# Deep repository

## for spent nuclear fuel

SKB

# The Facility

*No method exists today for rendering spent nuclear fuel harmless. But radiotoxicity does decline with time. In order to minimize the risk of someone being injured – today or in the future – we must focus on making sure that no one comes into contact with it. A deep repository is a safe way to do this.*

Operation of a nuclear power plant gives rise to different types of waste, referred to collectively as nuclear waste. This waste is divided into different classes depending on how radioactive it is.

Low-level waste (LLW), for example, consists of trash, scrap and used protective clothing. It has a very low radiation level. Its radioactivity declines to harmless levels after a few hundred years.

Intermediate-level waste (ILW) consists primarily of the filter resins that are used to remove radioactive particles from the reactor water. It has a higher radiation level than the LLW and must therefore be surrounded by a radiation shield of concrete or steel.

High-level waste (HLW) consists primarily of spent nuclear fuel, which must be both cooled and radiation-shielded. Certain internal parts of the reactor, such as the control rods, are also high-level, but do not require cooling.

### Well-engineered system

Sweden has a well-functioning organization for managing various types of radioactive waste. There is an interim storage facility for spent nuclear fuel, a final repository for LILW, and a specially-built vessel with transport casks and containers for shipping the radioactive waste between the nuclear installations. The Swedish Nuclear Fuel and Waste Management Co (SKB) has been given the task of managing and disposing of the waste in a safe manner.

But two important components are lacking to make the waste system complete: an encapsulation plant for encapsulating the spent nuclear fuel in copper, and a deep repository to deposit the canisters in. SKB has also been assigned the task of building these facilities.

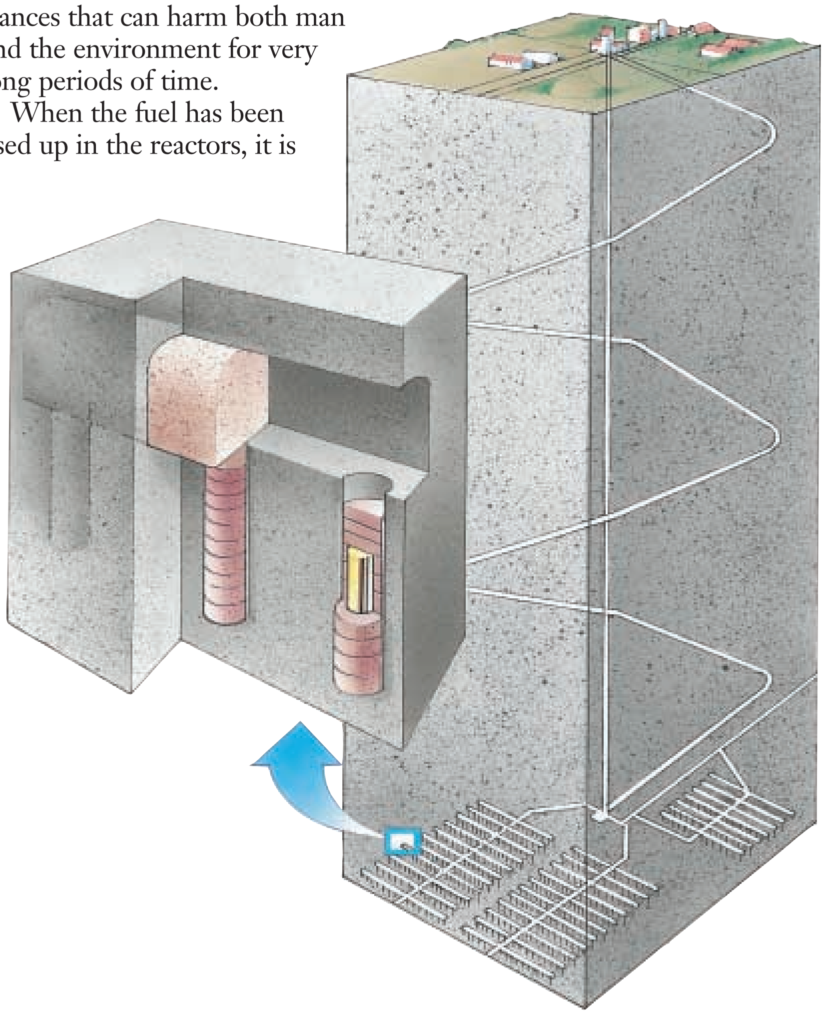
We have been pondering what the deep repository should look like, as well as which materials and technology should be used, for nearly 30 years. Our method involves encapsulating the fuel in copper and embedding it in bentonite clay at a depth of about 500 metres in the rock.

### Radioactive for a long time

There is every reason to have respect for the spent nuclear fuel. It will contain radioactive substances that can harm both man and the environment for very long periods of time.

When the fuel has been used up in the reactors, it is

The deposition holes are eight metres deep and just under two metres in diameter.



The spent nuclear fuel will be encapsulated in copper. The copper canisters will then be deposited in the bedrock, embedded in clay, at a depth of 500 metres.

Each deposition hole is lined with blocks and rings of bentonite. Here a block is lifted into place.

stored for around one year in on-site pools at the nuclear power plants. During this time its radioactivity declines by about 90 percent.

The fuel is then taken to the central interim storage facility for spent nuclear fuel (CLAB) located in the vicinity of the Oskarshamn Nuclear Power Plant. There the fuel will be stored for about 30 years before being encapsulated and deposited in a deep repository. About one percent of the radioactivity remains at deposition compared with when the fuel has just been taken out of the reactor.

The radioactivity continues to decline even after the fuel has been deposited. After around 100,000 years it is down to the same level as in the enriched uranium from which the fuel was made.

### Two parts

The deep repository consists of two parts: a surface facility and an underground facility. The surface facility is a medium-sized industrial complex. Besides offices and personnel quarters there is also a factory for fabricating the bentonite blocks that will be used to line the deposition holes and a receiving section for transport casks with copper canisters.

A long access tunnel runs from the surface facility down to a system of deposition tunnels at a depth of approximately 500 metres. Each deposition tunnel contains a number of vertical holes in which the copper canisters with the spent nuclear fuel will be emplaced.

### Shields and protects

The canisters with the spent nuclear fuel are brought to the deep repository in transport casks, which also act as radiation shields. They also protect the canisters in the event of an accident. The transport casks are driven underground by electric trucks.

There the canisters are transferred to a deposition machine. The machine, which is remote-controlled and radiation-shielded, drives up to the hole where the canister is to be deposited and lowers it into the hole. The deposition hole has first been lined with rings of bentonite clay.

When all the holes in a deposition tunnel are full, the tunnel is backfilled with a mixture of bentonite clay and crushed rock. The main access tunnel is also backfilled when all fuel has been deposited.

**THE DEEP REPOSITORY**

**Number of canisters**
4 500
200 – 400 during initial operation

**Deposition**
200 canisters per year

**Jobs**
400 – 600 persons during construction phase

150 persons during initial operation

220 persons during regular operation

The canisters are placed in the deposition holes with the aid of a specially-built machine.

# The Design

*The more we know about the rock, the better we can design the deep repository for spent nuclear fuel. At the same time, we want to keep our options open as long as possible so we can incorporate the latest technical and scientific advances.*

The deep repository is based on the KBS-3 method, where KBS stands for Nuclear Fuel Safety (in Swedish). A KBS-3 type deep repository can take several different forms. In our main alternative, the copper canisters with the spent nuclear fuel are emplaced in vertically bored deposition holes at a depth of about 500 metres. We call this alternative KBS-3V, where the letter "V" stands for vertical.

### Step by step

SKB wants to proceed in steps when building the deep repository. The repository will be built in two stages. Between 200 and 400 canisters (of a total of about 4500) will be deposited in the initial phase. According to the plan, canister deposition will begin in about 15 years. The experience gained will be evaluated before we proceed to phase two. Only if the results of this evaluation are positive will we proceed to phase two.

SKB is currently conducting site investigations, which include thorough investigations of the bedrock from the ground surface, in the municipalities of Östhammar and Oskarshamn. We will then build the deep repository on the most suitable of these sites.

During construction of the underground portion of the deep repository, we will carry out supplementary investigations of the bedrock from repository level. This so-called detailed characterization will provide a basis for locating the deep repository's

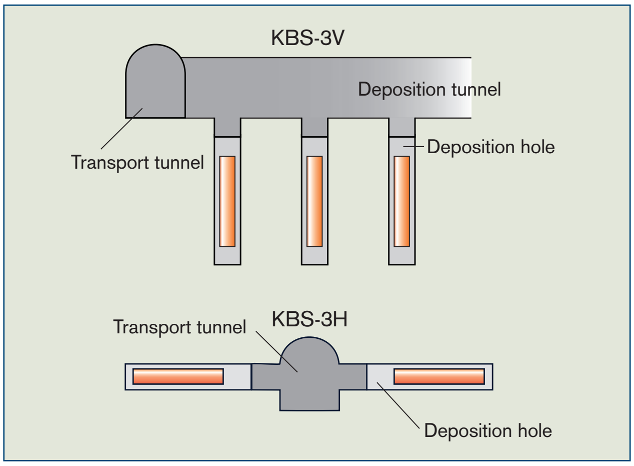
Site investigations, i.e. thorough investigations of the bedrock from the ground surface, are being conducted in the municipalities of Östhammar and Oskarshamn.

central area and the tunnels that will be used during initial operation. Further investigations will then gradually enable us to determine the final locations of tunnels and deposition holes.

When the site investigations are concluded and applications for permits to site and build the deep repository are submitted to the authorities, we must make a number of choices: Should the descent to the deep repository's underground facility take the form of a ramp or a shaft? Should the repository be built in one or two levels? At precisely what depth should the canisters be deposited? How should the deep repository's barriers be designed?

There are also questions connected to operation in the repository: Should the machines used in the repository be electric- or diesel-powered? What form should the radiation protection take? How should transport up from and down to the repository take place?

If the canisters are deposited horizontally, deposition tunnels are not needed and the quantity of extracted rock can be halved.




### Different design premises

SKB has compiled all the data needed to engineer, design and build the repository. A number of overall design premises have crystallized from these data. These requirements and conditions determine the design of the deep repository and its parts.

The design premises may be determined by e.g. legal requirements, environmental requirements or the changes the deep repository will undergo after closure.

The design premises are fairly general at the present time. As work on the deep repository progresses, they will become increasingly detailed.

The rock must be thoroughly investigated prior to construction.

### Vertical or horizontal

We also have a more fundamental question to decide on regarding the configuration of the repository. Should the canisters be deposited vertically or horizontally?

Today it is possible to drill much longer and straighter holes than ten years ago. This makes it possible to deposit the canisters horizontally in long deposition holes with the same or greater safety.

The quantity of rock that needs to be excavated is thereby reduced. We can reduce the impact on the environment, since less crushed rock has to be hauled up from and down in the tunnel. We may even be able to reduce the costs. This version of the KBS-3 method is called KBS-3H, where the letter "H" stands for horizontal.

### Freedom means flexibility

We want to retain as much freedom of choice as possible for as long as possible, since this enables us to incorporate the latest technical and scientific advances.

Naturally, the safety requirements must always be met. This is true both during construction and operation and in the post-closure period. Safety during construction and operation is subject to the provisions of the radiation protection, nuclear activities and occupational safety laws. We examine long-term post-closure safety regularly in our safety assessments.

# Safety

The deep repository should not affect man or the environment.

*SKB's method for disposing of spent nuclear fuel is based on the use of multiple barriers to prevent radionuclides from reaching the ground surface. If one barrier should fail, the others take over so that safety is not jeopardized.*

Unlike many other kinds of waste, radioactive waste is only hazardous for a limited time. The radionuclides decay and are gradually transformed into stable substances that are no longer radioactive. This decay takes place spontaneously and is independent of conditions in the environment.

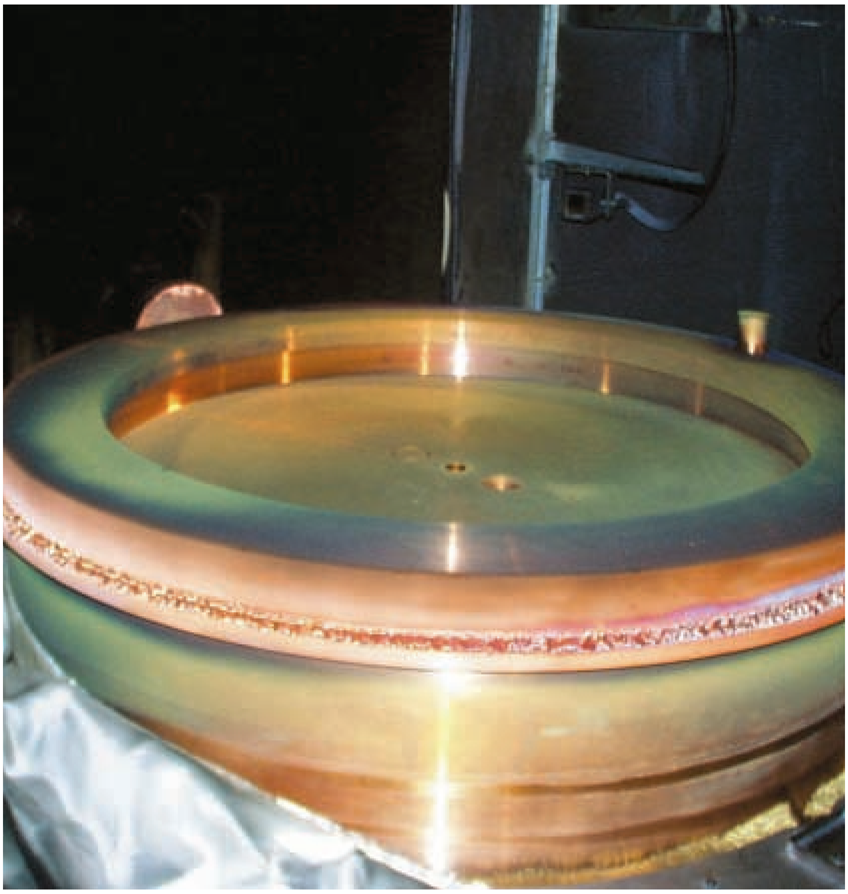
Eight tonnes of enriched natural uranium are needed to fabricate one tonne of fuel. The spent fuel consists mainly of uranium dioxide. After 100,000 years, the radiotoxicity of the fuel is the same as that of an equivalent amount of enriched uranium. That's why 100,000 years is a guideline we set for how long the repository should function.

## Natural materials

The most important thing in such a time perspective is to make sure the fuel does not dissolve so that radionuclides enter the environment and the human body. The radiation from the encapsulated fuel is not a problem on the surface. A few metres of rock is enough to stop it.

SKB has chosen to build the repository with materials that occur naturally in the earth's crust. The idea is that the repository should imitate nature as closely as possible. In this way we avoid undesirable effects from man-made materials.

Furthermore, the repository is built according to the multiple barrier principle. The canister, the bentonite clay and the rock together guarantee safety. If one barrier should fail, the others take over.



As long as the canister is intact, no radionuclides can escape into the environment.

## Canister isolates

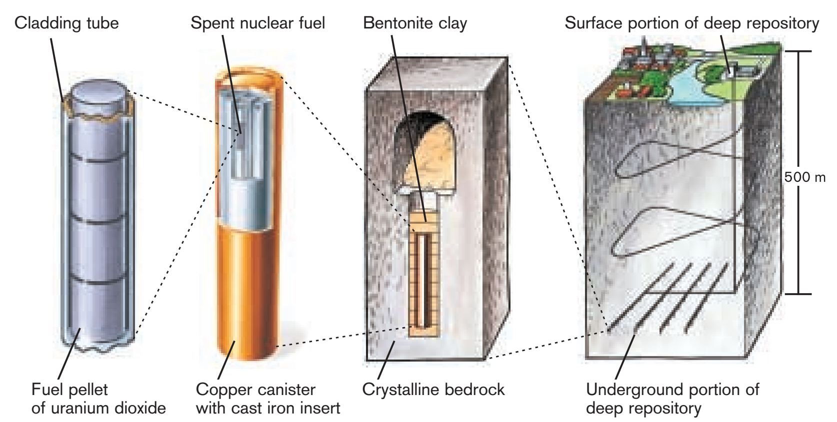
The first barrier is the copper canister. Its function is to isolate the fuel from the environment. As long as the canister is intact, no radionuclides can escape. The biggest threats to the canister down in the repository are corrosion (caused mainly by oxygen and sulphur compounds dissolved in the groundwater) and rock movements, which could break the canister apart.

Copper is a material that resists aggressive substances in the groundwater very well. A cast iron insert enables the canister to withstand great mechanical loads.

## Buffer seals

The canister is surrounded by a layer of bentonite clay called a buffer, since it protects the canister against small movements in the rock and keeps it in place. The buffer has two additional functions. The bentonite absorbs water while swelling, which makes it extremely difficult for the groundwater to penetrate the clay layer and reach the canister.

At the same time, the bentonite acts as a filter. The radionuclides adhere to the surface of the clay particles. In the unlikely event that a canister should fail, by far most of the radionuclides will remain in the canister. Most of those that do escape will be trapped in the bentonite. In this way, transport of radionuclides up to the surface is greatly retarded, allowing the radioactivity to decay further.




Multiple barriers prevent the radionuclides from reaching the ground surface.

## Rock protects

The rock also delays the transport of the radionuclides. But its primary purpose is to protect the canister and the buffer from mechanical damage and to offer a stable chemical environment. For the canister, it is important that the groundwater is free of dissolved oxygen. A low water flow rate in the rock is an advantage for all barriers.

*Our way of life gives rise to hazardous waste. Some of it is radioactive.*

*We in Sweden bear a common responsibility for our country's radioactive waste. It must not be passed on to future generations, but rather be managed and disposed of today.*

*The Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering AB, SKB) has been assigned this task.*

*We have developed a system for disposing of the waste safely and permanently.*

*This brochure deals with how we should design the deep repository for spent nuclear fuel to best protect man and the environment, in both the short and long term.*

SKB

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