Cold Trap Dismantling and Sodium Removal at a Fast Breeder Reactor - 12327

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Abstract

The first German prototype Fast Breeder Nuclear Reactor (KNK) is currently being dismantled after being the only operating Fast Breeder-type reactor in Germany. As this reactor type used sodium as a coolant in its primary and secondary circuit, seven cold traps containing various amounts of partially activated sodium needed to be disposed of as part of the dismantling.

The resulting combined difficulties of radioactive contamination and high chemical reactivity were handled by treating the cold traps differently depending on their size and the amount of sodium contained inside. Six small cold traps were processed on-site by cutting them up into small parts using a band saw under a protective atmosphere. The sodium was then converted to sodium hydroxide by using water.

The remaining large cold trap could not be handled in the same way due to its dimensions (2.9 m x 1.1 m) and the declared amount of sodium inside (1,700 kg). It was therefore manually dismantled inside a large box filled with a protective atmosphere, while the resulting pieces were packaged for later burning in a special facility.

The experiences gained by KNK during this process may be advantageous for future dismantling projects in similar sodium-cooled reactors worldwide.

Introduction

The Compact Sodium-cooled Reactor Facility KNK was an experimental nuclear power station with 20 MW of electrical power output. Initially, between 1971 and 1974, the plant was operated with a thermal core and referred to as KNKI. Between 1977 and 1991, it was run with a fast core as KNKII.

The reactor is currently being completely decommissioned down to green field conditions in ten permission steps according to the German Atomic Law. The current permission step nine includes dismantling the thermal isolation, removal and cutting of the primary shielding and dismantling the activated parts of the biological shield.

Besides the decommissioning of the reactor, KNK faced the challenge of having to dispose of seven cold traps which were used to clean the primary and secondary circuit and to remove the sodium oxide as well as the sodium hydroxide. During operation, KNK had two primary cold traps, one secondary cold trap and one starting cold trap. As soon as one cold trap lost its cleaning effect, it was exchanged immediately. In total KNK had after shut-down in 1991 five primary and two secondary cold traps.

After dismantling the cold traps at the KNK site, the original plan was to store the cold traps -packed in specially designed containers- directly without further treatment in a repository. For this purpose they were delivered to our waste management department (HDB). Due to the high chemical reactivity of the sodium, this was however not possible. Therefore it became necessary to dismantle the cold traps and to neutralize the sodium in order to be able to dispose of the non-reactive material as radioactive waste.

Design of the cold traps

The five primary cold traps and one of the two secondary cold traps had only a sodium mass of 125 kg each. But since they were used for cleaning the primary cooling circuit, they were contaminated with Cs-137 and H-3. Due to the Cs-137 contamination, the cold traps had a dose rate up to 30 mSv/h. The secondary cold traps had only H-3 contamination. But since one of the secondary cold traps was used for the start-up process it was larger than the other secondary cold trap. It had a total sodium mass of about 1,700 kg and a diameter of 1.08 m. Table 1 shows an overview of the technical data of the cold traps. Cold traps number 5 and 6 are the secondary cold traps.

No.	**Dose rate [µSv/h] in 2003**	**Cs- 137 activity [Bq] In 2005**	**Total Beta activity [Bq]**	**Total mass cold trap [kg]**	**Sodium Mass [kg]**	**Length incl. studs [cm]**	**Dia-meter incl. cooling fins [cm]**
1	30 - 2.100	4,4 E 09	1,58 E 13	330	125	210	42
2	7 - 2.000	7,0 E 08	1,58 E 13	450	125	210	42
3	40 – 250	2,6 E 07	1,58 E 13	450	125	210	42
4	30 - 1.800	2,6 E 07	1,58 E 13	450	125	210	42
5*	< 1	-	7,5 E 11	3,200	1,700	328	108
6*	< 1	-	5,0 E 08	450	125	210	42
7	60 - 30.000	5,6 E 09	1,58 E 13	450	125	210	42

* Secondary cold traps

Table 1: Technical data of the five primary and the two secondary cold traps

Treatment of the small cold traps

The small cold traps -the five primary cold traps as well as one secondary cold trap- could be treated on-site at KNK. During the decommissioning of the KNK reactor, a specially designed space for cutting and dismantling sodium contaminated components was installed. Since it is not permitted to dispose of sodium-contaminated radioactive waste, all sodium-contaminated parts had to be cleaned before delivery to HDB.

After delivering the cold trap to the KNK site, the cold trap was removed from its shielding and transportation container. After checking the integrity of the cold trap, it was transferred to the dismantling facility and put under an inert atmosphere.

At the dismantling facility, the cold trap was put on the table of a log band saw and cut into slices. Each slice must contain no more than 10 kg of sodium each for safety reasons. To ensure this amount, each small cold trap is cut into 16 slices. If necessary, mobile shielding was installed. The cutting was done automatically and supervised using cameras. The surface of the slices was protected against any reactions by covering it with paraffin oil.

The slices were put manually or semi remote-controlled into specially designed washing baskets. These washing baskets were put into 200 l drums completely filled with nitrogen.

The washing baskets were stored in buffer storage until further treatment. The buffer storage is kept under nitrogen atmosphere to avoid the contact of air with sodium and a possible resulting reaction.

The loading and unloading of the washing baskets into and out of the buffer storage was done by using special shielding equipment. Therefore the shielding equipment was put on top of the 200 l drum. The washing basket was removed from the 200 l drum and pulled into the shielding equipment. After moving the shielding equipment on top of the buffer storage, the washing basked was pulled out of the shielding equipment into the buffer storage. The unloading of the washing baskets out of buffer storage and the transport to the washing facility was done in the same way.

Fig. 1: Cutting of the cold trap into slices

After cutting the cold trap into slices and storing them in the buffer storage one washing basket after the other was transferred to the washing facility. In this washing facility, the sodium reacted with steam in a controlled way. Therefore the washing basked was put into the nitrogen-filled washing facility. There, the washing facility was heated up in order to melt the sodium. The sodium drips into a collecting tray under the washing basket. After that, a constant flow of steam water is let into the washing facility. Under these conditions the sodium reacts with water to sodium hydroxide solution while producing hydrogen. The resulting amount of hydrogen is measured constantly. During the washing process it must be avoided that a hydrogen level of 2 Volume-% is exceeded. When no further hydrogen production is detected the reaction between sodium and steam water is finished. To avoid any hidden sodium particles, the sodium basket is filled with water. 40 l of sodium hydroxide solution result from the washing of each cold trap slice containing 10 kg of sodium each.

The resulting sodium hydroxide solution is collected inside a special tank and transported to HDB. At HDB the sodium hydroxide solution is neutralized by using hydrochloride acid and evaporated. The now sodium-free metallic components are put into a steel drum for later super-compaction at the HDB site.

The cutting of each small trap takes about two weeks working two shifts a day. Each cut slice containing maximum 10 kg of sodium is washed during one week. Therefore it was able to treat two small cold traps per year.

The large secondary cold trap

The large secondary cold trap from the KNK reactor is causing decommissioning problems in terms of the size of vessel, the amount of sodium contained within it and the storage of the material resulting from any decommissioning activity. The cold trap is 1.08m in diameter and 3.28 m long. It is made from ferritic steel and contains about 1700 kg of sodium in which a large number of pall rings are embedded.

The dose rate measured from the vessel is less than 1 µSv/hr and the specific activity was quoted with 3000 Bq/g; the only radionuclide present was tritium.

Therefore a dismantling at the KNK site was not possible. A transport of the large secondary cold trap away from KNK to another site was also not possible since the cold trap did not conform to ADR regulations. The large secondary cold trap was for a long time considered to be a disposal problem with a high risk for the KNK project cost and schedule.

After an extensive research of disposal possibilities KNK got in contact with NDSL, who have a long experience in treating sodium. The requirement was to remove all the sodium from the vessel and associated components and dispose of it safely. NDSL had already experiences in disposing the SNR300 cold trap from the Kalkar fast breeder. They own a glove box (see Fig. 2) suitable for the complete large secondary cold trap which can be filled with nitrogen and their personnel have significant experience in handling and treating alkali metals.

Since it was not possible to install the glove box and its equipment at the KNK site, the glove box was transported to our waste management department HDB near KNK. The HDB has a controlled area with enough space to install the glove box and connect it to the existing infrastructure such as ventilation, electrical power and nitrogen supply. Since the HDB has a license to treat radioactive waste but no hazardous material such as sodium it was necessary to apply for the approval at the Baden-Wuerttemberg Environmental Ministry.

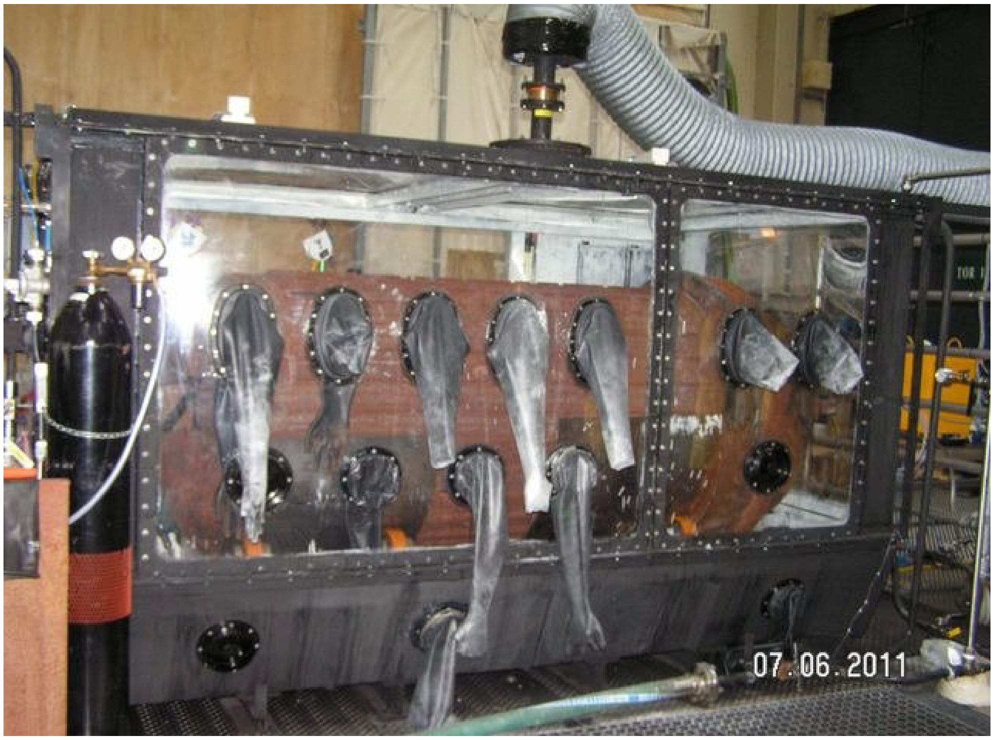

Fig. 2: Glove box with the inserted large secondary cold trap

The glove box was off-loaded using the building crane onto the transit platform and placed in its operational position. The top part of the glove box was removed to enable the cold trap to be inserted. The cold trap was lifted into the glove box. The glove box upper part was then replaced and the glove box resealed.

Piping connections were made between the glove box and the building ventilation extract system as well as the electrical system. Afterwards the system was tested to demonstrate:

- The ability to purge the glove box of oxygen and to maintain an atmosphere of at least 95% nitrogen.
- The Ability to rotate the vessel on the glove box internal rollers to allow access to all parts of the vessel.
- Operation of sufficient power and lighting within the glove box to allow for safe and

accurate use of power tools.

- Correct operation of the gaseous extract system through the filter to the building system.
  - Monitoring of the glove box atmosphere.
  - Operation of the posting port.
  - Demonstration of contingency actions to be undertaken in the event of:
  - Power failure.
  - Ventilation extracts failure.
  - Safe shut-down due to external events such as building fire.

Operations commenced with the grinding off of sufficient sections of the cold trap vessel steel to provide access to the sodium (see Fig. 3). This was done using an electrically powered grinder fitted with slitting discs. At this stage samples of the sodium were removed for analysis of tritium levels on site at Karlsruhe.

Fig. 3: Opened secondary cold trap given view to the sodium

The sodium, with its embedded Pall rings, was then dug out from the vessel using vibrating chisels; the sodium was removed in pieces of between 0.5 and 1 kg and placed in either polyethylene bags or drums for posting out of the glove box.

The sodium for incineration is then placed in polyethylene kegs inside UN Class 1 drums for transport to the incinerator. Before this the sodium was put in polyethylene bags which were filled with nitrogen and sealed. The kegs and the drums were also filled with nitrogen. The amount of sodium in the kegs (10kg), and the packaging medium (nitrogen) was dependent upon the requirements of the incinerator operator.

Once all of the sodium had been removed, the steel size was reduced by using grinders. The steel was packed into UN class 1 drum under nitrogen atmosphere for further incinerating.

After dismantling the whole cold trap and packing into drums the inner surface of the glove box was cleaned with water spray. Aqueous caustic liquid collected in the bottom of the glove box was collected using tissues. Afterwards, air was let into the glove box so that the workers could enter.

Experiences in dismantling the large secondary cold trap

As already mentioned the disposal of the KNK large secondary cold trap was considered as a difficult challenge for a long time. After its removal from the KNK in 1998 it was debated for a long time how and where to dismantle it. A dismantling at the KNK site was not possible since the log band saw was not big enough to cut a diameter of 1.08 m and there was not enough capacity at the buffer storage. To establish a new log band saw and to increase storage capacity would have prolonged the decommissioning project time for several years. The washing of the estimated 1,700 kg sodium by itself would have taken 170 weeks.

With the decision to bring a glove box to our site, which was perfectly suited for putting the whole cold trap inside, the dismantling the large secondary cold trap took only about 8 weeks. The glove box with its connection to the existing infrastructure and the possibility to ensure a stable nitrogen atmosphere inside the box was ideal to dismantle the cold trap securely. An additional advantage was that NDSL provided skilled personnel with high experience in sodium treatment. But on the other hand, dismantling the cold trap manually inside a glove box is very hard and exhausting.

During dismantling the secondary cold trap two surprises happened. First the estimated amount of 1,700 kg was too high. Inside the cold trap was only 890 kg sodium. The difference between declared and real amount sodium is likely due to the fact that it was removed while emptying the secondary circuit. The second surprise was that we estimated the H-3-activity with 3,000 Bq/g before starting the dismantling. The H-3 estimation was based on the operation duration at the KNK, the H-3 results of the small secondary cold trap, decay of H-3 and diffusion. During dismantling the large secondary cold trap several sample were taken out of the sodium and were analyzed. A homogenous H-3 amount of 1.9 E 05 Bq/g was analyzed throughout the whole sodium. Therefore the real H-3 activity was about 60 times higher than the estimated amount. This result shows that the H-3 was not able to diffuse out of the cold trap but instead bonded to the sodium.

But neither the lower amount of sodium nor the higher H-3 activity had an negative effect on the work or the further incineration of the sodium and the sodium contaminated steel.

Conclusions

The dismantling of a prototype fast breeder reactor provides the challenge not only to dismantle radioactive materials but also to handle sodium-contaminated or sodium-containing components. The treatment of sodium requires additional equipment and installations to ensure a safe handling. Since it is not permitted to bring sodium into a repository, all sodium has to be neutralized either through a controlled reaction with water or by incinerating. The resulting components can be disposed of as normal radioactive waste with no further conditions. The handling of sodium needs skilled and experienced workers to minimize the inherent risks. And the example of the disposal of the large KNK cold trap shows the interaction with others and also foreign decommissioning projects can provide solutions with were unknown before.