Ansökan enligt kärntekniklagen

- **Toppdokument**
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      Redovisning av säkerhet efter förslutning av slutförvaret
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      - **Spent fuel report**
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      - **Buffer production report**
      - **Backfill production report**
      - **Closure production report**
      - **Underground opening construction report**
        - Ramprogram för detaljundersökningar vid uppförande och drift
      - **FEP report**
      - **Fuel and canister process report**
      - **Buffer, backfill and closure process report**
      - **Geosphere process report**
      - **Climate and climate related issues**
      - **Model summary report**
      - **Data report**
      - **Handling of future human actions**
      - **Radionuclide transport report**
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      - **Site description of Forsmark (SDM-Site)**
  - **Bilaga AV**
    Preliminär plan för avveckling
  - **Bilaga VP**
    Verksamhet, organisation, ledning och styrning
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Technical Report

TR-10-12

Design and production of the KBS-3 repository

Svensk Kärnbränslehantering AB

December 2010

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Design and production of the KBS-3 repository

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Preface

An important part of SKB's licence application for the construction, possession and operation of the KBS-3 repository is the safety report. The safety report addresses both safety during operation of the KBS-3 repository facility (**SR-Operation**), and the long-term safety of the KBS-3 repository (**SR-Site**).

For the construction of the KBS-3 repository SKB has defined a set of production lines:

- the spent nuclear fuel,
- the canister,
- the buffer,
- the backfill,
- the closure, and
- the underground openings.

These production lines are reported in separate *Production reports*, and in addition there is a *Repository production report* presenting the common basis for the reports.

This set of reports addresses design premises, reference design, conformity of the reference design to design premises, production and the initial state, i.e. the results of the production. Thus the reports provide input to **SR-Site** concerning the characteristics of the as built KBS-3 repository and to **SR-Operation** concerning the handling of the engineered barriers and construction of underground openings.

The preparation of the set of reports has been lead and coordinated by Lena Morén with support from Roland Johansson, Karin Pers and Marie Wiborgh.

This report has been authored by Lena Morén.

Summary

The report contains the common basis for a set of *Production reports,* presenting how the KBS-3 repository is designed, produced and inspected. The set of reports is included in the safety report for the KBS-3 repository and repository facility.

The report presents the role of the Production reports within the safety report and their common purposes and objectives. An important part of the report is to present the background and sources to the principles to be applied in the design, the functions of the KBS-3 repository and the barrier functions the engineered barriers and rock. Further, the methodology to substantiate detailed design premises for the engineered barriers, underground openings and other parts of the KBS-3 repository is presented. The report also gives an overview of the KBS-3 system and its facilities and the production lines for the spent fuel, the engineered barriers and underground openings. Finally, an introduction to quality management, safety classification and their application is given.

Substantiation of design premises

Based on international treaties, national laws and regulations SKB has substantiated functions and design considerations as a specification of the KBS-3 repository, and as guidelines for the design of its engineered barriers and underground openings. The properties of the spent nuclear fuel are another important basis for the design of the KBS-3 repository.

The safety and radiation principles of most importance for the design of the KBS-3 repository are the multi barrier principle, the defence-in-depth principle and.radiation protection principles to protect both human health and the environment and both current and future generations. The time required for the radiotoxicity of the spent nuclear fuel to decay to naturally occurring levels is also important for the design.

The functions of the KBS-3 repository are maintained by its engineered barriers and the rock. The barrier functions of the engineered barriers and the functions of the underground openings, to utilise the rock as a barrier, are substantiated from the functions of the KBS-3 repository to contain the spent fuel and retard the dispersion of radioactive substances. The properties of the engineered barriers and underground openings, e.g. their geometry and strength, shall sustain the functions. The substantiation of detailed design premises for these properties is an iterative process requiring input and feedback from technical development and safety assessments.

The design premises related to the functions in the KBS-3 repository are based on the results from the assessment of the long-term safety and the identification of a number of design basis cases. To be technically feasible the different parts of the repository must fit, and work, together, and the design of one component may constitute a design premise for another. The properties of importance for the function in the KBS-3 repository shall be possible to achieve and inspect and the production methods may provide design premises. With respect to the operational safety the canister shall remain tight for all conceivable occurring loads. To minimise the radiation doses to the personnel it is desirable that the canisters are always fit for deposition and that retrieval of deposited canisters is avoided, this implies that loads occurring during handling and operation also provide premises for the design.

The KBS-3 repository

In the KBS-3 repository the spent nuclear fuel has been encapsulated in tight, corrosion resistant and load bearing canisters; the canisters have been deposited in crystalline rock at a depth of 400–700 metres; the canisters have been surrounded by a buffer which prevents the flow of water and protects them and the cavities in the rock that are required for the deposition of canisters have been backfilled and closed.

All spent nuclear fuel from the Swedish nuclear power programme shall be encapsulated, deposited and finally stored in the KBS-3 repository. After closure, the KBS-3 repository shall contain the spent nuclear fuel and isolate it from man and the environment. If the containment is breached, the

final repository shall prevent or retard the dispersion of radioactive substances so that the ionising radiation, if some of the radioactive substances finally reach the environment at the surface, does not cause harm.

A KBS-3 repository comprises the rock at the repository site, the canisters containing spent nuclear fuel, buffer, backfill and closures as well as engineered and residual materials that remain in the rock once the underground openings have been backfilled and closed.

The KBS-3 system and the production lines

The KBS-3 system refers to the nuclear facilities etc that are required to realise the final deposition of spent nuclear fuel according to the KBS-3 method. The KBS-3 system consists of a central facility for intermediate storage and encapsulation of spent nuclear fuel (Clink), a system for transportation of canisters with spent nuclear fuel and a final repository facility.

The purpose of Clink is to store the spent nuclear fuel until its decay power has decreased to levels suitable for deposition and to select assemblies for encapsulation, encapsulate them and deliver sealed canisters. The purpose of the transport system is to transport encapsulated spent fuel from Clink to the final repository facility and deliver canisters fit for deposition. The final repository facility is the facility required to construct the KBS-3 repository.

The production lines refer to all the activities and stages required to handle the spent fuel and to produce and inspect the engineered barriers and install them in the KBS-3 repository. The production also comprises the specification of the components to be delivered and the methods for manufacturing and inspection. For the underground openings the methods to successively adapt the design to the conditions at the site and to construct the different underground openings as well as their capability to result in underground openings that conform to the design premises are presented.

As mentioned there are design premises related to technical feasibility, i.e. that the different parts of the repository must fit and work together during the production of the KBS-3 repository. Some of these design premises are the result of interfaces between the spent fuel line, the production lines of the engineered barriers, the production of the plugs and the construction of the underground openings. An overview of the interfaces and the resulting design premises are given in the report.

Quality management, safety classification and their application

Within the Production reports quality refers to the degree to which the characteristics of the finished parts of the KBS-3 repository contribute towards sustaining the functions of importance for the long-term safety. Quality management refers to activities to direct and control an organisation with regard to quality. Quality control and quality assurance are parts of the quality management relevant for the Production reports. The quality control is focused on *fulfilling* the quality requirements while the quality assurance is focused on providing *confidence* that quality requirements will be fulfilled. For the production of the KBS-3 repository quality control and quality assurance imply that procedure documents to be applied when carrying out the activities that impact, and provide confidence in, the quality of the finished KBS-3 repository shall be available within the quality management system.

To adapt the different parts in the KBS-3 repository to their importance for the safety SKB intends to apply a classification system. The different parts of the KBS-3 repository are classified with respect to their importance for the functions of the KBS-3 repository to contain, prevent or retard the dispersion of radioactive substances. The safety classes are denominated *B – Barrier function* and *PB – Impact on barrier function* respectively. The extent of quality assurance measures is determined by the safety classification. This implies that more extensive quality assurance measures are required for parts with safety class B than for parts with safety class PB. SKB intends to establish quality plans for the engineered barriers, underground openings and other parts of the KBS-3 repository. The quality plans shall specify which procedures and associated resources that shall be applied by whom and when for the activities that impact the quality.

Sammanfattning

Rapporten omfattar de gemensamma utgångspunkterna för en grupp *Produktionsrapporter* som redovisar hur KBS-3-förvaret är utformat, producerat och kontrollerat. Gruppen av rapporter ingår i säkerhetsredovisningen för KBS-3-förvaret och förvarsanläggningen.

Rapporten redovisar Produktionsrapporternas roll i säkerhetsredovisningen och deras gemensamma syften och mål. En viktig del av rapporten är att redovisa bakgrund och källor till principerna som ska tillämpas vid utformningen, KBS-3-förvarets funktioner, de tekniska barriärernas och bergets barriärfunktioner. Vidare redovisas metodiken för att underbygga detaljerade konstruktionsförutsättningar för de tekniska barriärerna, bergutrymmena och andra delarna i KBS-3-förvaret. Rapporten ger också en överblick över KBS-3-systemet och dess anläggningar och produktionslinjerna för det använda kärnbränslet, de tekniska barriärerna och bergutrymmena. Slutligen, ges en introduktion till kvalitetsledning, säkerhetsklassning och deras tillämpning.

Underbyggande av konstruktionsförutsättningar

Baserat på internationella avtal, nationella lagar och föreskrifter har SKB underbyggt funktioner och designöverväganden som en specifikation av KBS-3-förvaret och som riktlinjer för utformningen av dess tekniska barriärer och bergutrymmen. Det använda kärnbränslets egenskaper är en annan viktig utgångspunkt för utformningen av KBS-3-förvaret.

De säkerhets och strålskyddsprinciper som har störst betydelse för utformningen av KBS-3-förvaret är flerbarriärsprincipen, djupförsvarsprincipen och strålskyddsprinciperna att skydda både människors hälsa och miljön och både nuvarande och kommande generationer. Tiden det tar för det använda kärnbränslets radiotoxicitet att avklinga till naturligt förekommande nivåer är också viktig för utformningen.

KBS-3-förvarets funktioner upprätthålls av dess tekniska barriärer och av berget. De tekniska barriärernas barriärfunktioner och bergutrymmenas funktioner att utnyttja berget som barriär är underbyggda av KBS-förvarets funktioner att innesluta det använda kärnbränslet och fördröja radionuklidtransport. Egenskaperna hos de tekniska barriärerna och hos bergutrymmena, t ex deras geometri och hållfasthet, ska upprätthålla funktionerna. Att underbygga detaljerade konstruktionsförutsättningar för dessa egenskaper är en iterativ process som kräver input och återkoppling från teknisk utveckling och säkerhetsanalyser.

Konstruktionsförutsättningar relaterade till funktioner i KBS-3-förvaret är baserade på resultat från analysen av den långsiktiga säkerheten och identifieringen av en uppsättning konstruktionsstyrande fall. För att vara tekniskt genomförbara måste de olika delarna av förvaret passa ihop och fungera tillsammans, och en del kan utgöra en konstruktionsförutsättning för en annan. Egenskaperna med betydelse för funktionen i KBS-3-förvaret måste vara möjliga att åstadkomma och kontrollera och produktionsmetoderna kan ge konstruktionsförutsättningar. Med hänsyn till driftsäkerhet ska kapseln förbli tät för alla tänkbara förkommande laster. För att minimera strålningsdoser till personal är det önskvärt att kapslarna alltid är tillåtna för deponering och att återtag av deponerade kapslar undviks, det medför att laster som förekommer under hantering och drift också ger konstruktionsförutsättningar.

KBS-3-förvaret

I ett KBS-3-förvar har det använda kärnbränslet kapslats in i täta, lastbärande kapslar som är motståndskraftiga mot korrosion, kapslarna har deponerats i kristallint berg på 400–700 meters djup och omgetts av en buffert som förhindrar vattenflöde och skyddar dem, och de utrymmen i berget som krävs för deponering har återfyllts och förslutits.

Allt använt kärnbränsle från det svenska kärnkraftsprogrammet ska kapslas in, deponeras och slutförvaras i KBS-3-förvaret. Efter förslutning ska KBS-3-förvaret innesluta det använda kärnbränslet och isolera det från människan och miljön. Om inneslutningen bryts ska slutförvaret förhindra och

fördröja utsläpp av radioaktiva ämnen så att den joniserande strålningen, om ämnena slutligen når miljön på markytan, inte orsakar skada.

Ett KBS-3-förvar omfattar berget på förvarsplatsen, kapslarna med använt kärnbränsle, buffert, återfyllning och förslutningar samt de konstruktioner och främmande material som finns kvar i berget då bergutrymmena återfyllts och förslutits.

KBS-3-systemet och produktionslinjerna

KBS-3-systemet avser de kärntekniska anläggningar mm som behövs för att genomföra slutförvaring av använt kärnbränsle enligt KBS-3-metoden. KBS-3-systemet består av en central anläggning för mellanlagring och inkapsling av det använda kärnbränslet (Clink), ett transportsystem för transporter av kapslar med använt kärnbränsle och en slutförvarsanläggning.

Clinks syfte är att lagra det använda kärnbränslet tills resteffekten har avklingat till nivåer lämpliga för deponering och att välja element för inkapsling, kapsla in dem och leverera förslutna kapslar. Transportsystemets syfte är att transportera inkapslat använt kärnbränsle från Clink till slutförvarsanläggningen och leverera kapslar tillåtna för deponering. Slutförvarsanläggningen är den anläggning som krävs för att bygga KBS-3-förvaret.

Produktionslinjerna avser alla aktiviteter och moment som krävs för att hantera det använda kärnbränslet och producera och kontrollera de tekniska barriärerna samt installera dem i KBS-3-förvaret. Produktionen omfattar även specifikation av komponenter som ska levereras och metoderna för tillverkning och kontroll. För bergutrymmena beskrivs metoderna att successivt anpassa utformningen till förhållandena på platsen och för att bygga de olika bergutrymmena, samt deras förmåga att åstadkomma bergutrymmen som överensstämmer med konstruktionsförutsättningarna.

Som nämnts finns konstruktionsförutsättningar relaterade till teknisk genomförbarhet, dvs att de olika delarna av förvaret måste passa ihop och fungera tillsammans under produktionen av KBS-3-förvaret. Några av dessa konstruktionsförutsättningar är resultatet av gränssnitten mellan bränslelinjen, produktionslinjerna för de tekniska barriärerna, produktionen av pluggar och utbyggnaden bergutrymmen. I rapporten ges en överblick över gränssnitten och de resulterande konstruktionsförutsättningarna.

Kvalitetsledning, säkerhetsklassning och deras tillämpning

Inom Produktionsrapporterna avser kvalitet den grad till vilken egenskaperna hos de färdigställda delarna av KBS-3-förvaret bidrar till att upprätthålla funktionerna med betydelse för den långsiktiga säkerheten. Kvalitetsledning avser aktiviteter för att leda och styra en organisation med avseende på kvalitet. Kvalitetsstyrning och kvalitetssäkring är delar av kvalitetsledningen som är relevanta för Produktionsrapporterna. Kvalitetsstyrningen är inriktad mot att *uppfylla* kvalitetskrav och kvalitetssäkringen är inriktad mot att ge *tilltro* till att kvalitetskrav uppfylls. För produktionen av KBS-3-förvaret innebär kvalitetsstyrning och kvalitetssäkring att rutiner som ska tillämpas när aktiviteterna som påverkar, och ger tilltro till, kvaliteten hos det färdigbyggda KBS-3-förvaret ska finnas i kvalitetsledningssystemet.

För att anpassa de olika delarna i KBS-3-förvaret till deras betydelse för säkerheten avser SKB tillämpa ett klassningssystem. De olika delarna i KBS-3-förvaret är klassade med hänsyn till sin betydelse för KBS-3-förvarets funktioner att innesluta, förhindra och fördröja spridningen av radioaktiva ämnen. Säkerhetsklasserna benämns *B – barriärfunktion* respektive *PB – påverkar barriärfunktion*. Omfattningen av kvalitetssäkringsåtgärderna bestäms av säkerhetsklassningen. Det innebär att mer omfattande kvalitetssäkringsåtgärder krävs för delar med säkerhetsklass B än för delar med säkerhetsklass PB. SKB avser att upprätta kvalitetsplaner för de tekniska barriärerna, bergutrymmena och andra delarna i KBS-3-förvaret. Kvalitetsplanerna ska specificera vilka rutiner och tillhörande resurser som skall användas av vem och när för aktiviteterna som påverkar kvaliteten.

Contents

1 Introduction

1.1 General basis

This report contains the common basis for a set of reports, referred to as the *Production reports*, presenting how the final repository for spent nuclear fuel is designed and constructed. It is part of the safety report for the final repository and repository facility for spent nuclear fuel.

The final repository is based on the KBS-3 method developed by SKB. The term "KBS-3 repository" refers to the final repository and the term "KBS-3 repository facility" refers to the facility within which the KBS-3 repository[1] is constructed. During the operational phases the KBS-3 repository facility will contain areas where canisters are being deposited and buffer and backfill installed as well as areas where construction of new deposition tunnels and holes are underway, it will also contain finished parts of the KBS-3 repository where deposition has been completed. When all canisters with spent fuel have been deposited, the KBS-3 repository facility will be decommissioned and the KBS-3 repository closed, see Figure 1-1.

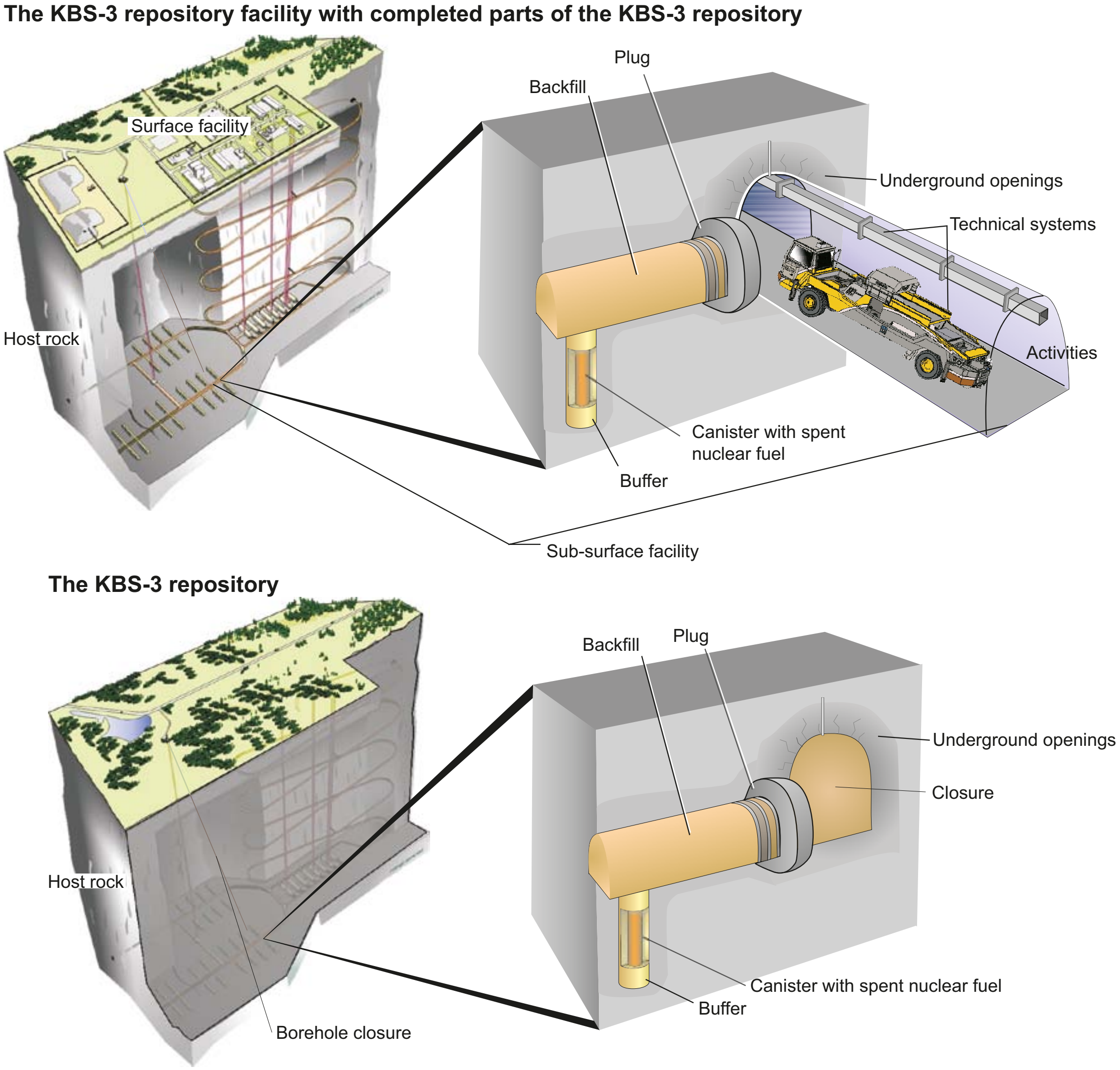


Figure 1-1. *The KBS-3 repository facility and the KBS-3 repository. The KBS-3 repository is constructed within the KBS-3 repository facility.*

[1] The terms "KBS-3 repository" and "final repository" are used synonymously as are the terms "KBS-3 repository facility" and "final repository facility".

The establishment of a KBS-3 repository requires that there is a system, the KBS-3 system, comprising the facilities, etc that are needed for the final disposal of spent nuclear fuel according to the KBS-3 method. The KBS-3 system consists of a central facility for interim storage and encapsulation of the spent nuclear fuel, a transport system for the transportation of canisters with encapsulated spent nuclear fuel and a final repository facility.

The KBS-3 repository and its engineered barriers and underground openings are produced within the KBS-3 system. SKB has defined the following production lines for the construction of the KBS-3 repository:

- the spent nuclear fuel,
- the canister,
- the buffer,
- the backfill in deposition tunnels,
- the closure,
- the underground openings.

The production lines comprise the deliveries to the KBS-3 system, and the activities to handle the spent nuclear fuel, to produce and install the engineered barriers and to design and construct the underground openings.

1.2 The role of this report within the safety report

The safety report to be submitted by SKB for approvals to construct, possess and operate the KBS-3 repository facility comprises two main parts:

- the safety of the facility during construction and operation, **SR-Operation**,
- the long-term safety of the repository, **SR-Site**.

The structure of the safety report is illustrated in Figure 1-2.

Both **SR-Site** and **SR-Operation** refer to the Production reports presenting how the KBS-3 repository is designed and constructed. The individual reports that form the set of Production reports and their short names used as references within the set of Production reports are illustrated in Figure 1-3, their full names are given in Table 1-1.

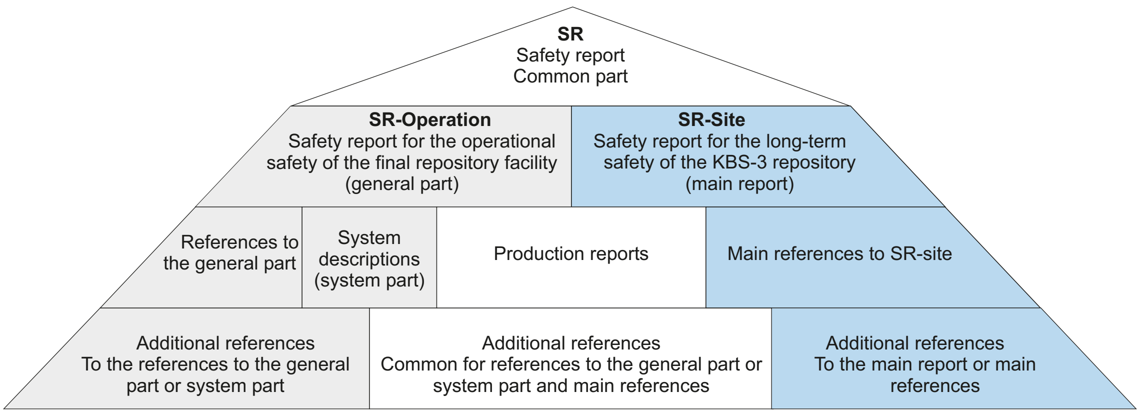


__Figure 1-2.__ The structure of the safety report. Grey parts belong to the safety report for the safety of the facility during construction and operation, blue parts belong to the safety report for the long-term safety and white parts are common for the two parts.

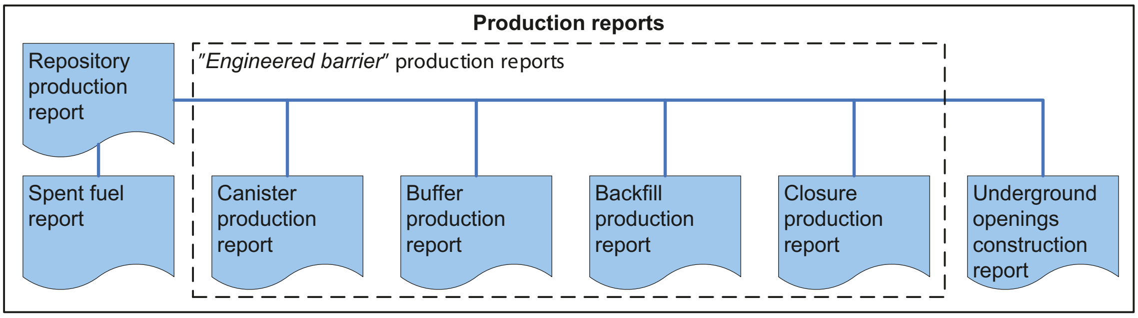


Figure 1-3. The set of Production reports and their short names. The canister, buffer backfill and closure production reports are commonly referred to as the "Engineered barrier" production reports.

Table 1-1. The set of Production reports and their full and short names.

Full title	Short name used within the Production reports	Text in reference lists
Design and production of the KBS-3 repository	Repository production report	**Repository production report, 2010.** Design and production of the KBS-3 repository. SKB TR-10-12, Svensk Kärnbränslehantering AB.
Spent nuclear fuel for disposal in the KBS-3 repository	Spent fuel report	**Spent fuel report, 2010.** Spent nuclear fuel for disposal in the KBS-3 repository. SKB TR-10-13, Svensk Kärnbränslehantering AB.
Design, production and initial state of the canister	Canister production report[1]	**Canister production report, 2010.** Design, production and initial state of the canister. SKB TR-10-14, Svensk Kärnbränslehantering AB.
Design, production and initial state of the buffer	Buffer production report[1]	**Buffer production report, 2010.** Design, production and initial state of the buffer. SKB TR-10-15, Svensk Kärnbränslehantering AB.
Design, production and initial state of the backfill and plug in deposition tunnels	Backfill production report[1]	**Backfill production report, 2010.** Design, production and initial state of the backfill and plug in deposition tunnels. SKB TR-10-16, Svensk Kärnbränslehantering AB.
Design, production and initial state of the closure	Closure production report[1]	**Closure production report, 2010.** Design, production and initial state of the closure. SKB TR-10-17, Svensk Kärnbränslehantering AB.
Design, construction and initial state of the underground openings	Underground openings construction report	**Underground openings construction report, 2010.** Design, construction and initial state of the underground openings. SKB TR-10-18, Svensk Kärnbränslehantering AB.

[1] Commonly referred to as the *"Engineered barrier"* production reports.

The Production reports provide the information on the handling of the spent nuclear fuel and the design and production of the engineered barriers and underground openings required to assess the long-term safety of the KBS-3 repository. The properties of the engineered barriers and underground openings are determined in the production and must be known to assess the long-term safety.

The Production reports provide information on the spent nuclear fuel to be deposited in the KBS-3 repository, how to produce and inspect the engineered barriers and underground openings and how to handle the spent fuel and engineered barriers within the facilities of the KBS-3 system. Further, they provide information on acceptable impairments on the engineered barriers in order for them to be fit for deposition or installation.

The stages of the production lines taking place in the nuclear facility of the KBS-3 repository facility are described in **SR-Operation**. The Production reports will provide input to Chapter 4: The operation and quality assurance of the facility and Chapter 5: The facility and its functions of **SR-Operation** (general part). Further, the **Spent fuel report** will provide input to Chapter 6: Radioactive substances in the facility of **SR-Operation** (general part). An illustration of the information provided by the Production reports for **SR-Site** (main report) and **SR-Operation** (general part) is given in Figure 1-4. Technical details and data are provided in each individual report included in the set of Production reports.

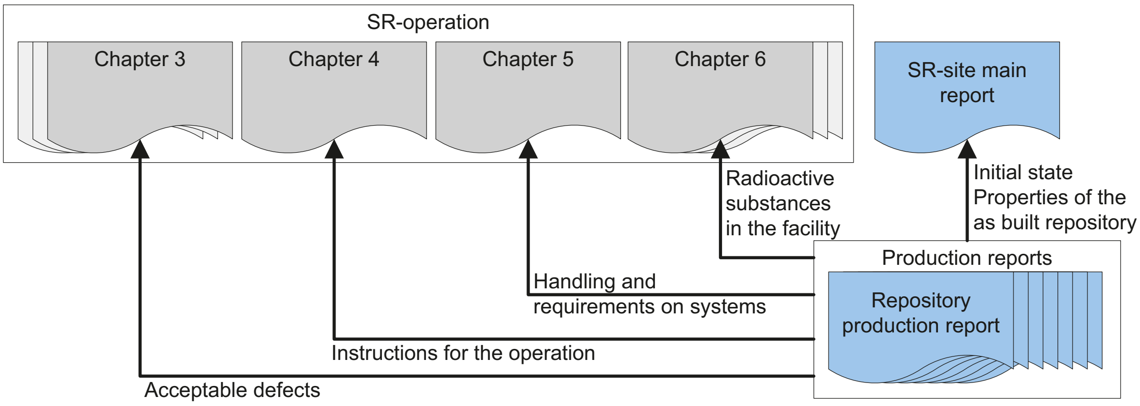


Figure 1-4. *General description of the information the Production reports provides for SR-Site and SR-Operation.*

1.3 Purpose, objectives and limitations

1.3.1 Purpose and objectives

The purpose of the set of Production reports is to present how the spent nuclear fuel is handled and how the engineered barriers and underground openings of the KBS-3 repository are designed, produced and inspected in a manner related to their importance for the safety of the KBS-3 repository.

With the Production reports SKB intends to present the design premises for the KBS-3 repository and their sources, and demonstrate how the engineered barriers and underground openings can be designed and produced to conform to the stated design premises. The Production reports shall present the current reference designs and production methods and summarise the research and development efforts that supports that the KBS-3 repository can be produced in conformity to the design premises.

The purpose of this report – **Repository production report** – is to give an overview of the barriers and barrier functions of the KBS-3 repository and to provide the overarching design premises for their design. The report shall also provide an overview of the KBS-3 system and the production lines for the handling of the spent nuclear fuel, the production of the engineered barriers and construction of the underground openings, and introduce design and production interfaces. The objectives of this report are to present:

- the role of the Production reports within the safety report,
- central concepts and their definitions,
- overarching design premises for the KBS-3 repository and its engineered barriers and underground openings,
- the methodology to derive and manage design premises,
- the KBS-3 repository, its barriers and their barrier functions,
- the KBS-3 system and the handling of the spent fuel and the production of the KBS-3 repository with focus on common aspects and interfaces and dependencies between the production lines,
- an overview of quality management and safety classification of the engineered barriers, underground openings and other parts of the KBS-3 repository and their application within the Production reports.

The purpose of the **Spent Fuel report** is to present the spent nuclear fuel to be deposited, provide the information about the spent nuclear fuel needed for **SR-Site,** to present the spent nuclear fuel to be handled and to give an overview of its way through the KBS-3 system.

The purpose of the ***"Engineered barrier"* production reports** and the **Underground openings construction report** is to provide information on design premises, design, production and construction and the resulting initial state as a basis for the safety assessment **SR-Site**. The ***"Engineered barrier"* production reports** and the **Underground openings construction report** shall also provide information to **SR-Operation** concerning the handling, deposition and installation of the engineered barriers and construction of the underground openings.

1.3.2 Limitations

This report provides a description of the KBS-3 system and its facilities. Assessments of its safety, environmental impact, costs etc are presented in other documents within or outside the safety report.

The Production reports present how the engineered barriers and underground openings are designed, and produced to conform to the stated design premises. Other aspects of the production, e.g. workers safety or logistics are reported elsewhere.

The Production reports present one design of the KBS-3 repository and its engineered barriers and underground openings that can be produced in conformity to the design premises, alternative designs are reported elsewhere. It is foreseen that the presented design will be developed and improved as a result of technology development and safety assessments. Planned research and development is presented in SKB's research, development and demonstration programmes (RD&D-programmes).

The **Spent fuel report** is based on SKB's reference scenario for the operation of the nuclear power plants and includes a presentation of the spent nuclear fuel that currently is stored in the interim storage facility. Alternative operation scenarios for the nuclear power plants are not included.

The "***Engineered Barrier"* production reports** and **Underground openings construction report** present the design considerations taken with respect to the application of best available safety and radiation protection technique and how they have affected the design. Motivations for the described reference design and methods as being the best available are presented separately.

The **Underground openings construction report** contains a description of how the repository is adapted to the selected site. The selection of a site for the repository and the location of the other facilities within the KBS-3 system are presented in other documents. Further descriptions of the rock as one of the barriers of the repository are included in the **SR-Site**.

The only aspect of control of nuclear material, safeguards, discussed in the Production reports is its impact on the design of the KBS-3 repository.

1.4 Structure and content

1.4.1 This report

This report sets the production reports in their context and provides the common basis for the **Spent fuel report**, the **"*Engineered barrier*" production reports** and the **Underground openings construction report**.

The purposes and limitations of the Production reports and their role in the safety report are presented in this chapter. This chapter also contains an overview of the structure and content of the reports and a presentation of some concepts of importance for the reports.

In Chapter 2 the substantiation of design premises for the KBS-3 repository is presented. The different kinds of design premises related to the different levels of detail in the design and their sources are presented. The treaties, laws and regulations of importance for the design, the spent fuel to be deposited, as well as the approach to substantiate design premises from the results of the safety assessment and technology development are discussed.

In Chapter 3 the functions and considerations SKB has substantiated based on the treaties, laws and regulations as a specification of the KBS-3 repository, and as guidelines for the design, are presented. The spent fuel to be deposited and its impact on the design are discussed. The purposes, basic designs and barrier functions of the engineered barriers as well as the purpose and functions of the underground openings and plugs are stated.

In Chapter 4 the facilities of the KBS-3 system and the production lines are introduced. The chapter contains a presentation of the facilities their purposes and main activities as well as an overview of the production lines and their interfaces.

Finally in Chapter 5 an introduction to quality management, safety classification and their application within the production of the KBS-3 repository is given.

1.4.2 The spent fuel report

The **Spent fuel report** comprises a description of the spent fuel to be deposited and the properties of the spent fuel of importance for the design and safety of the KBS-3 repository. The requirements on the handling of the spent fuel that are related to the design and safety of the KBS-3 repository are stated. The fuel is not produced but handled within the KBS-3 system, and the production line in the **Spent fuel report** comprises a presentation of the handling in accordance with the requirements. Finally, for the initial state the resulting radionuclide inventory and other properties of the encapsulated spent nuclear fuel required for the safety report are presented.

1.4.3 The engineered barrier production reports

The general flow of information in the "***Engineered barrier*" production reports** can be described as follows:

- design premises,
- reference design,
- conformity of reference design to design premises,
- production,
- initial state, i.e. the results of the production.

The barrier functions and design considerations introduced in Chapter 3 in this report are repeated and forms the basis for the detailed design premises for each engineered barrier given in the ***"Engineered barrier*" production reports.** The reference designs of the engineered barriers are specified and their basis discussed. The conformity of the reference designs to the design premises is analysed. The presentation of the production starts with the main parts of the production lines presented in Chapter 4 in this report and an introduction to the reference methods applied in the production. This introduction is followed by more detailed descriptions of the individual stages of the production line. The initial state comprises results of the production and the conformity of the produced engineered barriers to their reference designs and design premises.

1.4.4 The underground openings construction report

The design premises for the underground openings are presented in the same way as for the engineered barriers, i.e. starting from the functions and considerations presented in Chapter 3 in this report and followed by the more detailed design premises. The presentation of the design premises is followed by a description of the rock engineering and site adaptation including a presentation of the rock engineering methodology SKB intends to apply. The reference designs of the underground openings comprise their site specific layouts and properties, and their conformity to the design premises. The production part in the **Underground openings construction report** comprises a presentation of the reference methods to construct and inspect the different underground openings and an overview of possible mitigation measures that may be used to rectify non-conformity to the design premises. As for the engineered barriers the results of the construction comprise the initial states of the different underground openings and their conformity to their reference designs and design premises.

1.5 Central concepts

In this section some concepts of importance for the Production reports are defined and explained. ***Concepts are written in bold italics,*** *definitions are written in italics* and explanations are written in normal text. The concepts are introduced in alphabetic order. Regarding quality management SKB has decided to apply the vocabulary in the standard /ISO 9000:2005/.

barrier: *physical confinement of radioactive substances* Applicable in nuclear facilities in connection with their construction, possession and operation /SSMFS 2008:1 definitions/.
an engineered (man-made) or natural part of final repository that has barrier function Applicable in final repository /SSMFS 2008:21 2,3 §§ with general recommendations/.

barrier function: *the way a barrier functions to contribute to contain the radioactive substances or to prevent or retard their dispersion* Also includes the capability of a barrier to preserve the function of other barriers.

conformity: *fulfilment of a requirement* /ISO 9000:2005/.

design premises: *information forming a necessary basis for design* Design premises comprise requirements and other premises for the design. Requirements express needs or expectations. Other premises comprise quantitative information on features, performance, events, loads, stresses, combinations of loads and stresses and other information, e.g. regarding environment or adjacent systems necessary for the design. In the Production reports design premises is used as a common term for all information required for the design, and no distinction is made between requirements and premises.

initial state: *the properties of the spent fuel at the time for encapsulation, the properties of the engineered barriers once they have been finally placed in the final repository and will not be further handled within the repository facility, the properties of the underground openings at final installation of buffer, backfill or closure.*

inspection: *conformity evaluation by observation and judgement accompanied as appropriate by measurement, testing or gauging* /ISO 9000:2005/.

organisation: *group of people and facilities with an arrangement of responsibilities, authorities and relationships* /ISO 9000:2005/.

procedure: *specified way to carry out an activity or process* /ISO 9000:2005/.

process: *set of interrelated or interacting activities which transforms inputs to outputs* /ISO 9000:2005/.

product: *result of a process* /ISO 9000:2005/.

production line: The ordered sequence of stages in the handling of the spent nuclear fuel and production of the engineered barriers. The successive – as more information on the conditions in the rock gets available – design, site adaptation and construction of underground openings.

qualification: *investigation and demonstration which shows that a person or a testing, processing or integration process can fulfil its specified tasks* /SSMFS 2008:13/.

qualification process: *process to demonstrate the ability to fulfil specified requirements* /ISO 9000:2005/.

quality plan: *document specifying which procedures and associated resources shall be applied by whom and when to a specific project, product, process or contract* /ISO 9000:2005/.

record document: *document stating results achieved or providing evidence of activities performed* /ISO 9000:2005/.

reference design: *a design that is valid from a defined point in time until further notice. The established reference design shall be used as the precondition for technical development, further design and the analyses of safety, radiation protection and environmental impact.* A reference design may be either general or site specific.

requirement: *a need or expectation that is stated, generally implied or obligatory* /ISO 9000:2005/ See design premise above and Chapter 2.

specification: *document stating requirements* /ISO 9000:2005/ See design premise above and Chapter 2.

test: *determination of one or more characteristics according to a procedure* /ISO 9000:2005/.

verification: *confirmation, through the provision of objective evidence that specified requirements have been fulfilled* /ISO 9000:2005/.

validation: *confirmation, through the provision of objective evidence that the requirements for a specific intended use or application has been fulfilled* /ISO 9000:2005/.

2 Substantiation of design premises

2.1 Introduction

The "***Engineered barrier*" production reports** and **Underground openings construction report** shall contain the design premises for the engineered barriers and underground openings of the KBS-3 repository. The design premises are derived from the following sources:

- international treaties,
- Swedish laws and regulations,
- stakeholder demands and agreements,
- the properties of the spent nuclear fuel,
- the chosen method for final disposal, the barriers of the final repository and their barrier functions, couplings and interdependencies between them and decisions made in the design,
- the production and handling of the engineered barriers and the construction of the underground openings,
- the repository site,
- the general knowledge about processes that may impact the barrier functions and the safety of the repository,
- the safety assessment, primarily the long-term safety but also the operational safety part.

There are different kinds of design premises related to the different sources and levels of detail in the design.

The most general, highest level, specify the problem to be solved and the basic principles that shall be applied in the design. These top level design premises are based on laws and regulations, stakeholder demands and decisions and agreements.

The next two levels of detail provide high-level specifications of the method and system to solve the problem. At these two levels the KBS-3 method and KBS-3 repository and its barriers are specified and their purpose and functions are described. The design premises on these levels are based on the basic principles to be applied, laws and regulations, the properties of the spent nuclear fuel and the chosen method to manage the spent fuel.

Finally, the design premises expressing the properties that the different components of the sub-systems, i.e. the barriers and parts of the KBS-3 repository, must have in order to maintain the functions are specified. These design premises specify the properties to be designed and provide quantitative information on features, events and processes that shall be considered when determining a reference design. The design premises on this level are based on the required functions and feedback from performed safety assessments and technical development. Within the Production reports these design premises have been divided into: design premises related to the functions in the KBS-3 repository, design premises from other parts of the KBS-3 repository and design premises related to the production and operation.

To manage the different kinds of design premises and their interdependencies SKB has developed a requirement management system – RMS /Morén and Wikström 2007/ within which the design premises are reviewed, settled and documented. Within the RMS information such as review status, sources, translation is kept for each design premise. In Figure 2-1 the different kinds of design premises, their sources and their related level of detail in the design are illustrated together with an example from SKB's RMS.

The design premises specifying the problem to be solved by the KBS-3 repository and the functions of the KBS-3 repository and its engineered barriers and underground openings are presented in this report – **Repository production report**. The design premises for the reference designs are presented in the **"*Engineered barrier*" production reports** and the **Underground openings construction report**.

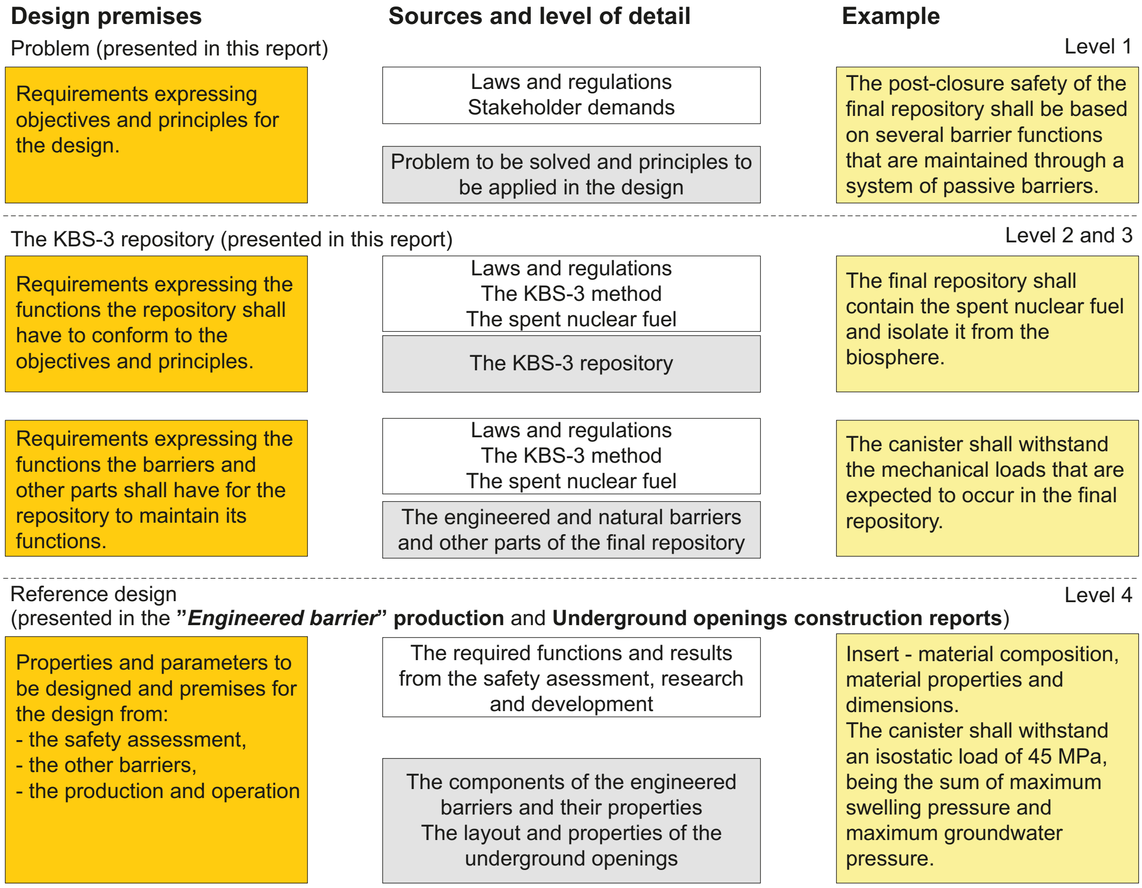


Figure 2-1. *Different kinds of design premises, their sources and the corresponding degree of detail in the design with an example from SKB's RMS.*

2.2 Laws and regulations and stakeholder demands

The final repository shall conform to the requirements in relevant laws and regulations. Stakeholder demands expressed in SKB's guiding principles: safety, efficiency and responsiveness shall be considered in the design. Further, the final repository for spent nuclear fuel shall be adapted to the scope and time schedule of the Swedish nuclear power programme.

The international treaties and national laws and regulations relevant for the design of a final repository for spent nuclear fuel are the following.

International treaty:

- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

National laws:

- Act on Nuclear Activities /SFS 1984:3/.
- Radiation Protection Act /SFS 1988:220/.

Regulations:

- SSMFS 2008:1 Regulations concerning safety in nuclear facilities.
- SSMFS 2008:12 Regulations concerning physical protection of nuclear facilities.
- SSMFS 2008:21 Regulations concerning safety in connection with the disposal of nuclear material and nuclear waste.
- SSMFS 2008:37 Regulations on the protection of human health and the environment in connection with the final management of spent nuclear fuel and nuclear waste.

In addition, the following treaties and act, which primarily concern the documentation and inspection of nuclear material and thus the operation of the KBS-3 repository facility, will indirectly affect the design of the final repository.

International treaties:

- Treaty on the Non-Proliferation of Nuclear Weapons.
- Treaty establishing the European Atomic Energy Community (Euratom Treaty).

National law:

- Act on Inspections according to International Agreements on Non-proliferation of Nuclear Weapons /SFS 2000:140/.

The Swedish Environmental Code /SFS 1998:808/ shall be applied for all activities that may impact the environment. Its main purpose is to provide for a sustainable development which implies that the current and future generations shall be assured a healthy and good environment. It includes the common rules of consideration that shall be applied to achieve this. The purpose of the environmental code and the rules of consideration shall be kept in mind in the design the final repository for spent nuclear fuel.

In addition, the underground openings as well as methods and technical systems to produce the different parts of the final repository shall conform to the Work Environment Act /SFS 1977:1160/ with regulations. The design of the underground openings shall also conform to the Planning and Building act /SFS 1987:10/ and the Act on Technical Requirements for Construction works /SFS 1994:847/ with regulations.

The repository shall be constructed to conform to the requirement that spent nuclear fuel and nuclear material that is not going to be reprocessed and re-used shall be finally deposited /SFS 1984:3 10, 14 §§, Joint convention on the Safety of Spent Fuel management and on the Safety of Radioactive Waste Management/. Principles of particular importance for the safety of the final repository and having a strong influence on the design are the multi-barrier principle, the defence-in-depth principle and the radiation protection principles to protect both human health and the environment and both current and future generations.

According to the multi-barrier principle the safety of the repository shall be maintained through a system of passive barriers which, in one or several ways, contribute to the containment, prevention or retardation of dispersion of radioactive substances, either directly or by protecting other barriers. The barrier system shall be designed to withstand features, events and processes that can affect their post-closure performance and the safety shall be maintained in spite of a single deficiency in a barrier /SSMFS 2008:21 2, 3, 5, 7 §§/. This principle and these paragraphs are important for substantiating the functions of the KBS-3 repository and its barriers.

According to the defence-in-depth principle nuclear accidents shall be prevented through a facility-specific design which shall incorporate multiple barriers as well as a facility-specific defence-in-depth system. The defence in depth system shall comprise several, overlapping levels of technical equipment, operational measures and administrative procedures to protect the facility's barriers and to maintain their effectiveness as well as to protect the surroundings if the barriers should not function as intended /SSMFS 2008:1 1 chp 2 §, 2 chp 1 §/. The defence-in-depth principle will impact the design and operation of the final repository facility. Regarding the final repository the construction, manufacturing, handling, testing and inspection of the final repository barrier system shall be dependable.

According to the radiation protection principles human health, and the environment, shall be protected from detrimental effects of ionising radiation throughout the entire handling and execution of the various stages in the management of the spent nuclear fuel, and in the post-closure period. Man and the environment both within and outside the national borders shall be protected and predictable future impact on human health must not exceed currently acceptable levels /SFS 1988:220 1, 6 §§; SSMFS 2008:37 3, 5, 6 §§, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management Article 1 ii, Article 4/.

SKB's objectives for a system to manage spent nuclear fuel and the principles which shall form the basis for the system design as documented within the requirement management system are presented in /SKBdoc 1241883/.

2.3 The spent nuclear fuel to be deposited

One property of the spent nuclear fuel, which contributes to the long-term safety and is of essential importance for the KBS-3 method, is the form of the spent nuclear fuel. The bulk of the fuel to be deposited consists of uranium oxide, which has very low solubility in a KBS-3 repository environment. With respect to this the fuel to be deposited in a KBS-3 repository shall be in oxide form or in some other form with similar low solubility in the groundwater that may penetrate deposited canisters.

The spent nuclear fuel to be finally deposited form an important basis for the design of the final repository. Parameters that will affect the design of the final repository are the radiotoxicity and decay power and the total amount of spent fuel to be deposited. Both the radiotoxicity and decay power are determined by the radionuclide inventory and will decrease as the radioactive decay proceeds. Also the dimensions of the fuel assemblies will impact the design.

The final repository shall provide protection against the harmful effects of radiation for as long as is necessary with respect to the radiotoxicity of the spent nuclear fuel. The radiotoxicity of the spent nuclear fuel and the time required for it to decay to levels corresponding to the radiotoxicity of the uranium ore once used to manufacture it is illustrated in Figure 2-2. The time for the radiotoxicity of the spent fuel to decay to naturally occurring levels is an important input to the design of the KBS-3 repository and its engineered barriers.

The requirement that the engineered barriers shall maintain their barrier functions with respect to features, events and processes that can affect their performance has resulted in a maximum allowed temperature in the KBS-3 repository. The maximum allowed temperature will together with the total amount of spent fuel and the number of fuel assemblies in each canister determine the minimum size of the final repository. The temperature in the final repository will depend on the decay power of the spent nuclear fuel, the dimensions and thermal properties of the engineered barriers, the distances between the deposited canisters and the thermal properties of the host rock. The decay power will decrease with time. Consequently the time period from when the fuel assemblies are taken out of the nuclear power reactor until they are encapsulated and deposited in the final repository will impact the size of the repository. The fuel parameters of importance for the design of the final repository are further discussed in the **Spent fuel report,** Section 2.3.

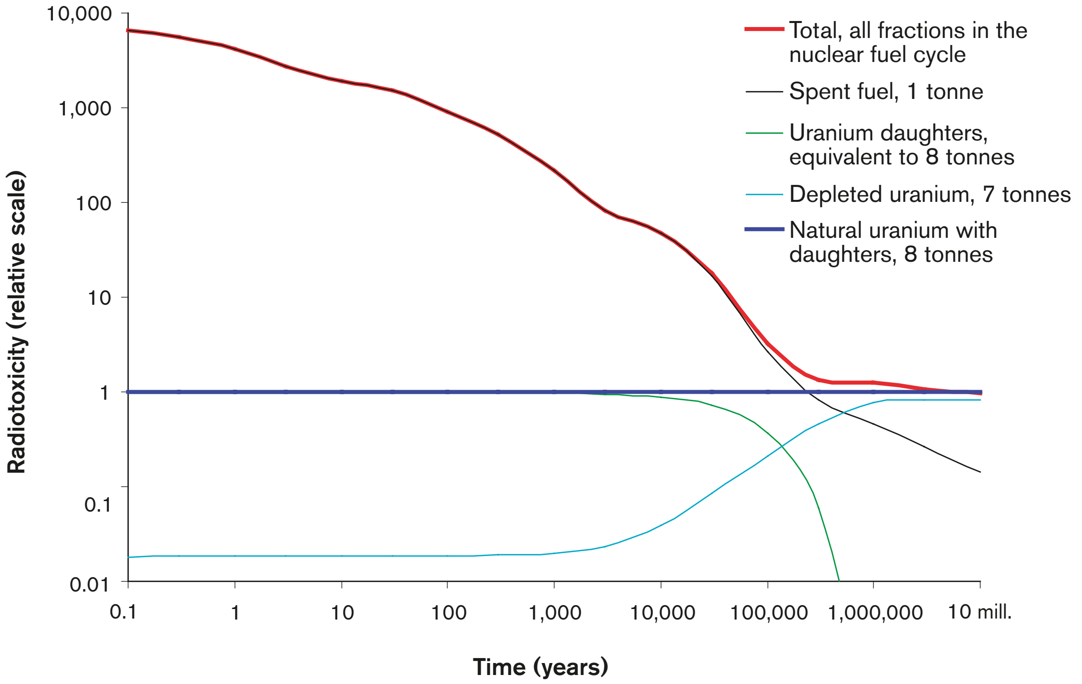


Figure 2-2. *Radiotoxicity on ingestion of uranium ore (blue line), and of all fractions that arise when the same quantity of uranium mineral is used in the nuclear fuel cycle (red line). The different fractions comprise the spent fuel, the depleted uranium and the uranium daughters that are separated in the uranium mill, from /Hedin 1997/.*

2.4 Functions of the KBS-3 repository and design considerations

2.4.1 Functions of the KBS-3 repository

The safety and radiation protection principles introduced in Section 2.2 and the properties of the spent nuclear fuel, mainly its radiotoxicity and its decay with time, constitute the basis for the substantiation of the functions of the KBS-3 repository. The purpose of the final repository is to protect man and the environment from unacceptable radiological impact. In the final report of the KBS (nuclear fuel safety) project – Final storage of spent nuclear fuel – KBS-3 /SKBF/KBS 1983/ which has given the name to the KBS-3 method – it is stated that:

"*This can be achieved in two ways. One is to* ***contain*** *the radioactive substances for a sufficiently long period of time to allow the process of decay to reduce activity to acceptable levels. The other is that the radioactive substances are* ***diluted****, i.e. released and dispersed so slowly that the maximum concentrations that can reach man are acceptably low.*"

In the current regulations the term diluted is not used but it is stated that the functions of the barriers of a final repository shall be: to in one or several ways, contribute to contain the radioactive substances or to prevent or retard their dispersion /SSMFS 2008:21 3 §/. In a final repository based on the KBS-3 method containment as well as prevention or retardation of dispersion of radioactive substances are employed to protect man and the environment from radiation. This approach is common for final repositories developed in many other countries.

In addition to the safety and radiation protection principles and the radiotoxicity of the spent nuclear fuel, the host rock and geological conditions are important when determining the functions of a final repository. The functions of the KBS-3 repository and its engineered barriers and underground openings constitute a specification of a KBS-3 repository, and are high level premises for the design of its engineered barriers and underground openings. The functions of a KBS-3 repository and its barriers and other parts are presented in Chapter 3 in this report.

2.4.2 Design considerations

For some design premises quantitative criteria for the evaluation of the conformity of the design to the design premises are provided. Based on the functions of the final repository quantitative premises for the design of the engineered barriers and underground openings can be substantiated. In some cases the functions as such can be verified against quantitative criteria, i.e. for the protection of man and the environment from ionising radiation quantitative dose and/or risk criteria are stated. However, there are also some design premises for which no absolute quantitative criteria for the conformity of the design can be given. Examples are that the technical solutions shall be well-tried or tested and be cost-effective. In the Production reports these design premises are referred to as design considerations.

The design considerations are presented in Section 3.9 in this report. They shall be regarded in the design of the engineered barriers and underground openings and in the development and choice of methods to manufacture, install, construct and inspect them.

2.5 Design premises from safety assessment, design and technology development

2.5.1 General approach

The development of the design premises and design of the KBS-3 repository, its engineered barriers and underground openings, has been and is an iterative process with several loops of design, technology development and assessment. In addition, for the underground openings the successively more detailed site descriptive model is an important design premise for the development of the design.

The high level design premises are in principle expressed in laws and regulations, or based on the properties of the spent nuclear fuel or the chosen method to finally dispose the spent nuclear fuel. These high level design premises for a KBS-3 repository are presented in Chapter 3 in this report.

However, the substantiation of lower level design premises for the design of the properties, e.g. geometry, material composition and strength, of the engineered barriers and underground openings require input and feedback from technical development and safety assessments. The properties shall provide the required functions and be technically feasible to achieve. A flow chart for the iterative process of substantiation of design premises, design and technology development and safety assessment is given in Figure 2-3.

The lower level design premises stating the properties and parameters to be designed and the premises the design shall conform to are in the Production reports divided into design premises:

- related to the functions in the KBS-3 repository,
- from other parts of the KBS-3 repository,
- related to the production and operation.

The sources of these categories of design premises and where they are discussed and presented within the Production reports is presented in Table 2-1.

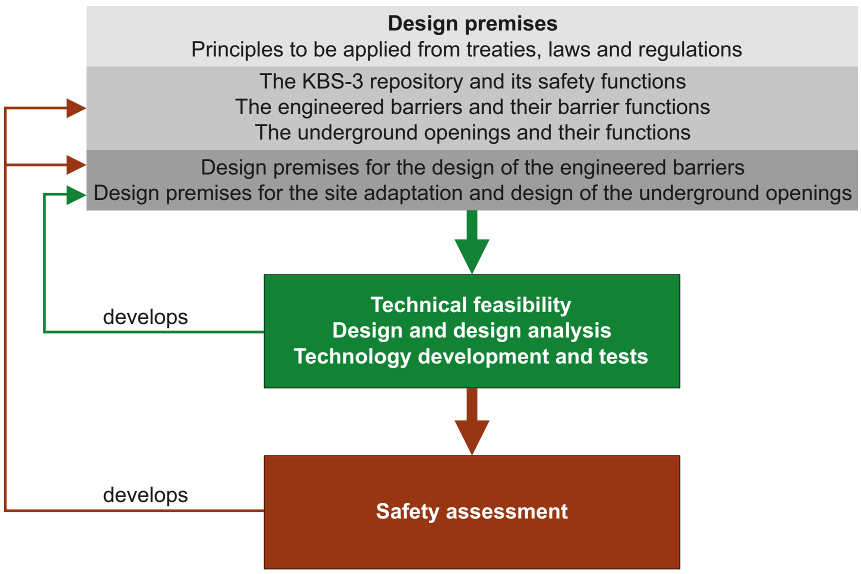


Figure 2-3. *The iterative process of substantiation of design premises from design, technology development and safety assessment.*

Table 2-1. The different categories of detailed design premises, their sources and references to where they are discussed and presented.

Design premise category	Source	Discussed and presented in
Related to the functions in the KBS-3 repository	Assessment of long-term safety	Substantiation discussed in Section 2.5.2 (this report) Design premises presented in Sections 2.3 of the ***"Engineered barrier"* production reports**[1] and the **Underground openings construction report**
From other parts of the KBS-3 repository	Spent nuclear fuel Technology development and reference designs and methods	Substantiation discussed in Section 2.5.3 (this report) Design premises presented in Sections 2.3 of the ***"Engineered barrier"* production reports**[1] and the **Underground openings construction report**
Related to production and operation	Technology development and reference designs, methods and procedures Operational safety assessment	Substantiation discussed in Sections 2.5.4 and 2.5.5 (this report) Design premises presented in Sections 2.3 of the ***"Engineered barrier"* production reports**[1] and the **Underground openings construction report**

[1] For the plug in deposition tunnels Section 2.5 in the Backfill production report

Regarding the design premises from other parts of the KBS-3 repository, they are stated in the production report for the part – i.e. spent fuel, engineered barrier or underground opening – imposing the premise, and repeated and verified in the production line for the part that shall conform to the design premise.

In addition to the design premises for the design of the different parts of the KBS-3 repository there are premises for the development of the methods to produce and construct them. The properties that contribute to the functions and safety of the KBS-3 repository shall be possible to achieve by proven or well-tested technology. The production and operation shall be dependable, cost-effective and carried out in the prescribed rate. The detailed premises for the development of methods are presented in the chapters presenting the production and construction respectively in the **"*Engineered barrier*" production reports** and **Underground openings construction report**.

It is foreseen that the lower level design premises derived from the safety assessment, technical development, production and construction will develop as a result of further assessments, research and development. To make the development traceable all design premises and also the reference designs are documented within SKB's requirement management system.

2.5.2 Design premises related to the functions in the KBS-3 repository

The design premises related to the functions in the KBS-3 repository are based on the results from the assessment of the long-term safety.

Any design must start from a specification of what shall be achieved and the required functions. The design shall have the capability of sustaining the functions. Whether a specific design results in a final repository that conform to the safety criteria can only be determined through a safety assessment where all parts of the system are evaluated together.

In the general recommendations to SSM's regulations concerning safety in connection with the disposal of nuclear material and nuclear waste, SSMFS 2008:21, it is stated that: "*The safety assessment should also aim at providing a basic understanding of the repository performance on different time-periods and at identifying requirements regarding the performance and design of different repository components.*"

The safety assessment methodology and methods for deriving design premises from the assessment have gradually been developed. In the most recent assessment of long-term safety, SR-Can /SKB 2006/, the roles through which the repository components contribute to safety were expressed as safety functions. Associated to the safety functions are safety function indicators which are measurable or calculable quantities through which the safety functions can be quantitatively evaluated. For some of the safety function indicators it was also possible to specify function indicator criteria which are quantitative limits used to assess whether the safety function is maintained or not.

Further, in the general recommendations to SSM's regulations concerning safety in connection with the disposal of nuclear material and nuclear waste, SSMFS 2008:21, it is stated that "*Based on scenarios that can be shown to be especially important from the standpoint of risk, a number of design basis cases should be identified".* Preliminary design bases cases and other design feedback were given in the safety assessment report SR-Can /SKB 2006/ and have been further developed in a specially dedicated report titled "Design premises for a KBS-3V repository based on results from the safety assessment SR-Can and some subsequent analyses" /SKB 2009/. This report comprise design premises for the design of the engineered barriers and underground openings related to their function in the KBS-3 repository, and is thus a key reference to the Production reports. It is within the Production reports referred to as **Design premises long-term safety**.

The approach to substantiate design premises from the assessment of the long-term safety and the resulting design premises are further discussed in **Design premises long-term safety.**

2.5.3 Design premises from other parts of the KBS-3 repository

Design premises from, or imposed by, other parts concern technical feasibility. Interactions and interdependencies between the different parts occurring in the KBS-3 repository after the parts are finally installed in the repository are addressed within the assessment of the long-term safety and expressed in the design premises from the assessment.

To be technically feasible the different parts of the repository must fit, and work, together so that they can acquire the properties needed to provide the required functions. Thus, the reference design of one component may constitute a design premise for another. For example, in order for the backfill in deposition tunnels to maintain its functions a sufficiently high density of the backfill material is required. The resulting backfill density depends on the installed material mass and on the deposition tunnel volume, and also on other properties of the tunnel to be backfilled. The reference design of the backfill is thus a design premise for the deposition tunnels.

In practice, the designs of the different parts are mutually adapted to achieve a technically feasible and robust solution. An exception is the spent nuclear fuel for which the design cannot be altered. However, requirements on the handling of the spent fuel may be imposed by the other parts of the KBS-3 repository.

2.5.4 Design premises related to production and operation

The properties of importance for the function in the KBS-3 repository shall be possible to achieve and inspect in the production. Further, to achieve a reliable production, loads occurring during handling and transportation shall be considered in the design of the canister, buffer, backfill and closure components.

According to the general recommendations to SSM's regulations concerning safety in connection with the disposal of nuclear material and nuclear waste, SSMFS 2008:21: "*... information, such as on manufacturing method and controllability, ... should be used to substantiate the design basis such as requirements on barrier properties.*".

The principles for substantiation of design premises from the operation and from the production of the engineered barriers and construction of the underground openings are illustrated in Figure 2-4. The figure also illustrates how the expected results of the production via the assessment of the long-term safety will provide input to the development of design premises.

The design must be such that the properties can be achieved and inspected in a reliable manner, and the methods for production and inspection may impose premises on the design (feedback B in Figure 2-4. The loads occurring during the handling must not significantly impair the properties of importance for the functions in the KBS-3 repository. Consequently, engineered barriers must not be exposed to loads that significantly impair the properties of importance for the functions in the KBS-3 repository. Further, they must be designed to withstand the loads that occur in the normal operation (feedback C in Figure 2-4).

The handling of the engineered barriers, most significantly the canister, will impact the operational safety. The substantiation of design premises related to the operation of nuclear facilities is regulated. A summary of how design premises for the handling of the engineered barriers are substantiated from the assessment of the operational safety is given in the next section.

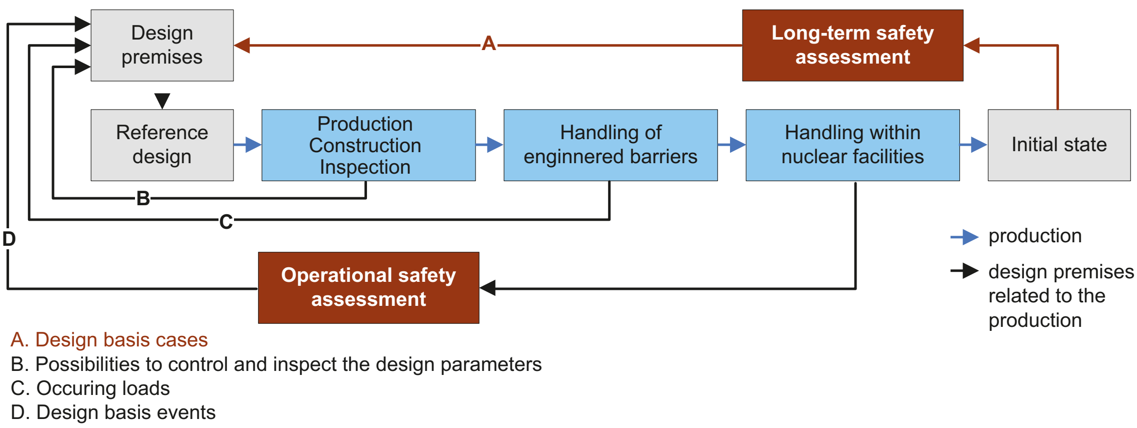


Figure 2-4. *Substantiation of design premises from the production and handling of the engineered barriers and construction of the underground openings. Design basis cases and design basis events are design premises from the assessments of the long-term and operational safety respectively (see Sections 2.5.2 and 2.5.5).*

2.5.5 Design premises related to the safe operation of the repository facility

The operational safety of the repository facility refers to technical, organisational and administrative measures to prevent i) the canister from being damaged in such a way that the containment is breached and radioactive substances dispersed, or ii) the occurrence of radiation doses higher than those accepted for normal operation of the facility. This means that the canister must be tight when it arrives to the repository facility and remain tight during handling within the facility. As a consequence of this the repository facility and its technical systems and equipment must be designed so that the canister cannot be exposed to loads and stresses that may result in leaks. The canister in turn must be designed to withstand the loads it may be exposed to, not only during normal operation but also for less likely events that may occur in the facility. The loads occurring during normal operation and less likely events constitute design premises for the canister.

To minimise the radiation doses to the personnel within the facility, and also due to the requirements on reliability and operational stability, it is desirable that the canisters and their contents are always fit for deposition and should not need to be retrieved for repair or replacement of the canister. Even if it will not result in canisters not fit for deposition, damages on installed buffer or backfill in deposition tunnels that will necessitate retrieval of deposited canisters from the deposition holes shall be avoided.

According to the general recommendations to SSM's regulations concerning safety in nuclear facilities the safety analysis of the KBS-3 repository facility should include: "*a set of events or scenarios … which can affect the function of the defence-in-depth system and, thereby, ultimately have a radiological impact on the environment*. The events shall be divided into classes based on their expected frequency. The event classes are denominated H followed by an integer, where a higher number indicates lower frequency of occurrence. Based on the classes design basis events should be identified.

SKB has classified events during normal operation and events that may occur during the lifetime of the facility as H1 and H2 events respectively, see **SR-Operation** (general part), Chapter 3. In accordance to the discussion above the systems handling the canister and the canister shall be designed so the canister is fit for deposition for all events classified as H1 or H2 events. The buffer and backfill in deposition tunnels and the systems of importance for their properties shall be designed so that H1 or H2 events will not result in that deposited canisters must be retrieved and brought back to the encapsulation plant for repair or replacement. However, damages on the buffer that require that the canister is brought back to a previous handling stage are acceptable if the canisters are still fit for deposition. Damages on the buffer or backfill that result in retrieval of all canisters in a deposition tunnel are unacceptable for H1 or H2 events.

Unanticipated and unlikely events that are not expected to occur are classified as H3 and H4 events, respectively, see **SR-Operation** (general part), Chapter 3. The canister shall be designed to remain tight for events classified as H3 or H4 events. Should a H3 or H4 event occur it shall be reported to SSM and its consequences analysed. If the properties of the canister required for it to sustain its barrier functions in the final repository are jeopardised it shall be returned to the encapsulation plant for repair or replacement. Furthermore, buffer or backfill that are anticipated not to sustain their barrier functions as a result of a H3 or H4 event shall be replaced and deposition holes with unacceptable damages not used for deposition.

3 The KBS-3 repository

3.1 The KBS-3 repository and its functions

3.1.1 Definitions, purpose and basic design

A KBS-3 repository is a final repository for spent nuclear fuel in which:

- the spent nuclear fuel is encapsulated in tight, corrosion resistant and load bearing canisters,
- the canisters are deposited in crystalline rock at a depth of 400–700 metres,
- the canisters are surrounded by a buffer which prevents the flow of water and protects them,
- the cavities in the rock that are required for the deposition of canisters have been backfilled and closed.

All spent nuclear fuel from the Swedish nuclear power programme which shall not be reused shall be encapsulated, deposited and finally stored in the KBS-3 repository. After closure, the KBS-3 repository shall contain the spent nuclear fuel and isolate it from man and the environment. If the containment is breached, the final repository shall prevent or retard the dispersion of radioactive substances so that the ionising radiation, if some of the radioactive substances finally reach the environment at the surface, does not cause harm.

A KBS-3 repository comprises the rock at the repository site, the canisters containing spent nuclear fuel, buffer, backfill and closures as well as engineered and residual materials that remain in the rock once the underground openings have been backfilled and closed.

In a KBS-3 repository, the canisters with spent nuclear fuel can be deposited either horizontally in a drift (KBS-3H) or vertically in deposition holes (KBS-3V). The reference alternative is vertical deposition. A closed KBS-3 repository with vertical deposition of the canisters, and its natural and engineered barriers and parts is illustrated in Figure 3-1.

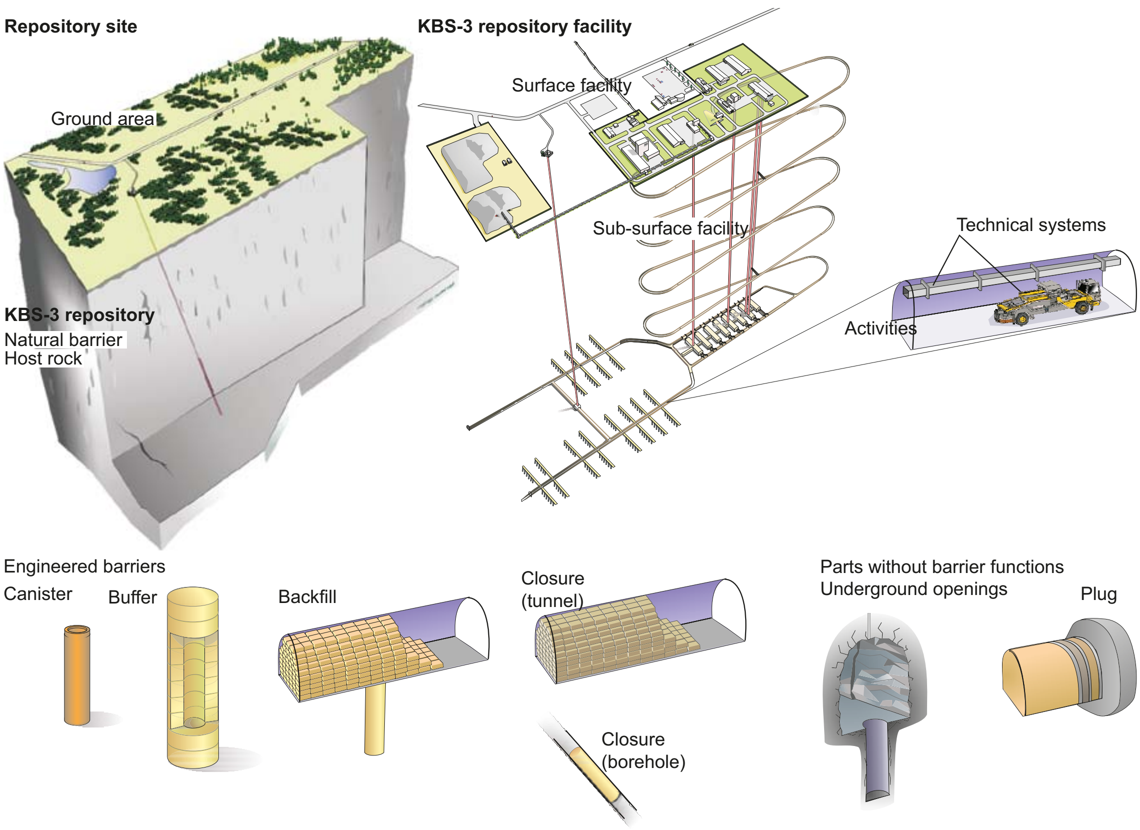


Figure 3-1. *The KBS-3 repository after closure with its natural and engineered barriers and parts without barrier functions.*

All spent nuclear fuel from the operation of the twelve licensed Swedish nuclear power plants – both existing and arising from the future operation of the ten remaining reactors – and from the Ågesta reactor, which is not reprocessed and re-used shall be deposited in the KBS-3 repository. The KBS-3 repository shall also accommodate fuel residues from the Studsvik facility. In the following this spent fuel is referred to as the spent fuel from the currently approved Swedish nuclear power programme.

3.1.2 The functions and properties of the KBS-3 repository

SKB has based on the treaties, laws and regulations presented in Section 2.2 substantiated the following functions and considerations as a specification of the KBS-3 repository, and as guidelines for the design of its engineered barriers and underground openings. *The functions and considerations* are high level design premises (level 2 in Figure 2-1) and *are written in italics*.

In line with the multi-barrier principle and radiation protection principles, the KBS-3 repository shall:

- *contain the spent nuclear fuel and isolate it from the biosphere,*
- *if the containment is breached – prevent and retard the dispersion of radioactive substances so that the ionising radiation, if some of the radioactive substances finally reach the environment at the surface, does not cause harm,*
- *have a system of passive barriers which, in one or several ways, shall contribute to contain, prevent or retard the dispersion of radioactive substances, either directly, or indirectly by protecting other barriers in the barrier system,*
- *provide protection against the harmful effects of radiation for as long as the radiotoxicity of the spent nuclear fuel is significantly higher than the radiotoxicity of naturally occurring uranium ores.*

Further:

- *Measures taken to facilitate access, surveillance or retrieval of disposed nuclear fuel, or to impede intrusion, shall not be detrimental to the safety of the final repository.*

In line with the principles stated in the international treaty "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management" the following shall be considered in the design of the KBS-3 repository.

- *The barriers of the final repository shall be passive.*
- *Consideration shall be given to unintentional intrusion in the design of the final repository so that the repository site after closure of the repository facility can be utilised without compromising the freedom of action, needs and aspirations of future generations.*
- *On completion of deposition, it shall be technically feasible for the final repository facility to be closed.*

In line with the defence-in-depth principle and the principle to apply the best available technique the following shall be considered in the design of the KBS-3 repository.

- *The barrier system of the final repository shall be capable of withstanding malfunctions and features, events and processes that could have a detrimental impact on their functions.*
- *The construction, manufacturing, deposition, installation and non-destructive testing of the final repository barrier system shall be reliable and operationally stable.*
- *Among technically feasible alternative designs, techniques and measures, those alternatives which in the short term best restrict radiation doses to human-beings and which in the long term are judged to offer the best protective capability shall be selected.*

In line with non-proliferation principles and the Euratom Treaty the final repository facility shall:

- *be well protected and guarded against intrusion and illegal diversion of nuclear material.*
- *be accessible for and be provided with necessary means for the inspection of nuclear material.*

This will to some extent affect the design of the final repository.

It is important to recognise that it is the demands stated in the laws and regulations that the final repository shall conform to. The functions and considerations stated above constitute guidelines for the design, and are intended as a means to achieve designs that conform to laws and regulations. The treaties, laws and regulations used as the basis for this high level specification of the KBS-3 repository are described in /SKBdoc 1241883/.

According to the reactor owners, and SKB's own demands the final repository shall:

- *accommodate all spent nuclear fuel from the currently approved Swedish nuclear power programme,*
- *shall have a high level of quality and be cost-effective,*
- *be flexible for alternative designs within the KBS-3 method.*

Further:

- *The final repository shall be constructed and the final repository facility operated for a limited period of time adapted to the operating times of the nuclear power plants.*

As stated in Section 2.2 the environmental code and the rules of consideration shall be kept in mind in the design of the final repository for spent nuclear fuel. This means that environmental impact such as emissions into water and air, noise and vibrations and impact on groundwater shall be considered in the design and development of methods for construction, manufacturing, installation and inspections. Further, the consumption of raw materials and energy shall be considered and – with respect to the safety of the final repository – as far as possible be limited.

3.1.3 The engineered barriers and other parts of the KBS-3 repository

The functions of the final repository shall be provided by the following barriers and their barrier functions:

- the canister,
- the buffer,
- the host rock,
- the backfill,
- the closure.

And utilise the barrier functions of the host rock by:

- the adaptation of the underground openings to the thermal, hydrological, mechanical and chemical properties of the host rock.

In addition, there are plugs of importance for the installation of the backfill and closure that will remain in the final repository. In order to avoid significant reduction of backfill or closure density the plugs have to remain in the final repository in a long-term perspective. Further, the plugs must not contain materials that may impact the barrier functions of the barriers. However, the plugs have no long-term functions in the final repository.

The functions and properties of the engineered barriers, the underground openings and the plugs are presented in Sections 3.2 to 3.8. The barrier functions of the engineered barriers and functions of the underground openings and plug constitute specifications of each engineered barrier or part of the repository. They are in similarity with the safety functions of the KBS-3 repository substantiated by SKB based on the treaties, laws and regulations presented in Section 2.2. The treaties, laws and regulations considered when substantiating the specifications are accounted for in /SKBdoc 1241883/, which also include references to which of the functions of the KBS-3 repository the different barrier functions contribute to.

The barrier functions of the engineered barriers and functions of the underground openings and plugs form the basis for substantiation of premises for the design and are repeated in the **"Engineered barrier" production reports** and the **Underground openings construction report** (Section 2.2.1 in the reports). For the spent nuclear fuel the properties of importance for the safety and design of the final repository are introduced in this report and further discussed in the **Spent fuel report,** Section 2.3.

3.2 The spent nuclear fuel

3.2.1 Definition

In the Production reports, spent nuclear fuel refers to the fuel to be encapsulated and deposited in the KBS-3 repository.

Encapsulated spent fuel is the spent nuclear fuel within the canister ready for deposition in the KBS-3 repository. Gases and liquids in the cavities of the canister and the fuel assemblies are considered as a part of the encapsulated spent fuel.

3.2.2 Properties of importance for the design and long-term safety of the KBS-3 repository

The spent nuclear fuel constitutes the nuclear waste or nuclear material to be finally deposited in the KBS-3 repository. The KBS-3 repository is designed to protect man and the environment from unacceptable radiological impact from the radionuclide inventory in the spent nuclear fuel. The spent fuel is not considered as a barrier in the KBS-3 repository. Only fuels in oxide form or in some other form with low solubility are accepted for encapsulation and disposal in a KBS-3 repository, see Section 2.3. These kinds of spent nuclear fuel have properties that will contribute to prevent and retard the dispersion of radioactive substances.

The properties of the encapsulated spent fuel of importance for the design of the engineered barriers and the layout of the repository and safety of the final repository, are:

- the enrichment,
- the burnup,
- the irradiation and power history,
- the age from the point in time the fuel assembly was discharged from the nuclear reactor,
- the dimensions and materials,
- encapsulated liquids and gases.

The enrichment and burnup will affect the propensity for criticality. The fuel assemblies shall be selected for encapsulation, with respect to the design of the canister, so that criticality under no circumstances can occur in the canister.

The burnup and age of the spent fuel assemblies will determine the radionuclide inventory and thus the radioactivity of the spent fuel. The radioactivity in turn will determine the decay power, radiation and radiotoxicity of the spent fuel. The decay power in each canister will determine the distances between deposition holes so as not to exceed the maximum allowed temperature in the repository. The radiation at the canister surface must not exceed levels assumed in the assessments of the operational and long-term safety. The radionuclide inventory and the radiotoxicity of the spent fuel constitute important input to the assessments of the operational and long-term safety.

The irradiation and power history will, in comparison to the burnup, have a minor impact on the radionuclide inventory of the spent fuel assemblies. However, the power history will impact the part of the radionuclide inventory located at the fuel grain boundaries and in the gaps within the fuel cladding. This part of the inventory will in comparison to the radionuclides embedded in the fuel matrix be released very rapidly if the spent fuel pellets are exposed to vapour or water, hence this is of importance for the assessments of the operational and long-term safety.

The dimensions of the spent fuel assemblies must be considered when determining the dimensions of the canister.

The content of encapsulated gases and liquids must be limited since they may cause corrosion of the canister.

The parameters presented above and the requirements on the handling of the spent fuel assemblies within the facilities of the KBS-3 system they impose are further discussed in the **Spent fuel report**, Section 2.3 and Chapter 3.

3.2.3 Kinds of spent fuel to be deposited

The spent fuel to be deposited in the final repository mainly consist of fuel assemblies from the Swedish boiling light water reactors – BWR assemblies – and pressurised light water reactors – PWR assemblies. The BWR assemblies constitute the largest number of assemblies as well as the largest amount in tonnes of uranium to be deposited.

In addition to the BWR and PWR assemblies there are some miscellaneous fuels to be deposited in the KBS-3 repository. They consist of a limited number of BWR and PWR MOX (mixed oxide fuel) assemblies which result from concluded reprocessing agreements from the early operation of the nuclear power plants. The miscellaneous fuels also comprise spent fuel from the Ågesta reactor and fuel residues from the Studsvik facility.

The spent fuel to be deposited is further discussed in the **Spent fuel report**, Chapter 2.

3.3 The canister

3.3.1 Definition and purpose

The canister is a container with a tight, corrosion resistant shell of copper and a load bearing insert in which spent nuclear fuel is placed for deposition in the final repository. The canister shall contain the spent nuclear fuel and prevent the release of radionuclides into the surroundings. The canister shall also shield radiation and prevent criticality.

The canister is also a barrier, i.e. a physical confinement of radioactive substances /SSMFS 2008:1/, in the final repository facility during operation and a confinement during transports of the encapsulated spent nuclear fuel.

3.3.2 The barrier functions of the canister

The KBS-3 repository shall accommodate all spent nuclear fuel from the currently approved Swedish nuclear power programme. This means that the canister shall:

- *contain the various types of spent nuclear fuel that results from the currently approved Swedish nuclear power programme.*

In order for the KBS-3 repository to contain, prevent or retard the dispersion of radioactive substances, the canister shall:

- *contain the spent nuclear fuel and prevent the dispersion of radioactive substances,*
- *withstand the mechanical loads that are expected to occur in the final repository,*
- *withstand the corrosion loads that are expected to occur in the final repository.*

In order for the KBS-3 repository to maintain the multi-barrier principle and have several barriers, which individually and together contribute to maintain the barrier functions, the canister shall:

- *not significantly impair the barrier functions of the other barriers,*
- *prevent criticality.*

After the canister is sealed, it shall contain the spent nuclear fuel and prevent criticality also in the facilities and the transport system included in the KBS-3 system. Furthermore, with respect to the safe operation of the KBS-3 system it shall be possible to:

- *transport, handle and deposit the canister in a safe way without significantly affecting the properties of importance for the barrier functions in the final repository.*

The final repository facility shall be accessible for and be provided with necessary means for the inspection of nuclear material. With respect to this, the following is stated for the design of the canister.

- *In the control of nuclear material, each sealed canister shall represent a reporting unit.*

3.3.3 Basic design of the canister

The canister is cylindrical and consists of a tight copper shell and a load bearing insert.

Copper has been selected due to its resistance against corrosion in the chemical environment in the KBS-3 repository. Copper cannot provide the mechanical strength required with respect to the mechanical conditions in the final repository and must thus be complemented by a load bearing insert. The ductility of the copper and the related capability to resist strains that may be the result of deformations against the load bearing insert is a prerequisite for the selection of copper as material of the tight shell.

The insert shall provide sufficient mechanical strength. Cast iron is currently considered the most favourable material that can provide the strength and be manufactured with high reliability. In addition to the strength the propensity for criticality, i.e. the possibility to distance the fuel assemblies from each other, has been considered in the design of the insert.

All canisters shall have the same external dimensions. The reason for this is to facilitate, and thereby make the handling of the canister cost-effective, safe and reliable. Further, BWR and PWR assemblies shall not be mixed in the same canister. As a consequence there shall be two versions of insert, one adapted to the dimensions of the BWR assemblies and one adapted to the PWR assemblies, further the height of the canister will be determined by the length of the tallest fuel assembly (a BWR assembly). The miscellaneous fuels shall be encapsulated either in BWR or PWR canisters.

The number of assemblies shall be twelve in a BWR insert and four in a PWR insert. This is based on an assessment of costs where the decay power of the spent fuel assemblies and its impact on the layout of the repository and the operational periods of the nuclear power plants as well as of the facilities of the KBS-3 system were considered. Other factors that were considered were the safe handling of the canister, the possible geometrical configuration of the assemblies in the insert and the propensity for criticality.

3.4 The buffer

3.4.1 Definition and purpose

The buffer is a clay containing swelling minerals. The buffer surrounds the canister and fills the space between the canister and the bedrock. The buffer shall prevent flow of water and protect the canister. In case the containment provided by the canister should be breached the buffer shall prevent and retard the dispersion of radioactive substances from the canister to the bedrock.

The buffer blocks on top of the canister also serve as radiation protection during the backfilling of the deposition tunnel.

3.4.2 The barrier functions of the buffer

In order for the KBS-3 repository to contain, prevent or retard the dispersion of radioactive substances, the buffer shall:

- *prevent flow of water (advective transport) in the deposition hole,*
- *keep the canister in its centered position in the deposition hole as long as required with respect to the safety of the final repository.*

To protect the canister and preserve the containment the buffer also shall:

- *have ability to limit microbial activity.*

To contribute to prevent or retard the dispersion of radioactive substances the buffer also shall:

- *prevent that colloids are transported through it.*

In order for the KBS-3 repository to maintain the multi-barrier principle and have several barriers which individually and together contribute to maintain the barrier functions the buffer must:

- *not significantly impair the barrier functions of the other barriers.*

For the final repository to provide protection against harmful effects of radiation as long as required regarding the radiotoxicity of the spent nuclear fuel, and to withstand events and processes that can affect the barrier system the buffer shall:

- *maintain its barrier functions and be long-term durable in the environment expected in the final repository,*
- *allow the canister to be deposited without causing damages that significantly impair the barrier functions of the canister or buffer.*

The latter is also required with respect to the operational safety of the KBS-3 repository facility.

3.4.3 Basic design of the buffer

The buffer consists of compacted bentonite clay components to be installed in the deposition hole. Bentonite has been selected since it have capability to provide the barrier functions stated in Section 3.4.2. Bentonite generally describes clay consisting essentially of montmorillonite, regardless of its origin and occurrence. Different kinds of bentonite clays may be selected for the buffer.

3.5 The backfill

3.5.1 Definition and purpose

The backfill is the material installed in deposition tunnels to fill them. The purpose and function of the backfill in deposition tunnels is to sustain the multi-barrier principle by keeping the buffer in place and restrict groundwater flow through the deposition tunnels.

3.5.2 The barrier functions of the backfill

In order for the KBS-3 repository to maintain the multi-barrier principle and have several barriers which individually and together contribute to maintain the barrier functions the backfill shall:

- *limit flow of water (advective transport) in deposition tunnels,*
- *restrict upwards buffer swelling/expansion,*
- *not significantly impair the barrier functions of the other barriers.*

For the final repository to provide protection against harmful effects of radiation as long as required regarding the radiotoxicity of the spent nuclear fuel, and to withstand events and processes that can affect the barrier system the backfill shall:

- *be long-term durable and maintain its barrier functions in the environment expected in the final repository.*

3.5.3 Basic design of the backfill

The backfill consists of compacted bentonite clay blocks and pellets to be installed in the deposition tunnel. Alternative materials as well as installation techniques have been investigated. The block concept is currently considered as the most favourable in order to provide a sufficient installed density in an efficient and reliable manner.

3.6 The closure

3.6.1 Definition and purpose

The closure is the materials installed in investigation boreholes, rock caverns, shafts and ramp and tunnels that are not deposition tunnels, in order to fill and close them. The purpose and function of the closure is to considerably obstruct unintentional intrusion into the final repository and to restrict groundwater flow through the underground openings.

3.6.2 The barrier functions of the closure

In order for the KBS-3 repository to maintain the multi-barrier principle and have several barriers, which individually and together contribute to maintain the barrier functions, the closure shall:

- *prevent that water conductive channels that may jeopardise the barrier functions of the rock are formed between the repository and the surface,*
- *not significantly impair the barrier functions of other barriers.*

To maintain the multi-barrier principle the closure in different underground openings shall have the following barrier functions.

- *The closure in main tunnels shall prevent that the backfill swells/expands or is transported out from the deposition tunnels.*
- *The closure shall keep the closure in underlying or adjacent underground openings in place.*

In the design of the KBS-3 repository, unintentional intrusion shall be considered so that the repository site after closure of the repository facility can be utilised without compromising the freedom of action, needs and aspirations of future generations. From this follows that:

- *The closure in the upper part of the ramp, shafts and boreholes shall significantly obstruct unintentional intrusion into the final repository.*

For the final repository to provide protection against harmful effects of radiation as long as required regarding the radiotoxicity of the spent nuclear fuel and to withstand events and processes that can affect the post-closure performance the closure shall:

- *be long-term durable and maintain its barrier functions in the environment expected in the repository.*

3.6.3 Basic design of the closure

The design of the closure will depend on the underground opening to be closed and the function of the closure in the particular underground opening. In investigation boreholes and underground openings where flow of water shall be restricted pre-compacted clay components will be used as closure material. In underground openings where there are no restrictions on flow of water the closure consists of compacted rock material. In the upper part of underground openings connected to the surface, to obstruct intrusion, the closure consists of well fitted blocks of crystalline rock.

3.7 The underground openings

3.7.1 Definition and purpose

The underground openings are the cavities constructed in the rock that are required for the sub-surface part of the final repository facility. The underground openings comprise:

- the actual geometry and location of the cavities,
- the rock surrounding the openings that is affected by the rock construction works,
- the engineered materials for sealing and rock reinforcement, and residual materials from performance of activities in the final repository facility which, at deposition, backfilling or closure, remain in and on the rock that surrounds the openings.

The underground openings as such do not contribute to the safety of the KBS-3 repository and do not have any barrier functions. However, the locations of the deposition areas and deposition holes with respect to the thermal, hydrological, mechanical and chemical properties of the rock are important for the utilisation of the rock as a barrier and thus for the safety of the repository. Furthermore, disturbances on the rock surrounding the tunnels (the excavation damaged zone, EDZ) and engineered and residual materials that remain in the rock may impact the barrier functions of the rock and/or the engineered barriers, and must therefore be known when assessing the safety of the repository. In addition, the underground openings shall be designed with respect to the design premises imposed by the design of the buffer, backfill, closure and plugs.

3.7.2 The functions of the underground openings

In order for the KBS-3 repository to be able to accommodate all spent nuclear fuel from the currently approved Swedish nuclear power programme the underground openings shall:

- *accommodate the sub-surface part of the final repository facility with the number of approved deposition holes that are required to deposit all canisters with spent nuclear fuel.*

In order for the final repository to contain, prevent or retard the dispersion of radioactive substances, the rock shall provide stable and favourable conditions for the engineered barriers so that their barrier functions can be sustained for as long as necessary bearing in mind the radiotoxicity of the spent nuclear fuel. Should the containment provided by the canister be breached, the rock will contribute to the safety of the final repository by preventing or retarding the dispersion of radioactive substances. In order for the rock to sustain its barrier functions and to maintain the multi-barrier principle, the layout of the underground openings shall be adapted to the conditions at the repository site so that:

- *thermally favourable conditions are provided and the containment of radioactive substances can be sustained over a long period of time,*
- *mechanically stable conditions are provided and the containment of radioactive substances can be sustained over a long period of time,*
- *favourable hydrologic and transport conditions are provided and the containment, prevention or retardation of dispersion of radioactive substances can be sustained over a long period of time,*
- *chemically favourable conditions are provided and the containment, prevention or retardation of dispersion of radioactive substances can be sustained over a long period of time.*

In order for the KBS-3 repository to maintain the multi-barrier principle and have several barriers which individually and together contribute towards maintaining the barrier functions, the underground openings shall:

- *be designed so that they do not significantly impair the barrier functions of the rock or the engineered barriers.*

In the design of the KBS-3 repository unintentional intrusion shall be considered so that the repository site after closure of the repository facility can be utilised without compromising the freedom of action, needs and aspirations of future generations. With respect to this and the fact that the final repository shall isolate the spent fuel from the environment at the surface:

- *the repository depth shall be selected with respect to the human activities which, based on present living habits and technical prerequisites, may occur at the repository site.*

In order for the barrier system of the final repository to withstand failures and conditions, events and processes that may impact their functions, the underground openings shall:

- *allow the deposition of canister and buffer with the desired barrier functions,*
- *allow the installation of backfill and closure with the desired barrier functions.*

The latter is also required in order for the barriers of the closed final repository to be passive, and in order for it to be, technically feasible to close and seal the final repository facility after the deposition has been carried out.

For the nuclear operation of the final repository facility to be safe, the underground openings shall:

- *be designed so that breakdowns and mishaps in connection with the nuclear operations are prevented.*

The underground openings shall also be designed so that other activities in the final repository facility can be carried out in a safe way.

3.8 The plugs

3.8.1 Different kinds of plugs and their purpose

There are plugs at the end of deposition tunnels, and plugs utilised for various purposes during the installation of the closure.

The plug in deposition tunnels is the construction closing deposition tunnels during the operational phases. The plug shall close the deposition tunnels, keep the backfill in them in place and limit flow of water, which could harm the backfill or buffer, until the main tunnel has been filled and saturated.

The plugs used during the installation of the closure shall provide mechanical strength, and/or hydraulic control function during and after the installation until the closure on both sides of the plug has been installed and saturated. Plugs also contribute to a safe and secure installation of the closure.

The plugs have no barrier function in the KBS-3 repository. In the long-term the plugs must not impair the barrier functions of the engineered barriers or rock, this means that they shall remain in the repository and not contain substances that may have negative impact on the chemical conditions in the repository.

3.8.2 The function of the plugs

The functions presented below are applicable for the plugs at the end of deposition tunnels.

In order for the barrier system of the final repository to withstand conditions, events and processes that may impact its functions, the plug in deposition tunnels shall:

- *withstand the hydrostatic pressure at repository depth and the swelling pressure of the backfill until the main tunnel is filled,*
- *limit water flow past the plug until adjacent main tunnel is filled and saturated,*
- *be durable and maintain its functions in the environment expected in the repository facility and repository until the closure in the main tunnel is saturated.*

In the long-term perspective as a part of the final repository in order for the repository to maintain the multi-barrier principle, the plug in deposition tunnels must:

- *not significantly impair the barrier functions of the engineered barriers or rock.*

There are plugs required for the installation of the closure with similar functions. The plugs used during the installation of the closure may also have other functions, they are presented in the **Closure production report**, Section 3.6.

3.8.3 Basic design of the plugs

The design of the plugs shall be adapted to the conditions at the repository site. At this stage of development the designs of the plugs are preliminary. The current reference designs are presented in the **Backfill production report,** Chapter 7 and the in **Closure production report,** Section 3.6 respectively and are not further discussed in this report.

3.9 Design considerations

In this section the design considerations that shall be regarded in the design are presented. These mainly affect the development of methods to manufacture and handle the engineered barriers and to construct the underground openings and are similar for all parts of the final repository.

The system of barriers and barrier functions of the final repository shall withstand failures and conditions, events and processes that may impact their functions. Hence the following shall be considered.

- *The designs and methods for manufacturing, installation, test and inspection shall be based on well-tried or tested technique.*

The construction, manufacturing, deposition and non-destructive tests of the barriers of the final repository shall be dependable, and the following shall be considered.

- *Engineered barriers, underground openings and plugs with specified properties shall be possible to manufacture and install with high reliability.*
- *The properties of the engineered barriers, underground openings and plugs shall be possible to inspect against specified acceptance criteria.*

A reliable production is also required with respect to SKB's objective to achieve high quality and cost-effectiveness. Regarding cost-effectiveness the following shall be considered.

- *The designs and methods for manufacturing, installation, test and inspection shall be cost-effective.*
- *Installation and construction shall be possible to perform in the prescribed rate.*

Further, with respect to requirements in the Swedish Environmental Code /SFS 1998:808/, environmental impact such as noise and vibrations, emissions to air and water and consumption of material and energy shall be considered in the design. Methods to prepare and install the engineered barriers and plugs, and to construct the underground openings, must also conform to requirements in the Work Environment Act /SFS 1977:1160/ and regulations for occupational safety. Design premises related to these aspects can generally be met in alternative ways for designs that conform to the safety and radiation protection design premises.

4 The KBS-3 system and the production lines

4.1 The KBS-3 system

4.1.1 Definition and scope

The KBS-3 system refers to the nuclear facilities etc that are required to realise the final deposition of spent nuclear fuel according to the KBS-3 method. The KBS-3 system consists of a central facility for intermediate storage and encapsulation of spent nuclear fuel, a system for transportation of canisters with spent nuclear fuel and a final repository facility.

Note that the interim storage facility in contradiction to the other facilities and transport system for encapsulated spent fuel of the KBS-3 system is independent of the KBS-3 method for final disposal. However, SKB has decided to include the interim storage facility in the KBS-3 system. Further, SKB has decided to exclude all deliveries to the facilities of the KBS-3 system from the system as such. However, in this context it is important to stress that SKB will establish routines for qualification of suppliers, as well as for inspections of the activities performed by the suppliers. The deliveries are included in the production lines, see Section 4.2.

The facilities of the KBS-3 system, the delivery of spent nuclear fuel to it, and the way of the spent fuel through the facilities are illustrated in Figure 4-1. The figure also gives an overview of the deliveries of components required to produce and construct the engineered barriers and underground openings of the KBS-3 repository and their way through the facilities to their final installation in the KBS-3 repository.

4.1.2 The interim storage and encapsulation plant – Clink

Purpose and main parts

The purpose of the interim storage facility and encapsulation plant – Clink is to:

- store the spent nuclear fuel until its decay power has decreased to levels suitable for deposition in a KBS-3 repository,
- select assemblies for encapsulation, encapsulate them and deliver sealed canisters for transportation to the KBS-3 repository facility.

The Clink facility consists of two main parts, one for interim storage and one for encapsulation of the spent nuclear fuel. The interim storage part comprises two pools for wet storage. The spent nuclear fuel is placed in storage canisters in the pools. The encapsulation part comprises pools to receive transport canisters with spent fuel from the storage part, and positions for drying of the spent nuclear fuel, placement in the canister and sealing of the copper canister by welding the lid to the shell. The transfers between the parts are performed under water. In addition, the facility comprises the systems necessary to receive the spent nuclear fuel from the nuclear power plants and deliver encapsulated spent nuclear fuel for transportation to the KBS-3 repository, and for the surveillance of nuclear material.

Main activities

The main activities of the interim storage facility and encapsulation plant are to:

- receive and inspect the spent fuel from the nuclear power plants,
- store and monitor the spent nuclear fuel,
- select fuel assemblies for encapsulation,
- transfer the selected assemblies to the encapsulation part of the facility,
- prepare, inspect and dry the spent fuel to be encapsulated,
- place the spent fuel assemblies in the canister,
- seal the canister,
- inspect the sealed canister and approve it for transportation,
- place the canister in transportation casks for transport to the KBS-3 repository facility.

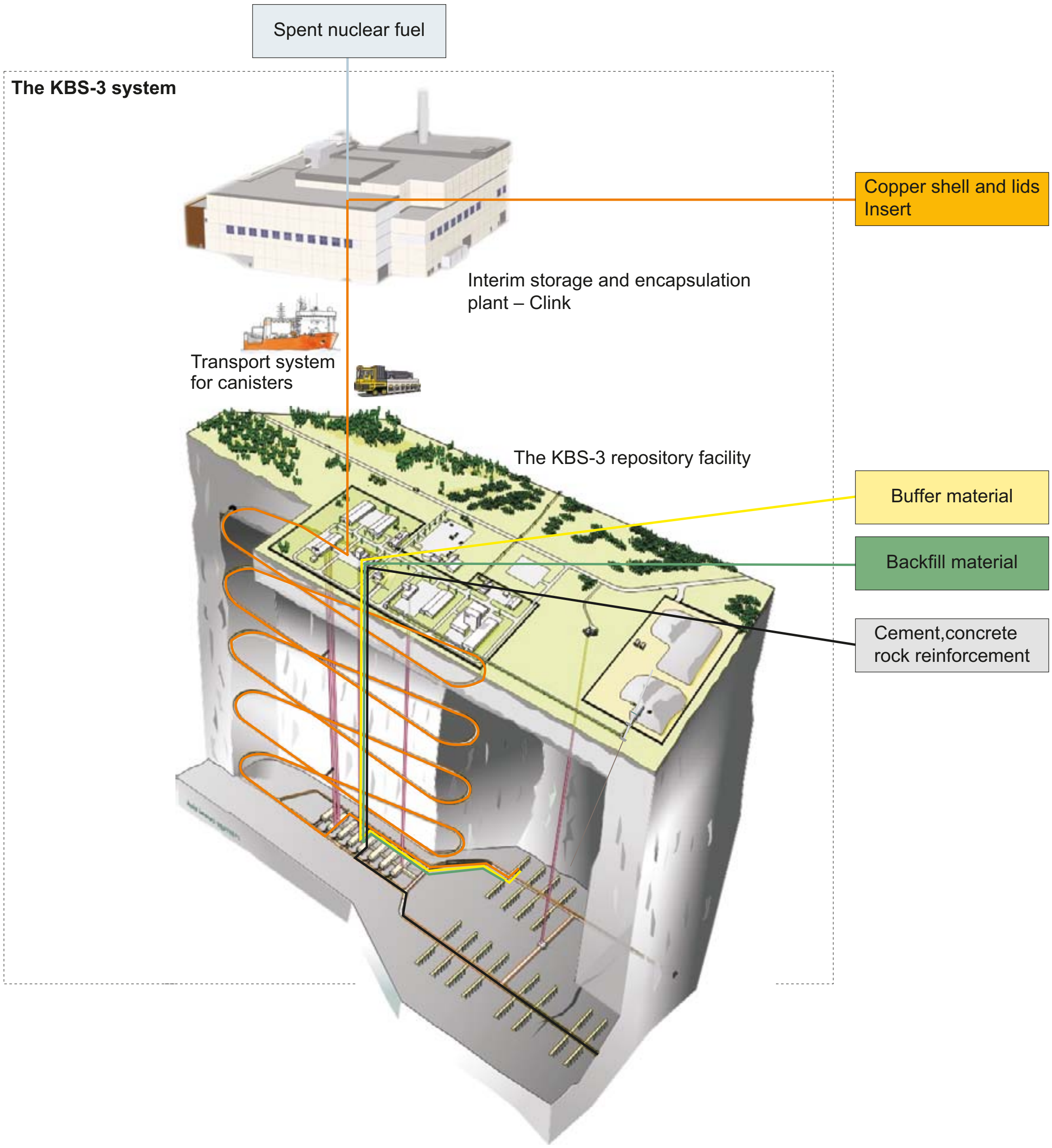


Figure 4-1. The KBS-3 system and its facilities and an overview of the spent fuels way through the system and the production of the KBS-3 repository.

4.1.3 The transport system for canisters with encapsulated spent nuclear fuel

Purpose and main parts

The purpose of the transport system is to transport the canisters containing the encapsulated spent nuclear fuel from the Clink facility to the KBS-3 repository facility in such a way that they are fit for deposition when they arrive at the KBS-3 repository facility.

The transport system comprises a number of canister transport casks (KTB). The transport system receives KTBs, each containing a single canister, at the Clink facility and delivers the KTBs to the KBS-3 repository facility. The transport is performed by a ship which is included in the transport system. In addition, the transport system comprises transport cask frames and vehicles to transport the KTBs on and off the ship and between the harbours and the facilities.

Main activities

The main activities of the transportation system are to:

- receive and accept the KTB with canister for transport at the Clink facility,
- put the KTB on a transport cask frame,
- load the terminal vehicle with the KTB resting on a transport cask frame at the Clink facility and transfer it to the harbour near to the facility,
- embark the transport cask frame with the KTB to the ship and perform the sea transport to the receiving harbour near to the KBS-3 repository facility,
- unship the transport cask frame with the KTB and transfer it with a terminal vehicle from the harbour to the KBS-3 repository facility,
- perform an acceptance inspection of the KTB and thereby deliver it to the KBS-3 repository facility,
- return empty KTBs to the Clink facility.

4.1.4 The KBS-3 repository facility

Purpose and main parts

The KBS-3 repository facility is the facility required to construct the KBS-3 repository. The KBS-3 repository facility is divided into a non-nuclear facility and a nuclear facility. The final repository is constructed and encapsulated spent nuclear fuel is handled within the nuclear facility.

The KBS-3 repository facility consists of the underground openings, the constructions and buildings above and below ground and the technical systems and equipment within the facility required to construct the KBS-3 repository and operate the facility. The finished parts of the KBS-3 repository lie within the KBS-3 repository facility. The KBS-3 repository facility with finished parts of the KBS-3 repository is illustrated in Figure 1-1.

Main activities

The main activities within the nuclear facility of the KBS-3 repository facility are rock construction works, deposition works and detailed investigations of the rock. To facilitate the regulated nuclear operation of the facility, and to keep the handling of the canister and the other engineered barriers in a clearly defined area, a partition wall physically separates the deposition works from the rock construction works.

On the rock construction works side of the partition wall main and deposition tunnels are excavated and deposition holes are drilled and prepared for deposition works. On the deposition works side canisters are deposited and buffer, backfill and plugs at the end of the deposition tunnels, towards their connection to the main tunnel, installed. As new tunnels and deposition holes are constructed and prepared for deposition new partition walls are installed. The partition wall is always placed so that construction and deposition works are physically separated. Transports to and from the construction side may pass closed deposition tunnels.

The main activities of the rock construction works are illustrated in Figure 4-2. Each of these main activities comprises several stages, e.g. drilling, blasting, removing of spoil etc.

Figure 4-2. *The main activities of the rock construction works. Each main activity comprises several stages.*

The deposition works comprise a deposition sequence and a backfill sequence. The main activities of the deposition sequence are illustrated in Figure 4-3 and the main activities of the backfill sequence are illustrated in Figure 4-4. The deposition sequence consists of installation of auxiliary equipment for the buffer, installation of the buffer blocks and deposition of the canister. Each main activity consists of several stages.

Since the buffer must not be saturated and start to swell before the backfill is installed, the succession of deposition and backfill sequences will affect the design of auxiliary equipment for the buffer and the design of the backfill. The reference procedure is to repeat the deposition sequence for all approved deposition holes in the deposition tunnel before the backfill sequence is initiated, and to include the final stages of the buffer installation, i.e. removal of auxiliary equipment and installation of pellets, in the backfill sequence.

The backfill sequence is initiated when the last deposition sequence in the deposition tunnel is finished. The backfill sequence is initiated by the backfilling of possibly occurring rejected deposition holes. Then the deposition tunnel is backfilled section by section as illustrated in Figure 4-4. If the section contains a deposition hole, the backfilling is initiated by removing the protective lid placed over the deposition hole and finishing the installation of the buffer. Then the backfill is installed in the following order: upper part of deposition hole; bottom bed; backfill blocks and finally pellet filling in the space between the rock surface and backfill blocks. When all sections of the tunnel are backfilled the plug is installed at the end of the tunnel.

More detailed descriptions of the activities in the KBS-3 repository facility, including all the stages of the rock construction works and the deposition sequence are presented in **SR-Operation** (general part), Chapter 5. The installation of the buffer and backfill, with all their stages, are described in the **Buffer production report**, Section 5.4 and in the **Backfill production report**, Section 5.4.

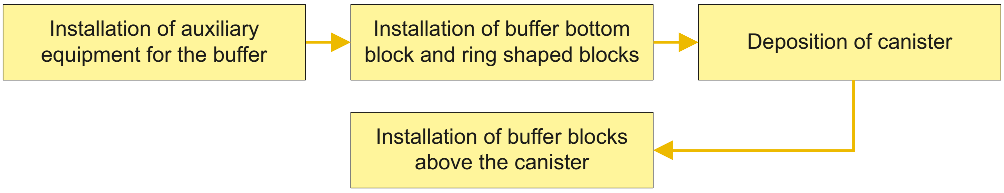


Figure 4-3. *The main activities of the deposition sequence.*

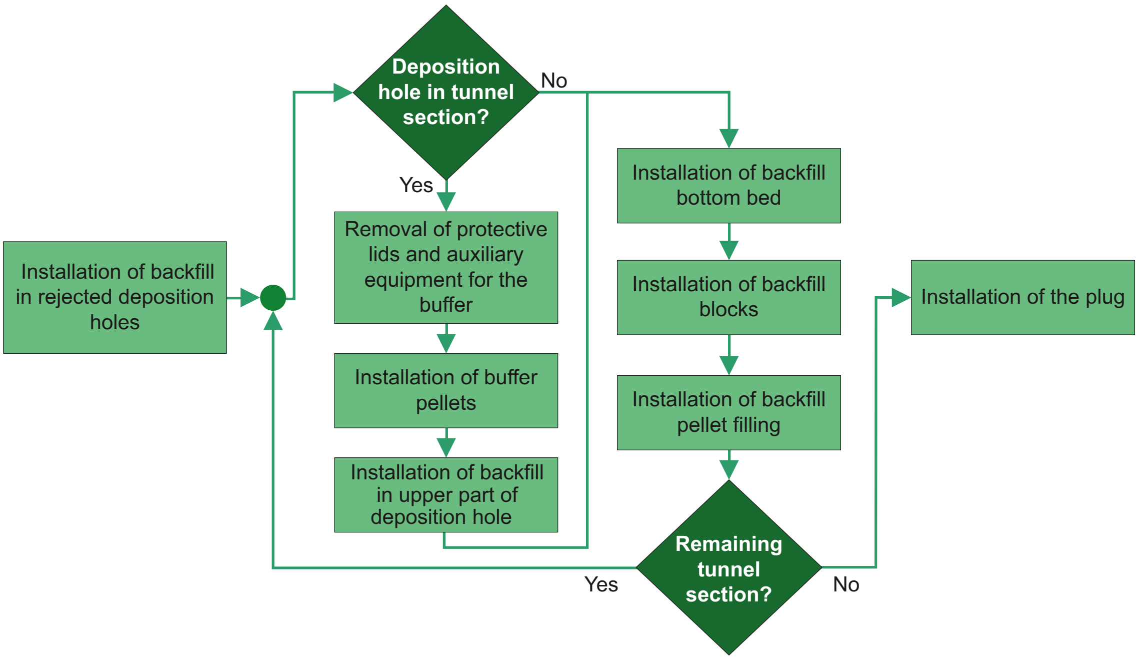


Figure 4-4. *The main activities of the backfill sequence.*

4.2 The production and the production lines

4.2.1 The production

The production of the engineered barriers comprises:

- the specification of the design of the components to be delivered,
- the methods to manufacture and inspect the specified designs,
- a production line that delivers components and ultimately engineered barriers that conform to the specified designs.

The production lines refer to all the activities and stages required to produce the engineered barriers and install them in the KBS-3 repository.

For the underground openings the specified design is the result of the application of a design methodology to successively, as more detailed information gets available, adapt the design to the conditions at the site. Methods for inspection comprise methods to investigate the host rock before the construction is initiated, methods to control the construction as well as inspection of the as built underground opening. No production line is described for the underground openings, but the methods to construct the different underground openings and their capability to result in underground openings that conform to the design premises are presented.

4.2.2 The production lines

There are production lines for each of the engineered barriers. For the spent nuclear fuel the activities in the handling correspond to the production line.

An overview of the main parts of the production lines of the engineered barriers is given in Figure 4-5. The figure also illustrates the main parts of the handling of the spent nuclear fuel and the construction of the underground openings. Each main part as illustrated in Figure 4-5 is in the **Spent fuel report** and in the **"*Engineered barrier*" production reports** divided into several stages in the handling and production respectively. For each stage the properties and design parameters of the engineered barriers that are affected and inspected within the stage are presented. It is specifically stated whether the parameters are determined, processed or finally inspected within the stage.

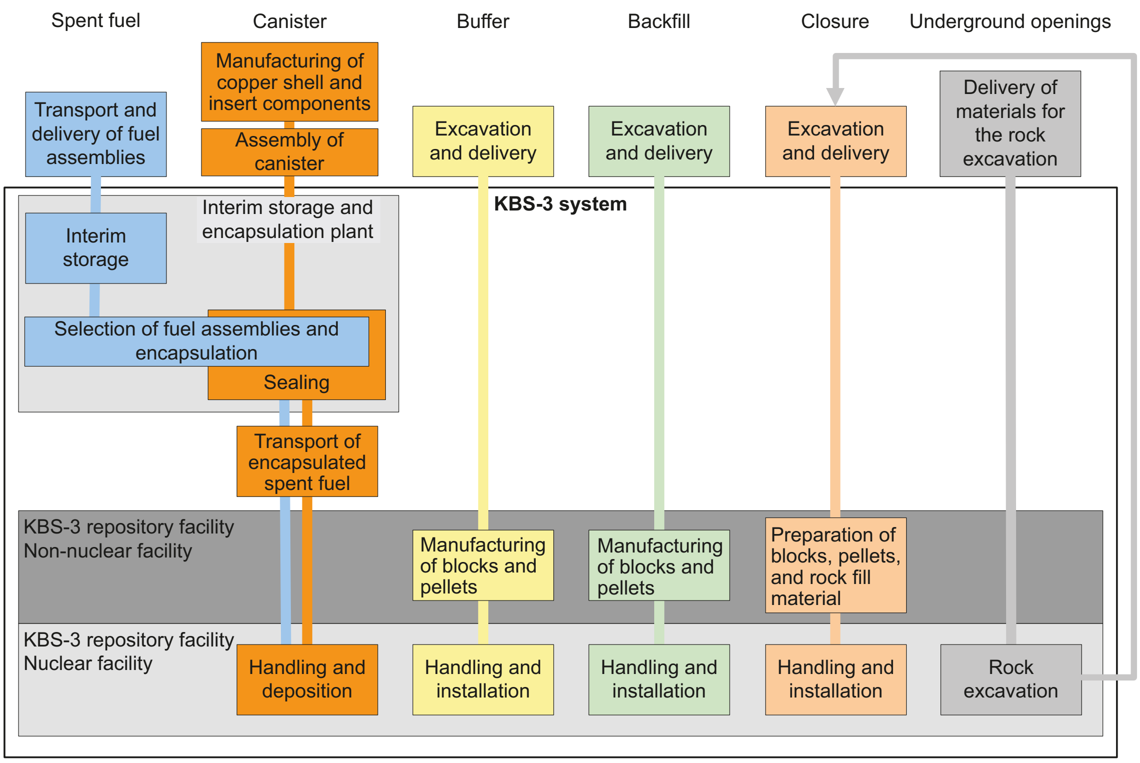


Figure 4-5. *Overview of the main activities in the handling of the spent nucear fuel, the production of the engineered barriers and the construction of the underground openings.*

4.2.3 Design and production line interfaces

As mentioned in Section 2.5.3 there are design premises imposed by the spent fuel or engineered barriers on other engineered barriers or underground openings related to technical feasibility, i.e. that the different parts of the repository must fit, and work, together during the production of the KBS-3 repository. These interfaces are in Sections 4.3 to 4.9 introduced for the spent fuel line, the production lines of the engineered barriers, the production of the plugs and the construction of the underground openings. For the spent fuel a summary of the requirements on the handling imposed by the design of the KBS-3 repository and its engineered barriers is presented. For each of the engineered barriers, plugs and underground openings the design premises imposed by other parts in the KBS-3 repository related to the technical feasibility are summarised, detailed descriptions are given in the relevant production report.

Sections 4.3 to 4.9 also include presentations of the interfaces between production lines, and how they are handled in the reports. In many cases the interfaces between the production lines result from the design premises the different parts of the KBS-3 repository impose on each other and/or are consequences of interfaces between the production lines.

In addition to design premises related to technical feasibility, there are design interfaces related to the functions the different parts of the KBS-3 repository shall sustain in the long-term time perspective. These interfaces and interdependences are related to the long-term evolution of the KBS-3 repository and are presented in **Design premises long-term safety** and not discussed in this report.

4.3 The spent fuel line

4.3.1 Overview

The main parts of the spent fuel line are illustrated in Figure 4-5, and an overview of all stages is given in the **Spent fuel report**, Figure 4-1. The spent fuel line starts with the delivery of the spent nuclear fuel assemblies to the Clink facility and ends when the spent fuel assemblies are finally placed in the canister and the steel lid is finally put on the cast iron insert.

4.3.2 Interfaces between the design of the KBS-3 repositry and its barriers and the handling of the spent fuel

The design of the KBS-3 repository will impose requirements on the selection of fuel assemblies for encapsulation. The assemblies shall be selected so that criticality cannot occur in the canister and so that the total decay power in a canister and the radiation on the canister surface do not exceed specified values, see **Spent fuel report**, Section 3.1.

Gases and liquids encapsulated together with the spent nuclear fuel may cause corrosion of the canister. The canister thus imposes that the fuel assemblies shall be dried and the air in the canister exchanged for inert gas before sealing of the canister, see **Spent fuel report**, Section 3.1.4.

4.3.3 Production line interfaces

The spent fuel line has an interface to the canister production line. The production of the canister and the handling of the spent nuclear fuel intersect in the encapsulation plant. The selection and inspection of fuel assemblies to be encapsulated are described in the **Spent fuel report**, Section 4.4. After the assemblies have been selected but before they are placed in the canister, they are dried. After the assemblies are placed in the canister a gas tight steel lid is put on the cast iron insert and the atmosphere in the canister is shifted. The drying of the fuel assemblies, the placement of them in the canister and the exchange of gas including the related inspections are presented in the **Spent fuel report,** Sections 4.7 to 4.8**.**

4.4 The canister production line

4.4.1 Overview

The main parts of the canister production line are illustrated in Figure 4-5, and an overview of all stages is given in the **Canister production report**, Figure 5-1. The canister production line starts with the ordering, manufacturing and delivery of components for the insert and copper shell and ends when the canisters are deposited within the buffer in the deposition holes.

4.4.2 Design interfaces

Only the spent fuel imposes design premises on the canister. The fuel channels of the cast iron insert shall be designed with respect to the dimensions of the largest BWR and PWR assembly to be deposited, see Section 3.3.3 and the **Canister production report**, Section 2.3.2.

Further, with respect to the prevention of illegal diversion of nuclear material, each canister shall be marked by a unique identity number, see the **Canister production report,** Section 5.1.3. After the steel lid is finally put on the cast iron insert it is not possible to inspect individual assemblies any more. Consequently, after this activity the canister is regarded as a unit in the inspection of nuclear material, and the individual identification codes of each assembly and the information of each assembly is linked to the canister they have been encapsulated in.

4.4.3 Production line interfaces

The canister production line has interfaces to the spent fuel line and the buffer production line. The spent fuel imposes that the dimensions of the fuel channels shall be inspected and approved prior to placement of the assemblies in the canister. Further, the canister shall be marked and the canisters way through the KBS-3 system after the spent fuel assemblies have been finally placed in the canister shall be documented to conform to regulations related to nuclear safeguards. The interface to the buffer production line is presented in Section 4.5.3.

4.5 The buffer production line

4.5.1 Overview

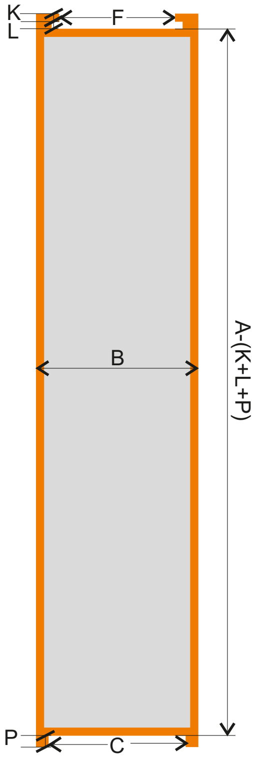
The main parts of the buffer production line are illustrated in Figure 4-5, and an overview of all stages is given in the **Buffer production report**, Figure 5-1. The buffer production line starts with the ordering, excavation and delivery of buffer material and ends with the installation of the buffer components in the deposition hole, i.e. filling of buffer pellets in the gap between the previously installed buffer blocks and deposition hole walls.

4.5.2 Design interfaces

Only the canister imposes design premises on the buffer. The canister imposes that the deposited buffer shall have a hole large enough to allow deposition of the canister. The dimensions of the canister that determine the required size of the hole within the deposited buffer rings are illustrated in Figure 4-6. Since the hole must be straight in order to allow deposition of the canister this will also result in design premises imposed by the buffer on the deposition hole, see Section 4.9.2.

4.5.3 Production line interfaces

The buffer production line has interfaces to the canister production line and to the construction of underground openings, i.e. preparation of deposition holes. The production line of the canister and buffer intersect in the final repository facility in connection to the deposition. The installation of the buffer comprises several stages as described in the **Buffer production report**, Section 5.4. After the ring shaped buffer blocks have been installed and the installation inspected the canister is deposited. To calculate the density of the deposited buffer the total volume of the deposited canisters must be known. The interface to the construction of underground openings is presented in Section 4.9.3.



Designation and name
A: Total length
B: Outer diameter
C: Inner diameter (copper base)
F: Inner diameter (copper lid)
K: Dimension (copper lid detail)
L: Dimension (copper lid detail)
P: Dimension (copper base detail)

Figure 4-6. *The dimensions of the canister determining the dimensions of the buffer blocks. The designations are the ones used in the specification of the canister reference design, see Canister production report, Figure 3-7 to 3-9 and Table 3-6.*

4.6 The backfill production line

4.6.1 Overview

The main parts of the backfill production line are illustrated in Figure 4-5, and an overview of all stages is given in the **Backfill production report**, Figure 5-1. The backfill production line starts with the ordering, excavation and delivery of backfill material and ends with the installation of the backfill components in the deposition tunnel, i.e. filling of backfill pellets in the space between the previously installed backfill blocks and deposition tunnel walls.

4.6.2 Design interfaces

None of the other engineered barriers, the underground openings or plug imposes design premises on the backfill.

4.6.3 Production line interfaces

The backfill production line has interfaces to the buffer production line, the production of the plug and the construction of underground openings, i.e. the preparation of deposition tunnels. The production of the buffer and backfill intersect in the final repository facility in connection to the installation of the backfill. When the auxiliary equipment used to protect the buffer is removed and the space between the buffer blocks and deposition holes walls has been filled with buffer pellets, the installation of the backfill can proceed, see Figure 4-4 and the **Buffer production report**, Section 5.4.5. The upper part of the deposition hole is considered to be a part of the deposition tunnel. The installation of backfill blocks and pellets in the upper part of the deposition hole is described in the **Backfill production report,** Section 5.4.5. The interface to the production of the plug is presented in Section 4.8.3 and the interface to the construction of underground openings is presented in Section 4.9.3.

4.7 The closure production line

4.7.1 Overview

The main parts of the closure production line are illustrated in Figure 4-5. At this stage of development only preliminary designs of the closure are provided and for the production only overviews of important tasks for the closure of the different kinds of underground openings are presented. For tunnels and shafts below a certain depth a similar concept as for the backfill in deposition tunnels is anticipated and the production line will be similar to the backfill production line.

4.7.2 Design interfaces

None of the other engineered barriers, the underground openings or plug imposes design premises on the closure.

4.7.3 Production line interfaces

The closure production line has interfaces to the plugs production lines and the construction of underground openings. The interface to the plugs production lines is presented in Section 4.8.3 and the interface to the construction of underground openings is presented in Section 4.9.3.

4.8 The production of plugs

4.8.1 Overview

The design and installation of plugs are related to the design and installation of the backfill and closure. The installation is initiated immediately after the installation of the backfill or closure, or for some plugs used during the installation of the closure as an integrated part of the installation. An overview of the production of the plug in deposition tunnels is illustrated in the **Backfill production report**, Figure 9-1. The installations of the plugs in connection to the closure of underground openings comprise the same main parts.

4.8.2 Design interfaces

The backfill and closure impose design premises on the plugs. The plugs must have sufficient strength to resist hydraulic pressure and the pressure generated by the backfill or closure material. Further, the plugs shall have sufficient tightness to limit the flow of water passed the plug until the materials on both sides of the plug are saturated.

4.8.3 Production line interfaces

The production of the plugs has interfaces to the backfill or closure production lines and to the construction of underground openings. The installation of the plugs commences in immediate connection to the installation of the backfill or closure. The properties of the backfill and closure are affected by the functions of the plugs. With respect to this it is important that the plugs are installed and gain their functions as soon as possible after the installation of the backfill or closure is finished.

4.9 The construction of the underground openings

4.9.1 Overview

The construction of the underground openings comprises the site adaptation of the design and the application of the methods to excavate and inspect the as built underground openings. The construction of the underground openings also includes the preparation of the underground openings for the installation of buffer, backfill or closure.

4.9.2 Design interfaces

The buffer, backfill, closure and plugs impose design premises on the underground openings.

The buffer and deposition holes

The nominal diameter and minimum height/depth of the deposition hole are imposed by the nominal buffer design. The allowed deviations in the geometry from the nominal are determined by the allowed variations in the width of the pellet filled gap between the installed buffer blocks and the rock surface. The allowed variation in deposition hole geometry are expressed as allowed variations of the deposition hole radii from the vertical centreline of the deposition hole. The buffer dimensions determining the nominal diameter, minimum depth and acceptable deviations in deposition hole geometry are illustrated in Figure 4-7. A detailed description is given in Section 2.3.2 of the **Underground openings construction report**.

The backfill and deposition tunnels

The acceptable deviation of the excavated deposition tunnel volume from the nominal is imposed by the reference design of the backfill. The design of the backfill also determines the acceptable occurrence of irregularities in the tunnel floor. Finally, the acceptable inflow to the deposition tunnel during the installation of the backfill is imposed by the backfill design and method to backfill the tunnels. The design premises imposed by the backfill for the deposition tunnels are presented in Section 2.3.2 of the **Underground openings construction report**.

The closure and ramp, shafts and tunnels other than deposition tunnels

The closure imposes similar design premises on the ramp, shafts and tunnels other than deposition tunnels as the backfill for the deposition tunnels. However, the acceptable hydraulic conductivity in these underground openings will be higher than in the deposition tunnels and above a certain depth and through passages of conductive features in the bedrock where no limitation of the conductivity is required. In practice this implies that the installed density of the closure can be lower, which in turn results in a wider range of acceptable geometries of the underground openings. Further, the limitation of inflow that is desired with respect to the operation of the KBS-3 repository facility is anticipated to be acceptable also for the closure. The design of the closure shall be adapted to the local conditions at the site. At this stage of development of the closure the detailed design premises imposed on ramp, shafts and tunnels other than deposition tunnels remain to be determined.

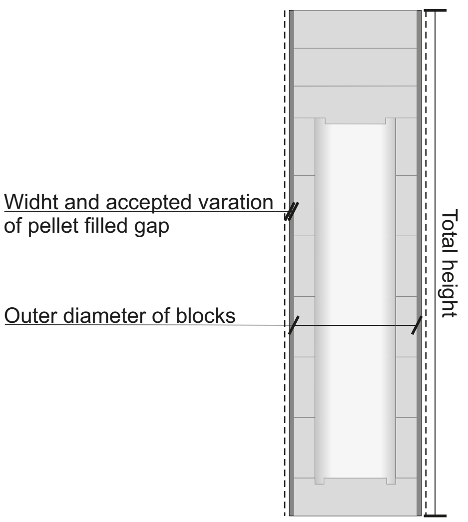


Figure 4-7. *The buffer dimensions that determine the nominal diameter, minimum depth and acceptable deviations in deposition hole radius.*

The plug in deposition tunnels

The plug in deposition tunnels imposes that the inflow to the area where it shall be installed is limited and that the strength of the rock is sufficient to resist the forces exerted by the plug. In addition, recesses and devices for anchoring shall be prepared in the underground openings in accordance with the specification of the plug.

4.9.3 Production line interfaces

The construction of the underground openings has interfaces to the production lines of the buffer, backfill, closure and plug. Common for all these intersections are that the inspection and preparation of the underground opening in question for installation of the buffer, backfill, closure or plug is performed as part of the construction of the underground opening.

The acceptance of deposition holes for deposition and preparations for installation of the buffer, e.g. cleaning and measuring of the geometry, are part of the construction of the underground openings. In deposition holes with rock fall out or other irregularities it is possible to adapt the installation of the buffer to the geometry of the deposition hole. Consequently, the determination of the geometry of deposition hole is an important input to the installation of the buffer, and to determine the variation in installed buffer density, see the **Buffer production report**, Sections 4.2, 5.4.8 and 6.1.4.

The acceptance of deposition tunnels and the preparation of them for installation of the backfill is a part of the construction of the underground openings. The required inspections and preparations are presented both in the **Backfill production report**, Section 5.4.3 and the **Underground openings construction report**, Section 5.2.6. Descriptions of how the inspections and preparations are carried out are given in the **Underground openings construction report**.

The required preparations for the plug in deposition tunnels are briefly described in Section 9.5 in the **Backfill production report** and in Section 5.2.5 in the **Underground openings construction report**. For the plugs used during the installation of the closure these details are not provided at this stage.

5 Quality management, safety classification and thier application

5.1 Quality management

SKB is certified according to /ISO 9001:2008/ and applies the fundamentals and vocabulary in /ISO 9000:2005/. In this section an introduction to how SKB intends to apply the standards for issues within the scope of the purpose and objectives of the Production reports is given.

According to /ISO 9000:2005/ quality management refers to activities to direct and control an organisation with regard to quality. Within the Production reports quality refers to the degree to which the characteristics of the finished engineered barriers, underground openings and other parts of the KBS-3 repository contribute towards sustaining the functions of importance for the long-term safety of the KBS-3 repository.

Quality control and quality assurance are parts of the quality management relevant for the Production reports. The quality control is focused on *fulfilling* the quality requirements while the quality assurance is focused on providing *confidence* that quality requirements will be fulfilled. Within the Production reports the quality management comprises direction and control of the activities that impact the properties of the finished engineered barriers, underground openings and other parts of the KBS-3 repository, while quality assurance comprise direction and control of activities intended to inspect or by other means verify achieved results.

For the production of the KBS-3 repository quality control and quality assurance imply that procedure documents to be applied when carrying out the activities that impact, and provide confidence in, the quality of the finished KBS-3 repository shall be available within the quality management system. In Table 5-1 activities controlling and assuring the quality that are relevant for the Production reports and for which procedure documents shall be available are presented. The activities are divided into those performed before the production commences and those performed during the production.

In addition to the activities presented in Table 5-1 all quality controlling and quality assuring activities shall, for quality assurance purposes, be documented in a traceable manner.

Table 5-1. Activities controlling or assuring quality relevant for the Production reports and for which procedure documents shall be included in the management system.

Quality controlling activities (Impact the fulfilment of quality requirements)	Quality assuring activities (Provide confidence in achieved results)
Before the production commences	
– substantiation of design premises	– investigations and analyses
	– review and acceptance
– design resulting in design specification	– analyses verifying the conformity of the design to the design premises
– development of systems and processes for production	– qualification and validation of technical systems and processes for production, handling and inspection
– development of systems and processes for inspection	
– purchasing of executing organisation	– qualification of executing organisation
During the production	
– deliveries to the production processes	– acceptance inspections of inputs to the production processes
– preparations before carrying out the production processes	– inspections and tests of systems used in the production processes
	– inspection of competence of executing organisation
– execution of the production processes	– controlling and steering of production processes
– deliveries from the production processes	– inspections of outputs from the production processes

The production of the engineered barriers, underground openings and other parts of the KBS-3 repository comprises nuclear activities as well as several technological branches and practices. With respect to this SKB intends to apply the principles and the terminology presented in /ISO 9000:2005/. Some terms from this standard of importance for the understanding of this chapter are presented in Section 1.5.

5.2 Safety classification

To adapt the different parts in the KBS-3 repository to their importance for the safety, and in line with SSMFS 2008:1, Chapter 3, 4 § with general recommendations, SKB intends to apply a classification system.

The safety classification of the engineered barriers, underground openings and other parts of the KBS-3 repository focus on the functions of the KBS-3 repository to contain, prevent or retard the dispersion of radioactive substances. The engineered barriers are safety classified since they in different ways, through their barrier functions, contribute to the safety of the KBS-3 repository. The underground openings are safety classified with respect to their importance for the barrier functions of the host rock. Other parts of the KBS-3 repository are safety classified since they may impact the barrier functions of the engineered barriers or host rock, and must be known to assess the long-term safety of the KBS-3 repository.

The safety classes of the KBS-3 repository are denominated *B – Barrier function* and *PB – Impact on barrier function* respectively (the letter P is from the Swedish word for impact). The following parts in the KBS-3 repository shall be safety classified.

- **The canister**
  - since it contains the spent nuclear fuel and the radioactive substances and completely isolate them from man and the environment.
- **The buffer**
  - since it provides stable and favourable conditions so that the containment can be sustained and also contributes to prevent or retard the dispersion of radioactive substances if the containment should be breached.
- **The backfill**
  - since it contributes to the multi-barrier principle and also can contribute to prevent or retard the dispersion of radioactive substances if the containment should be breached.
- **The closure**
  - since it contributes to the multi-barrier principle and substantially obstructs unintentional intrusion into the final repository.
- **The underground openings**
  - since their location in the host rock contributes to provide stable and favourable conditions so that the containment can be sustained and also contributes to prevent or retard the dispersion of radioactive substances if the containment should be breached,
  - since their properties impact the properties of the buffer, backfill and closure,
  - since the properties of the rock that is affected by the construction works, the materials for rock reinforcement and grouting and the residual materials from the activities in the final repository facility that remain at deposition, backfill and closure must be known in order to assess and evaluate the safety of the final repository.
- **The plugs**
  - since they impact the properties of the backfill and closure,
  - since they are left at closure and their properties must be known to assess and evaluate the safety of the final repository.

The safety classification of the different parts in the KBS-3 repository is presented in Table 5-2.

Table 5-2. Safety classification of the parts in the KBS-3 repository.

Safety class	Part in the KBS-3 repository
B	Canister
	Buffer
	Location of deposition holes
	Backfill
	Closure
PB	Layout and design of underground openings other than the location of deposition holes
	Damaged rock surrounding the underground openings (also deposition holes)
	Plugs and other remaining constructions

The extent of quality assurance measures is determined by the barrier functions and the different parts' importance for the safety of the KBS-3 repository. This implies that more extensive quality assurance measures are required for parts with safety class B than for parts with safety class PB. Further, within safety class B more extensive quality assurance measures shall be taken for parts that in the assessment of the long-term safety are shown to be more important for the safety. Within safety class PB the quality assurance measures are anticipated to be similar for all parts. The extent of quality assurance measures refer to e.g. how frequent, how profoundly and by which parties the quality assuring activities in Table 5-1 are performed.

5.3 Application in the production of the KBS-3 repository

5.3.1 General basis

In general SKB's management system, which is successively developed, shall be applied. The management system states the purposes and objectives of the quality management. From SKB's management system it is also clear how the quality management is linked to SKB's organisational structure with its arrangements of responsibilities, authorities and cooperation. For activities taking place within the nuclear part of the KBS-3 repository facility during the operational phases (trial and routine operation) Chapter 4 Quality assurance and the operation of the facility in **SR-Operation** (general part) is applicable.

Further, SKB intends to establish quality plans for the engineered barriers, underground openings and other parts of the KBS-3 repository. The quality plans shall specify which procedures and associated resources that shall be applied by whom and when for the activities in Table 5-1. The quality plans shall provide a concise picture of the direction and control of the quality controlling and quality assuring activities. They shall comprise the activities carried out before the production is initiated as well as the activities during the production until the initial state defined for the part in question.

In many cases established procedures for quality assurance are available. They are hereinafter referred to as conventional and are generally documented as standards. SKB intends to apply conventional procedures as far as possible and reasonable, e.g. for qualification of measuring equipment for inspection of weight, dimensions and placement and for inspection of construction materials such as steel and concrete. In some cases SKB intends to establish procedures that are unique for the KBS-3 repository, this e.g. applies to equipment and process for inspection of the tightness of the canister. In other cases conventional procedures can be adapted to SKB's needs, this is e.g. applicable for equipment and methods to inspect the mineral composition and characteristics of clay materials. In summary the quality control and quality assurance measures SKB plans can be divided into:

- unique – unique for the KBS-3 repository,
- adapted – established procedures documented as standards adapted to SKB's needs,
- conventional – established procedures documented as standards.

5.3.2 Quality plans and their scope

In Table 5-3 quality controlling activities performed before the production commences and during the production respectively, their results and the related quality assuring activities are presented.

The quality plans for the different engineered barriers, underground openings and other parts of the KBS-3 repository shall specify the procedure documents to be applied for the quality assuring activities in Table 5-3. For the activities performed before the production commences the resulting documents, systems and processes shall be specified and for activities performed during the production the objects to be inspected and tested shall be specified. Further, the quality plans shall include a plan for when and by whom the quality assuring activities shall be executed. The plan for execution of the quality assuring activities is regulated by the safety class. In /SKI 2006/ the term *control order* is used. Control order refers to SKB's and supplier's self inspections, so called third party inspections by independent institutions and SSM's proceeding reviews and inspections. The quality plans shall specify procedure documents for SKB's self inspections, which self inspections suppliers shall perform, and which documents, systems, processes, suppliers, executing organisations, deliveries and products that shall be subjected to third party inspections.

The review of record documents and specifications included in the safety report is regulated by SSM FS 2008:1 Chapter 4, 3 § and incorporated into SKB's procedure documents for review of documents.

Table 5-3. Quality controlling activities performed before the production commences and during the production respectively, their results and the related quality assuring activities.

Quality controlling activity	Result	Quality assuring activity	
Before the production is initiated			
Substantiate design premises	Record document Specification	Analyses and evaluations Documentation and handling in requirement management system [1]	Review and approval Documentation of procedure
Design	Record document Specification	Verifying analyses Documentation and handling in requirement management system [1]	
Development of technical systems for production and inspection	Specification Validated system	Documentation and handling in requirement management system [1] Qualification of system	
Development of processes for production and inspection	Qualified process Test certificate	Qualification of process	
Purchasing of executing organisation	Qualified suppliers and operators Test certificate	Qualification of executing organisation	
During the production			
Delivery to process	Input to process	Delivery inspection	Documentation of process parameters and results from tests and inspections Documentation of procedure
Preparations of process	Systems ready for duty Available organisation	Test of system Competence inspection	
Realisation of process	Product	Control and steering Extraction of test specimens and samples for analyses and destructive tests Non-destructive testing	

[1] Includes for instance determination of wording and relation to other requirements and design premises, and performed verification and inspection.

Concerning qualification of technical systems and processes for production and inspection as well as for qualification and purchasing of suppliers and executing organisations SKB consider conventional procedures to be applicable for safety class PB. In many cases conventional procedures are also applicable for safety class B. For safety class B adaptation to SKB's needs may be justified. Unique procedures are only considered to be justified for technology and equipment developed specifically for the KBS-3 repository and for some systems, processes and suppliers employed in the production of the canister.

For activities performed during the production the same considerations as for qualification are applicable. That is, conventional procedures can be applied for safety class PB, and in many cases also for safety class B. For safety class B adaptation to SKB's needs may be motivated, while unique procedures are considered to be justified solely for some parts of the production of the canister.

For the canister SKB intends to apply the guidelines presented in /SKI 2006/ for the review of record documents and specifications as well as for qualification of systems, processes and suppliers and for inspections during the production.

In addition to the previously discussed issues the quality plans shall include instructions for the handling of nonconformities. The handling of nonconformities shall be described for all activities in Table 5-3. The handling of nonconformities related to the operation of the nuclear part of the KBS-3 repository facility and the activities taking place within the facility are discussed in **SR-Operation** (general part), Chapter 4 The operation and quality assurance of the facility.

The Production reports specify the design premises and reference designs for the engineered barriers, the underground openings and other parts of the KBS-3 repository. They present, or summarise, analyses verifying the conformity of the reference designs to the design premises. From the presentations of the production included in the reports it is clear which technical systems, processes and suppliers that shall be quality assured. Further, the Production reports present the planned production with its quality assuring measures and the results that, based on current experiences, can be expected from the production.

6 References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.se/publications. References to SKB's unpublished documents are listed separately at the end of the reference list. Unpublished documents will be submitted upon request to document@skb.se.

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Unpublished documents

SKBdoc id, version	Title	Issuer, year
1241883 ver 1.0	Treaties, laws and regulations and related requirements on the design of the KBS-3 repository	SKB, 2010