
Degrading canister

- SKB safety studies of the final repository shows that it is very unlikely that a canister will break in the first 100 000 years.
- However due to the very long half life of U-235 (700 million year) the risk of criticality doesn’t cease beyond that time frame.
- SKB has stated that we will not accept criticality in any probable evolution of a damaged canister.

Klicka här för att ändra format

Ongoing work- Degrading canister

Main process: Corrosion of Cast Iron forms Magnetite.



Ongoing work – Scale 6.2 validation

- Keno results for our validation suites very close to 6.1 results.
- Tsunami-IP gives lower ck-values for MOX-experiment.
- Longer executions times using Scale 6.2

Administrative barriers

- With the introduction of Burn-Up- and Burnable Absorber credit as well as introduction of different kind of operational restrictions, criticality safety is no longer secured only with geometrically safe configuration. The defence in depth is depending on that the administrative barriers are in place and works properly. One example of a difficulty is how to secure that a modification of the plant, which not evidentially effects criticality, is reviewed by staff with criticality safety competence. Efficient administrative measures demands competence at different levels, and a clear-cut division of responsibility. In an organisation as SKB, geographically spread and consisting of units with different focus, this is a challenge maybe more difficult than writing a criticality safety report.