Handling of failed fuel: from reactor to final repository by reconditioning in Studsvik concrete cells

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Failed fuel has been stored in fuel pools at the nuclear power stations in Sweden since start-up of the reactors. Typically, after detection of failure the failed rod is extracted from the bundle and placed in a failed fuel cartridge. The failed fuel cartridge has the size of a fuel bundle and may contain several more or less severe failed rods. Each reactor fuel pool normally has one or several failed fuel cartridges. There are also examples of fuel failures where the failed rod or rods are stuck in the bundle and thus the whole bundle needs to be stored as failed in the fuel pool.

The failed fuel leak radionuclides to the pool water thus causing increased doses but also cause larger amounts of ion exchanger resin and related costs for handling and final disposal. Per Swedish rules, failed fuel shall be removed from the reactor pools without delay.

In the Swedish system for final disposal of spent nuclear fuel, KBS-3 (Birgersson, 2016), the fuel bundles are placed in a dry copper canister, 12 BWR bundles or 4 PWR bundle per copper canister. The copper canisters are placed in tunnels 500 meters down in the solid rock. The filling material around the copper canisters is bentonite clay. KBS-3 will be built near Forsmark nuclear station in mid-east Sweden.

The failed rods contain water and need to be dried before encapsulation for intermediate and final storage in KBS-3. Remaining water in the failed rods may cause further oxidation of the UO2 matrix to unstable oxides such as UO3 and U3O8. Radiolysis of the water may cause leaching of the fuel matrix in the copper canister for final disposal. Radiolysis of water also produce oxygen and oxidants and in presence of air in the copper canister this may produce nitric acid which may damage the copper canister. (About 10% air in argon are expected in the copper canisters after closure). Therefore, SKB has decided that all failed rods shall be dried before encapsulation for final disposal.

Transport from NPP

The failed fuel is transported from the reactor pool to Studsvik's Hot Cell Laboratory (HCL) in mid Sweden. Studsvik arrange the transports using either its NCS-45 cask with BWR bundle dimensions or its 29 ton cask with PWR bundle dimensions. The preferred option is to transport whole fuel cartridges with failed rods but for difficult cases whole bundle skeletons with failed rods stuck in the skeletons are transported. It is also possible to transport failed single rods using a suitable inner basket for the transport cask. In cases when the transport cask certificate does not cover the actual content to be transported, special arrangement for those transports must be applied for to the Swedish Radiation Safety Authority, SSM. The transports are normally by truck on road but for transports under special arrangement an INF 3 vessel is used directly from the NPP harbour to the Studsvik harbour. The sea transport is a compensatory measure in the special arrangement.

Cutting and drying

After unloading of the failed rods in hot cell, Figure72, the end plugs are cut off and the rods are cut into approximately 1 m segments. The 1 m segments then have open ends on both sides which is beneficial to ensure a proper vacuum drying and no enclosed water. After cutting, the rod segments are placed in a capsule for vacuum drying. The vacuum drying of one capsule typically requires 24 – 48 hours.

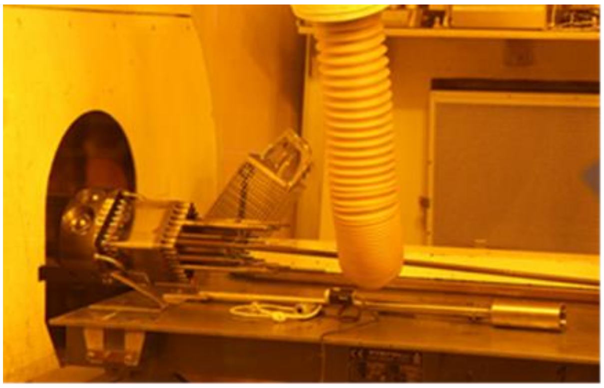

Figure 72: Unloading of failed fuel into hot cell

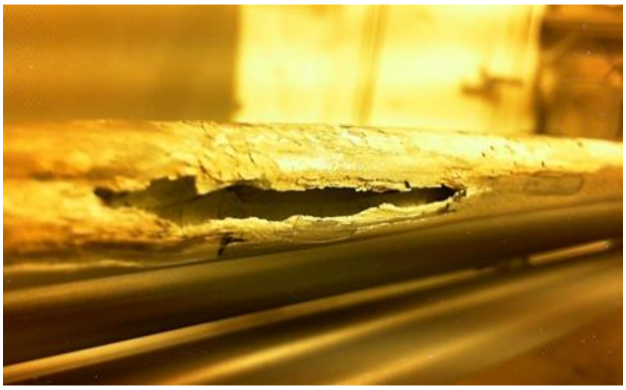

Figure 73: Failed fuel rod

To verify that the capsules are dry, Studsvik performs a pressure rebound test (PRT) according to Standard Guide for Drying Behavior of Spent Nuclear Fuel, ASTM C1553 (2012). At this test the system is closed after vacuum drying and the pressure is monitored for 30 minutes. If the pressure is lower than 4 mbar after 30 minutes the rod segments are considered to be dry.

Encapsulation and final storage

After vacuum drying the inner canister with failed rod segments is placed in a stainless steel primary canister. A lid with a center hole is welded. A final vacuum pumping and PRT is performed and finally the primary canister is filled with He and tight welded. The primary canister is approved by SKB, according to Swedish regulations, for final storage of fuel residuals in KBS-3. The stainless steel primary canister and welding of lid is shown in Figures 74 and 75.

Figure 74: Stainless steel primary canister

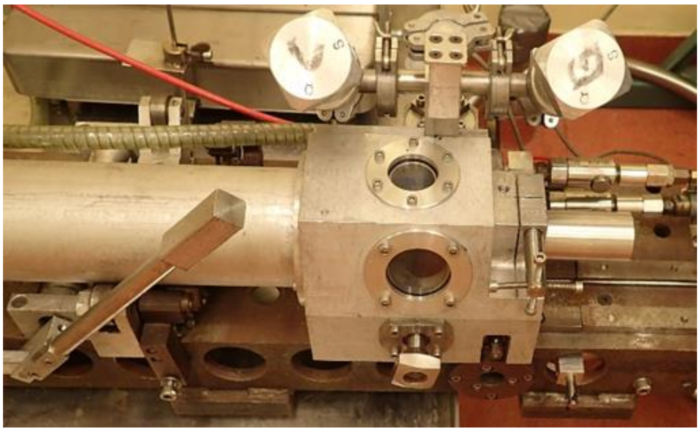

Figure 75: Hot cell welding equipment

After encapsulation 12 primary canisters are assembled in a transport box to the size of one PWR assembly. Alternatively, 3 primary canisters with wider dimensions are assembled to the size of one BWR bundle. Up to 100 failed rods can be packed in one PWR transport box and up to 40 failed rods in one BWR transport box.

The transport box with failed fuel are then transported to CLAB in Oskarshamn. CLAB is the intermediate storage for spent nuclear fuel in Sweden, operated by SKB. Transport boxes with encapsulated fuel residuals has regularly been sent from Studsvik to CLAB the past 30 years and recently also shipments of transport boxes with encapsulated failed fuel have started. Finally, all spent nuclear fuel in Sweden, including fuel residuals and failed fuel will be sent to the KBS-3 final storage.

References

ASTM C15533. (2012). Standard Guide for Drying Behavior of Spent Nuclear Fuel.

Birgersson, L. (2016). The barriers in the KBS-3 repository in Forsmark, SKB Public Report 1520261, 18 Jan.