Implementation of the Swedish concept of deep geological disposal

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The nuclear power industry was given the responsibility for management and disposal of all radioactive waste from its plants back in the 1970s. The owners of the nuclear power plants therefore jointly formed SKB, the Swedish Nuclear Fuel and Waste Management Company. A fund to finance the programme was set up a few years later. SKB was given the task of organizing the work of disposing of the waste. Over the past three decades we have built up a system for disposing of different types of radioactive waste in a safe manner.

The system in operation

SKB has now developed a system that ensures the safe handling of all kinds of radioactive waste from Swedish nuclear power plants for a long time to come. The cornerstones of the system that is now in operation are:

- A transport system with M/S Sigyn, a specially-built ship for shipping the waste, which has been in operation since 1982.
- A central interim storage facility for spent nuclear fuel (Clab) in Oskarshamn, which has been in operation since 1985.
- A final repository for short-lived, low and intermediate level waste (SFR) in Forsmark, which has been in operation since 1988.

Since the start-up this system has fulfilled its task in a safe and satisfactory manner.

Research, development and demonstration

Some important components are however lacking in order for the system to be complete. Most important are the facilities required for final disposal of the spent nuclear fuel. The Swedish method for disposing of spent nuclear fuel is called KBS-3. Since the 1970's we have been working with the development of the method which has become increasingly refined. It is based on the use of multiple protective barriers to isolate the fuel. The KBS-3-method entails encapsulating the spent nuclear fuel in copper canisters, which are embedded in bentonite clay at a depth of about 500 metres in the Swedish crystalline bedrock.

Much of the research and development for encapsulation and final disposal of spent nuclear fuel needs to be done on a full scale and in a realistic setting. SKB has therefore built a number of laboratories to carry out different research and development projects. Four R&D facilities should be mentioned:

- The Stripa mine, about 250 km west of Stockholm, was leased by SKB in 1976 when the ore reserves were exhausted. SKB started ***in situ*** experiments there to provide technical data for evaluating the suitability of granite for disposal. In the same year, the Swedish-American Cooperative (SAC) programme was established between SKB and the US Department of Energy for the time period 1977 to 1980. The International Stripa Project, which started in 1980 and ended in 1992, was conducted under the auspices of the Nuclear Energy Agency

(NEA) with the objectives to investigate several aspects of technology concerned with the feasibility and safety of disposal of long-lived, heat-generating radioactive waste at depth in granitic rocks.

- The Äspö Hard Rock Laboratory, which was built during the period 1990–1995, is situated on Äspö north of the Oskarshamn NPP. The purpose of the HRL is to enable research, development and demonstration to be done in a realistic and undisturbed rock environment down to repository depth. The underground laboratory consists of a tunnel, with the total length of 3,600 metres. Along this ramp we are conducting research and technology development on a full scale and in a realistic setting. Both technology-oriented experiments and scientific research are being pursued in the Äspö HRL in cooperation between both Swedish and international experts. The laboratory will serve as an important training facility during the construction of the final repository for spent fuel.
- The Canister Laboratory, situated in the Oskarshamn harbour area, was built during the period 1996–1998 to support the development of sealing technology for the copper canisters. It is used mainly for the development of equipment for welding of copper lids and bottoms and for nondestructive testing of the welds. Equipment and systems for handling of fuel and canisters in the future encapsulation plant are also tested and developed in the Canister Laboratory. Another purpose of the activities is to train personnel for commissioning of the encapsulation plant.
- The Bentonite Laboratory was built close to the underground Äspö HRL during 2006. SKB will investigate how the buffer material will behave in the final repository. The new laboratory enables full-scale experiments under controlled conditions. The bentonite laboratory makes it possible to vary the experiment conditions in a manner which is not possible down in the rock.

Facilities to be built

The development of the KBS-3-method has been carried out in parallel with the work to find a suitable site for the final repository. SKB reported the feasibility studies in 2000 together with a proposal of further site investigations on some sites. The Government gave the go-ahead for further investigations in 2001 and in 2002 we started site investigations in the municipalities Oskarshamn and Östhammar after confirmatory decisions by the municipality councils. The site investigations have now been going on for five years and drilling has just been concluded. An intensive period will now follow when all results are analyzed and evaluated, and eventually compiled into the permit application for the site that will be chosen. In addition to the final repository we also have to develop a canister factory and build an encapsulation plant for encapsulation of the spent fuel.

SKB plans to file the permit application for the final repository within a few years. It will be scrutinized by the regulatory authorities and reviewing bodies. Provided that a permit then will be issued the building could start around 2012, and the first canister may be disposed in 2020.

Meanwhile we already in November 2006 applied for a permit to build the encapsulation plant adjacent to the present-day Clab interim storage facility in Oskarshamn. The new facility will employ unique technology, including a friction stir welder for attaching the lids to the copper

canisters in which the spent nuclear fuel will be placed. According to plans, the construction of this facility will also start in 2012.

SKB performs safety assessments regularly. There we study what long-term effects the system for spent nuclear fuel, with a repository as the centre, will have on man and the environment. The analysis helps us to prioritize the development efforts by showing us where there is need for further efforts.

When we apply for permits to build the final repository, the safety assessment is an important supporting document. Our most recent safety assessment, called SR Can, was published in connection with the permit application for the encapsulation plant. This safety analysis is now under a broad national and international review, and all aspects that come up in this process will be taken care of in the next safety assessment, in connection with our coming permit application for the final repository.

Supports for a development process

The Swedish programme has evolved over the past 30 years in consensus between the nuclear power utilities and political interests. I want to especially mention three important principles behind this national mobilization.

- The first is a regulated step-wise implementation process. Since the middle of the 1980s, SKB has submitted an RD&D Programme every three years for the Government's approval. Before the Government makes a decision, the Programme is circulated and scrutinised in a broad review, which involves government authorities, research institutions and environmental organisations. This process allows recurrent reviews of the implementation work, and it gives all interested parties the possibility to examine our work and to express their opinions about it. The picture shows SKB's Program reports from the first report in 1984 to the last report which was issued a two weeks ago, 28 September 2007.
- A second important principle is a clear division of roles. The nuclear power utilities – the producers – are responsible for management of the waste. This responsibility is determined by law, and its implementation is in fact required to get and keep the licence to run the power plant. SKB is owned by the nuclear power companies and has been given the responsibility to take charge of waste management and find a method and site for final disposal. The regulators review SKB's programme and work to make sure it meets the requirements on safety and radiation protection.
- The third important principle is that of an organized local consultation. This is a legal obligation in the siting process according to the Environmental Code, but SKB started a broad consultation process already in the early 1990's. One very important contribution to the consultation process has been that the concerned local municipalities set up formal review teams with the explicit task of scrutinising and assessing SKB's proposals. The municipal review teams were given the mandate to question SKB's work and to request supplementary studies and investigations.

We feel that the long period with a dialogue with the local residents generally has lead to trust in our work. SKB has occasionally commissioned opinion polls on people's attitudes towards a deep repository. One of the clearest tendencies is that people with the most knowledge about

SKB and the deep disposal method are the ones who are the most positive. This is particulary clear in the municipalities where we perform investigations and where the issue has been discussed for a long time. Four out of five of the people in Oskarshamn and Östhammar are in favour of building a deep repository if a suitable site will be found in their municipality. This is a confidence in our project that must be maintained.

From thought to action

The Swedish nuclear fuel disposal programme is now close to take the first decisive step from theory to practice. For a long time now we have been devoting most of our resources to the development of this crucial component in the waste management system. We have built four laboratories to test and demonstrate our method on a full scale. At the same time we have worked intensively to find the site for the repository, one with suitable bedrock and a local population that accepts the repository.

We will now reach the end of this stage. Step by step, we are proceeding from thought to action, and we now have to take up a major challenge. After decades with extensive work on research, development and demonstration, we now will have to work out and design all the site specific facilities and systems. In the permit applications we must specify the technical solutions we intend to apply and show that they will work in the mining environment that a repository represents.